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SPORTS INJURIES

Prevention, Treatment and Rehabilitation

Fourth Edition

Lars **Peterson**
Per **Renström**

CRC Press
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Lars Peterson MD, PhD
Professor Emeritus in Orthopedics,
Department of Orthopedics, Institute of Clinical Sciences, Sahlgrenska Academy,
University of Gothenburg,
Gothenburg, Sweden

Per Renström MD, PhD
Professor Emeritus in Orthopedic Sports Medicine,
Department of Molecular Medicine and Surgery,
Centre for Sports Trauma Research and Education,
Karolinska Institutet,
Stockholm, Sweden

With valuable contributions by
Tommy Berglund, Lennart Molin, Tommy Bolic-Eriksson, Ole Roos, Anna Frohm, Anette Heijne,
Tommy Eriksson, Dale Reese and Erik Nexborn

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Contents

About the authors

Lars Peterson and Per Renström have co-authored the book *Sports Injuries* (1977, 1986, 2000, 2016), which is a worldwide bestseller.

The authors of this book were awarded the prestigious Duke of Edinburgh Prize, for outstanding contributions to education, clinical and/or research work in the field of Sports Medicine, and in the community, by the Institute of Sport and Exercise Medicine, in a ceremony at the House Of Lords, London, UK, in 2010.

Lars Peterson, MD, PhD, Professor Emeritus in Orthopedics, Sahlgrenska Academy, Gothenburg University, Göteborg, Sweden

Lars Peterson graduated from Gothenburg University in 1966. During his studies he played football/soccer and ice hockey at national elite level. He became a specialist in general surgery in 1972 and in orthopedic surgery in 1973. He was awarded a PhD in 1974 with his thesis *Fracture of the neck of the talus*.

Lars was the team physician for football/soccer and ice hockey teams for over 20 years and head physician for the Swedish national teams in football/soccer and ice hockey. He has been a member of FIFA's Medical Committee since 1979 and is one of the founding fathers of FIFA Medical Assessment and Research Center.

He has published over 200 scientific articles on orthopedics, Sports Medicine, rehabilitation, biomechanics, degradable synthetic materials, cell biology and therapy. He has written several textbooks, manuals and book chapters.

In 1987 Lars Peterson pioneered the treatment of articular cartilage injuries using autologous chondrocyte transplantation with cells isolated and cultured in the laboratory, the first cell therapy in Orthopedics. He was a founding father of the International Cartilage Repair Society in 1997 and its President 2001–2002.

He has lectured extensively nationally and internationally and received many prestigious international and national awards. In 2007 he was one of the first Europeans inducted into the 'Hall of Fame' by the AOSSM (American Orthopedic Society of Sports Medicine). In 2010 he was awarded 'Doctor Honoris Causa' at the Medical Faculty of the University of Helsinki, Finland, and in 2011 at The Universidad Catolica de San Antonio of Murcia, Spain. In 2015 he was awarded honorary membership and the Gold medal by The Swedish Football Association.

Lars has been married to Lillemor for over 50 years and has 4 children and 9 grandchildren.

Per A. Renström, MD, PhD, Professor Emeritus in Orthopedic Sports Medicine, Karolinska Institutet, Stockholm, Sweden

Per Renström specialised in Orthopedics and Sports Medicine at Sahlgrenska University hospital, Göteborg 1973–1988, at the University of Vermont, Burlington, Vermont, USA 1983–4, 1988–1997, and at the Karolinska Institutet and University Hospital in Stockholm 1987–2007, where he is now Professor Emeritus.

His main research areas include clinical management of athletic injuries, basic research in knee/ankle ligament and tendon biomechanics and healing. He was awarded his PhD in 1981 with his thesis *The below-knee amputee*. Per has been author of over 240 scientific publications in peer reviewed journals, 73 book chapters and 17 books and has received several prestigious research awards.

He is an active member of the Medical Services Committee of the ATP World Tour and of the Medical and Scientific Commission of the ITF (International Tennis Federation) and former physician for the Swedish Davis Cup team in tennis. He enjoyed being the physician for the Swedish as well as the US national teams in football/soccer. Per is honorary member of the classic football/soccer team GAIS and presently the physician for the Swedish Football Association.

Per was Chair for the Special Olympics, Sweden 1999–2007 and for the Swedish Council of Sports Science 2000–2008. After being Vice President of FIMS (International Federation of Sports Medicine) 1990–1998 he received the FIMS Gold Medal in 2000. Per was President of ISAKOS (International Society of Arthroscopy, Knee surgery and Orthopedic Sports Medicine) 2003–2005 and was awarded honorary membership in 2009. He was a member of the Medical and Scientific Commission of the IOC (International Olympic Committee) 1989–2012 and received the IOC President's Gold award in 2013. Per was awarded Honorary Fellowship by the Faculty of Sports and Exercise Medicine, Royal College of Physicians of Ireland in 2008 and of the United Kingdom in 2011. He was inducted in to the Hall of Fame by AOSSM (American Orthopedic Society of Sports Medicine) in 2009.

Per has been married to Lena for over 49 years and has 4 children and 6 grandchildren.

Acknowledgements for the fourth edition

This fourth edition is the result of several years of work, although the book is a continuing development based on the earlier three editions but it is also updated and evidence-based, taking into consideration the huge number of scientific publications during the last 15 years. There are some people that have helped and supported us greatly during the whole journey; for this we are very grateful.

Good illustrations are of greatest importance for the success of a book of this nature and add to the value of the book. In the 1970s Tommy Bolic-Eriksson, Mörkö, Sweden helped us with his great imagination and made some outstanding art work that is still part of this book. In the second and fourth editions Tommy Berglund, Göteborg, Sweden was the main illustrator and Lennart Molin, Göteborg, Sweden in the third. We are very grateful for their skillful and imaginative contributions that are part of the present book.

Tommy Berglund has made 100 new illustrations for this new edition. He has listened to our intentions and discussions and been very receptive and professional in carrying out his work.

Ole Roos, Mölndal, Sweden, our friend, has been responsible for the photographic work for all the four editions since 1977. His professional skills and true support are greatly appreciated.

Bildbyrån, Hässleholm, Sweden has supported us with many of the action pictures. We are grateful to Professors Marc Safran, Stanford University, California, USA and Björn Engström, ArthroClinic, Stockholm, Sweden and others for helping us with pictures. We acknowledge the support by the Swedish Football Association and the Swedish Athletics Association.

Rehabilitation after sports injuries is becoming increasingly important in Sports Medicine. We have had great help from two truly amazing physiotherapists, Anna Frohm and Annette Heijne, throughout this edition. Besides being co-authors of the rehabilitation chapter they have taken numerous rehabilitation pictures, which are invaluable for this book. Anna Frohm graduated with a PhD at Karolinska Institutet, Stockholm, Sweden and is today the Head of Sports Medicine at the Swedish Sports Confederation. Annette Heijne, PhD, is now the head of the Division of Physiotherapy, Department of Neurobiology, Care Sciences and Society at Karolinska Institutet. Thanks for sharing your great skills with us and the readers.

Concerning the text we have received some great advice from a few world class experts for a few sections including Professor Tommy Hansson, Sahlgrenska Academy, Göteborg, Sweden for Chapter 16 on the spine, Professor Bengt Saltin, Copenhagen, Denmark for sections on physiology and Todd Ellenbecker, DPT, MS and vice president of ATP World Tour for Chapter 10 on the shoulder. We also want to thank Scott Lynch, MD, Penn State University, USA for all his earlier great supportive work.

Dale Reese, the physiotherapist for the football/soccer team IFK Norrköping has been very instrumental in the translation of many chapters, as has Erik Nexborn, physiotherapist for Örgryte IS. Tommy Eriksson from the Swedish Athletic Association has shared his great expertise in describing the different taping techniques. We would also like to thank the editors in Oxford, UK, Ruth Maxwell, Kate Nardoni in particular and Naomi Wilkinson for their very valuable professional criticism and constructive suggestions for improvements of both text and language.

This book would not have been so successful through the years without the incredible support we have had from our wives, children and grandchildren. Thank you for all your patience and for all the time you have allowed us to work on this book.

Foreword

Sport, whether recreational or competitive, is now one of the most, if not the most, widespread forms of physical activity in the world. People of all ages with widely differing conditions and aspirations undertake some kind of sport for their physical, mental, social and cultural well-being and, thus, also for their health.

Although the positive benefits of sport are clear, it can pose a risk of injury. Therefore, it is in all of our interests to prevent injury by reducing possible risk factors through individualized training and competition programs. When injury does occur, speedy and appropriate treatment is required, followed by rehabilitation.

The need for expertise in Sports Medicine is therefore great, as is education, research and experience exchange in both healthcare and sport.

The ability to interpret the symptoms correctly and treat an injury properly are reasonable requirements of doctors, physical therapists, nurses, etc. Physical education teachers and sports coaches should be well informed on the subject and the athletes, regardless of level, should be encouraged to acquaint themselves with preventative exercise and self-care of an injury. Therefore, the goal of the authors was to write and illustrate the book so that the text and images together provide an understanding of different injury situations and their consequences, for individuals who are medically trained or not.

You have in your hands a new and valuable tool, namely a new production of the successful handbook Sports Injuries. This is the fourth edition, written by the professors in orthopedics Lars Peterson and Per Renström who are experts in Sports Medicine with an international reputation.

The first edition of the book was published in 1977 (i.e. 35 years ago) and became a success. This is largely because it addressed the most common injuries in sports competently and pedagogically, using understandable language plus pictures. When the second edition appeared in 1983 the text had been complemented with 'news' and excellent color images. In 1986 the book was published in English, entitled Sports Injuries. It has now been translated into 12 languages and has sold c. 800 000 copies—an impressive result and proof of quality!

I am confident that the book will continue to be a valuable addition to many different education programs. This applies primarily to doctors, physical therapists, nurses, etc. in healthcare, but also to physical education teachers and coaches, as well as sports and outdoor recreational leaders, wellness and fitness staff, and similar professions. Sports Injuries has become the 'gold standard' for the work of these professionals as well as the athletes themselves.

Finally, I want to emphasize that the authors, in addition to their roles as professors, practicing orthopedic surgeons, teachers and researchers in Sports Medicine both nationally and internationally, have extensive experience as sports physicians in a number of specialized sports federations and associations. With tireless dedication they have lectured and advised on sport as well as injury prevention and treatment. The contents of this book rest, therefore, on the knowledge and experience gained during more than 40 years in Sports Medicine, both at the national and international level.

On behalf of the sports world I thank Lars Peterson and Per Renström for yet another quality product to help prevent, treat and rehabilitate sports injuries, and hopefully a bestseller not only in Sweden but also around the world.

Bengt Sevelius
President and General Secretary of the Swedish national sports federation 1980–1998
Chairman of the Council of Europe's sports committee 1989–1993
Chairman of the Confederation of national sports federation and Olympic committees in Europe (ENGSO) 1995–2007

Preface

We, the authors of this book, have been much involved in Sports Medicine since the beginning of the 1970s, i.e. over 40 years. We were both physically very active growing up, Lars at elite level and Per at the level just below, and sports have played a huge role in our lives. When we became MDs we tried to combine our interest in sports with our medical profession. In the beginning this was a challenge as the discipline of Sports Medicine as such didn't really exist, despite the fact that even then, injuries were the major problem in sports. The injured athlete had nowhere to look for help. As being active in sport we were asked by many for advice and to handle all kinds of injury problems. We were also early on asked to give numerous lectures at courses in Sports Medicine around the country at different levels. There was very little written in this area and only very limited parts were evidence-based. Some major sports organizations such as the Swedish Sports Confederation and Swedish Football/Soccer Association asked us to write down our experiences in written form. As a result of this, the first edition of this book was published in Swedish in 1977. The next edition came in 1983 and in English, 1985, published by Dunitz Ltd., London. In a few years the book was translated into 12 languages and became globally the most widely spread sports injury book. The third edition was published in 2000 and now it is time for the fourth edition.

We have mostly worked in Orthopedics and Sports Medicine, which include prevention, diagnoses, treatment rehabilitation and prevention of sports injuries. We discovered early, that being continuously active in sports gave us an edge in dealing with sports related issues. We could understand not only the issues but also the injured the athlete's language in both the clinic and the locker room. We acquired specific knowledge about the loads on the body endured through sport, the specific injury mechanisms, and so on. We also found Sports Medicine to be very stimulating and much fun. It is rewarding to be part of a sport's medical team as they mostly deal with highly motivated and otherwise healthy patients. The interaction is usually quite positive and the management usually results in a very satisfied patient.

These 40+ years we have been involved in Sports Medicine have been an exciting and rewarding adventure, as we more or less had to start from scratch. During this period Orthopedics and Sports Medicine has been characterized by an unbelievable development. Since 1970 there has been a 'revolution', including the emerging of total joint replacement, minimally invasive procedures with the development of arthroscopic surgical techniques as well as the modern management of fractures. The value of early motion and evidence-based rehabilitation introduced by Sports Medicine has had an enormous impact in the healthcare field overall.

This new edition would not be a reality without the skillful advice and help of our co-workers as mentioned under Acknowledgements. We are truly grateful for their generous support. Finally we would like to thank especially our wives, Lillemor and Lena, and our children and grandchildren for all their support and great patience allowing us to spend hundreds of hours of work on this book.

We hope this book will be a valuable tool for many people active in sports and physical activity.

Lars Peterson, MD, PhD
Per Renström, MD, PhD

Glossary

Note: Illustrations of anatomic terms are listed in italic in the Index.

abduct: to move a part of the body away from the midline of the body.

adduct: to move a part of the body toward the midline of the body.

avulsion fracture: tearing off of an attachment to a bone.

bursa: a small sac of fibrous tissue, lined with a synovial membrane and filled with synovia.

cartilage: dense connective tissue composed of a matrix produced by specialized cells (chondroblasts).

chondral: describing cartilage.

concentric work: muscle contraction during shortening of the muscle.

crepitation: creaking or crackling sound.

cutting: a sudden sharp turn (e.g. as performed by the knee in running sports).

debridement: excision of devitalized material.

distal: situated away from the origin or point of attachment or the median line in the body.

dorsiflexion: backward flexion of the foot or hand or their digits, i.e. bending towards the upper surface.

eccentric work: muscle contraction during lengthening of the muscle.

epiphysis: the end of a long bone, initially separated by cartilage (growth plate) from the shaft of the bone.

evert: turn outwards.

exostosis: bony outgrowth.

hallux: the big toe.

hypertrophy: increase in the size of tissue or an organ brought about by the enlargement of its cells rather than by an increase in their numbers.

hypotrophy: decrease in the size of tissue or an organ brought about by the shrinking of its cells rather than by a decrease in their numbers.

invert: turn inwards.

isokinetic training: a form of muscle training performed at a constant speed and against a variable resistance.

isometric training: a form of muscle training performed at a constant position (without a change in the length of the muscle) and variable load.

isotonic training: a form of muscle training performed at variable load.

-itis: inflammation of an organ, tissue, etc.

kinetic chain: multisegmental motion involving one or more joints; ***closed*** when the distal segment is stable and the proximal is free; ***open*** when the proximal segment is stable and the distal segment is free.

lateral: relating to or situated at the outer side of an organ, tissue or the body.

ligament: a tough band of white fibrous connective tissue that links two bones together.

luxation: complete dislocation of a joint; opposing articular surfaces are no longer in contact.

medial: relating to or situated at the inner side of an organ, tissue or the body.

multiplane exercises: limbs are exercised in a variety of different planes of motion (frontal, sagittal).

osteochondral: describing bone and cartilage.

osteophytes: bony deposits.

periosteum: a layer of dense connective tissue that covers the surface of a bone, except at the articular surfaces.

plantar: relating to the sole of the foot.

pronation: the act of turning the hand or foot so that the palm or sole faces downwards.

proprioception: the ability to apprehend positional changes of parts of the body or degrees of muscular activity without the aid of sight.

proximal: situated close to the origin or point of attachment or close to the median line in the body.

rotator cuff: the area of mergence of the tendons of subscapularis, supraspinatus, infraspinatus and teres minor muscles.

subluxation: partial dislocation of a joint; opposing articular surfaces are no longer correctly aligned.

supination: the act of turning the hand or foot inward so that the palm or sole faces as far upwards as possible.

synovia: thick colorless lubricating fluid that fills a joint bursa and a tendon sheath, secreted by the synovial membrane.

trabecular: porous (cancellous) bone.

valgus: describing any deformity that displaces a joint towards the midline.

varus: describing any deformity that displaces a joint away from the midline.

1 Sports Medicine/Injuries in Sports and Society

Introduction

Physical activity and sports are the foundations for well-being and for protecting health. Sports are furthermore entertaining and lots of fun and generate a wonderful feeling of togetherness and comradery (Fig. 1.1). Unfortunately, participating in sporting activity carries certain risks for injury. In England sports injuries account for about 2 % of Accident & Emergency cases recorded.[1] In the USA there were 2.6 million Emergency department visits by athletes aged 5–24 years in 2001, and 500,000 physician visits by high school athletes. At that time, the estimated annual healthcare cost related to emergent care of the young athlete was two billion dollars.[2]

Tip

If a top level athlete is injured he/she cannot compete or train regardless of how much money the club has invested in the player.

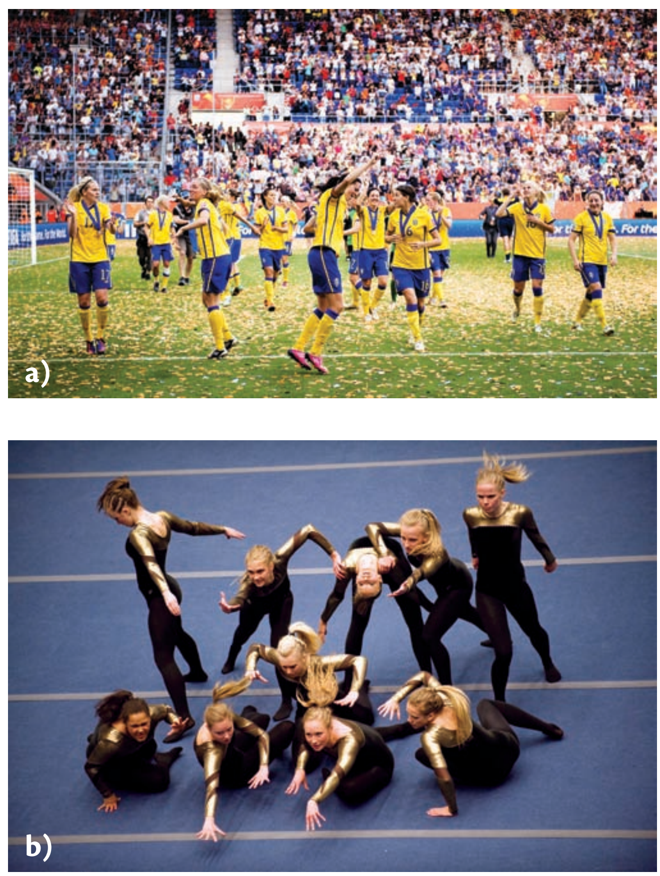

Figure 1.1 a, b) A feeling of togetherness and comradery is valuable in sport and is most often created in team sports. **a)** With permission by the Swedish Football Association, **b)** with permission, by Bildbyrån, Sweden.)

Our knowledge and experience concerning prevention, diagnosis, management, rehabilitation and return to sport after injuries and illnesses need to continuously improve and develop. To secure the highest quality and optimal healthcare, relevant education, research and experience gained in the field of Sports Medicine are of major importance.

The realization of the importance of a well-functioning Sports Medicine services program started to grow rapidly during the 1970s, when physicians, in cooperation with physiotherapists/athletic trainers, actively and successively started to take care of injured athletes and all others with problems of the musculoskeletal system.

Taking care of sport teams started to be common in Europe and the USA during the 1960s and exploded during the 1970s. Sports Medicine is a broad topic covering several disciplines including physiology, orthopedics, rehabilitation, internal medicine, infection and to a smaller extent pharmacology, pediatrics, gynecology, psychology, etc. Its role within sports itself is complex and is related to exercise and performance physiology, as well as to knowledge of the effects of physical activity and health-promoting lifestyles.

Tip

Knowledge and research in Sports Medicine should be a natural and well integrated part of sport as well as in health care, but this is not yet well accepted.

Sport at large has an important role for society as a whole. Sport and physical activity create joy and satisfaction for persons active in sport (Fig. 1.2). It also benefits social togetherness and has an acknowledged educational influence on children and adolescents.

Participation in sports and physical activity on a recreational level is likely to be the most important factor for human health and well-being at all ages. Physical activity can also be used as treatment for many different illnesses.

Physical activity decreases the risk of developing or dying from different cardiovascular diseases, not least as physical activity partly can prevent or slow the development of high blood pressure. Physical activity can furthermore decrease the risk for diabetes, cancer in the colon, obesity and osteoporosis, and can contribute to limit pain conditions in the musculoskeletal system. Physical activity has also some positive effect on sleep deprivation, minor depression, as well as stress and anxiety.[3] Current research shows, however, that people are less active today, which may cause some problems for future health.

Sports competition has it greatest importance during childhood and adolescence, when many exercise and compete in some form of organized sport. The acceptability of the competition component has been up for debate may times, but is described by athletes as an important component for the motivation to train. It is natural to compete in different ways during the growing years, which, in combination with large changes in body and soul during the same period, may create special, often complex and interesting, Sports Medicine questions.

Top level sport is very entertaining and is given large media coverage including on television, radio, in the

Figure 1.2 Joy is and should be an integral part of all sports. **a)** Joy in a classic national Swedish football/soccer team; **b)** joy among young football/soccer players; **c)** an Olympic medal gives great joy not only to the athlete but also to the fans. (With permission, by Bildbyrån, Sweden.)

press and in debate in society. Sport creates excitement, often inspires children and adolescents to start a sport, and audiences around the world like and celebrate sport superstars. These athletes have reached the top because of their extensive systematic training. Top level athletes push themselves to find their maximum, both in competition and training, over a long time, often several years. The goal for any athlete should be used to determine the exercise dose–response that works best for the individual, both the top level athlete as well as the recreational athlete. Through studying the effects of different training techniques and 'doses', research on performance aims to analyse the mechanisms behind improving the performance in athletes (Fig. 1.3).

Tip

Top athletes cannot reach the top – 'win gold' – without the help of research in sports science studies about optimal performance capacity and training.

If an athlete is injured he/she cannot train and compete for the team, regardless of how many millions of dollars the athlete has cost in a transfer. This is a well-known truth that is not well debated. In most sports injuries are a major problem. In Premier League football in England for example, at any one time 10% of the players are injured. Everyone with an injury is well aware of how frustrating it can be not to be able to take part. In most active and developed countries Sports Medicine research has resulted in a major Sports Medicine knowledge base for the management of injured athletes, including information on how to instigate a safe return to sport as soon as possible. Too early return and insufficient rehabilitation after an injury is a common cause for the recurrence of an injury.

Injuries during sport, exercise and physical activity

Participation in physical activity, exercise and sport may cause injury or painful conditions. For the competitive athlete an injury may result in a pause in training and competition. This can further be reinforced by waiting times for examination and evaluation with modalities such as magnetic resonance imaging (MRI)

Figure 1.3 a, b) Top level sport puts great demands not only on physical performance, but also on materials and equipment, etc. (With permission, by Bildbyrån, Sweden.)

and ultrasound, and for decisions on how to manage the injury. This may be an especially important aspect for some young athletes, resulting in their ceasing to participate in sport.

In top level athletes the management of injury or illness often requires specialized knowledge as some injuries can be rare and difficult to treat. Furthermore, most athletes, regardless of level, want a speedy and correct diagnosis, treatment and rehabilitation in order to get back to sport as quickly as possible.

In many countries these wishes of a quick service can be difficult to accommodate, not least because of priorities in treating other more general diseases and sick patient groups. Top level athletes, with their strong wish for a quick return to sport after an injury provide a strong driving force to develop new and effective therapy – and rehabilitation techniques. These top level athletes often generously participate in the testing of different new, hopefully more effective, rehabilitation methods, which later can be translated into routine health care.

Tip

Experience of the health management of top level athletes will help improve general health care.

One example of speedy rehabilitation and mobilization after surgery that Sports Medicine introduced during the 1970s is arthroscopic surgery, especially of the knee. This technique has been available for over 30 years and is now well accepted by the general population, and is considered a giant step forward.

Many injuries can last a long time and require months of rehabilitation before the athlete can return to the same activity level. A very knowledgeable Sports Medicine physician can, with the help of the latest science research and experience, get the athlete back to sport quickly and safely. It is therefore essential that the physician and physiotherapist who treat injured athletes have specific knowledge about not only Sports Medicine, but also about the available and current science and the specific sport involved.

Sports & Exercise Medicine for children and adolescents

Play, physical activity and sport is natural for children. However, it is import to understand how strenuous training of children will affect them (Fig. 1.4). A relevant question is then: When a child starts to specialize in sport what medical factors should be considered and studied? In most sports moving from junior to senior sport is a large, if not huge, step. During these years there is an increased risk for long-lasting injuries and thereby dropping out of sport. Therefore, research in Sports Medicine and Sports Science for the young and adolescents needs to be improved and extended.

Figure 1.4 a–d) Examples of good sports for children and youngsters. (With permission by Bildbyrån, Sweden; C, Andrea Samuelson.)

Sports & Exercise Medicine from a gender perspective

Research during the last few years has shown that women participating in football/soccer, handball, volleyball and basketball have a much higher risk (× 2.6 times) of injuries to the anterior cruciate ligament compared with men (Fig. 1.5). There is intensive ongoing research about the causes and reasons for this. Gender differences in hormonal effects, anatomy, biomechanics and balance have been identified as contributing factors, but the problem is far from being solved, and research is continuing apace to find ways to decrease and preferably prevent these injuries. Women participate in sport with increasingly equal opportunities as men, but the risk for injury is not yet equal.

The balance between training and competition

There is evidence that overuse injuries in sports and exercise (and perhaps also acute injuries) is related to insufficient balance between training/competition and amount of rest. The recovery period between competition and training is therefore very important in most sports, especially in top level sports. In a sport such as tennis the players play tough matches every day and an ice hockey player in a National Hockey League plays 3–4 matches per week, with travelling in between. How can the athletes have an optimal recovery after a tough match? It is important to recover not only energy levels, but also to recover power and strength to sustainable levels in the tissues, especially the muscles. Optimal recovery will prevent injury and illness and thereby allow for long and injury-free careers, which most likely will generate better results and thus success.

Figure 1.5 a, b) Young players, especially girls, have an increased risk during adolescence for serious knee injuries such as of the anterior cruciate ligament. (With permission, by Bildbyrån, Sweden.)

Sports & Exercise Medicine in healthcare

Most sports injuries such as acute orthopedic trauma cases including fractures, dislocations, strains and sprains are managed expertly by general healthcare providers and are treated routinely at most hospitals and clinics. Some sport injuries are, however, unusual or are of an overuse type and the diagnosis can be difficult to establish. Knowledge and experience of overuse injuries concerning diagnostics, treatment, rehabilitation and return to sport and not least prevention, is often limited in general healthcare systems. This may result in the injured athlete being passed between different practitioners, which may very frustrating for the athlete and may also cause unnecessary costs for society.

Tip

It is important that the latest scientific experience and evidence-based medicine are used in Sports Medicine and be of benefit for all athletes.

Sports Medicine has specific knowledge about injuries and illnesses that may cause problems for athletes. Every sport, from recreational sports to top level sports, and in different ages will generate its own specific problems. Sports & Exercise Medicine can be regarded as the athlete's 'work-based healthcare'. Financial support for Sports Science and Sports Medicine is, however, very limited. If, for example, 1–2% of public financing of top level sport was ear-marked for Sports Medicine service and research, such support would secure high quality knowledge about risk for injury, prevention and performance etc. However, such issues are not discussed openly by sports associations or society at large. It is our belief that the connections between Sports Medicine and sport at large should be much tighter and more open.

Why support Sports & Exercise Medicine?

- Everyone should be active with regular physical activity appropriate to their own ability but should be aware that there is risk for injury.
- The experiences from Sports & Exercise Medicine services will benefit everybody.
- Many injuries can be prevented.

Sports & Exercise Medicine background and history

History

The ancient Olympic Games starting in 776 B.C. in Olympia in Greece were initially a 1-day event but in 684 B.C. were extended to 3 days, and in the 5th century B.C, to 5 days. These Games included running, long jump, shot put, javelin, boxing, wrestling and equestrian as the most important events, and soon included pentathlon with discus throw. The Olympic Games were organized every 4 years (*the Olympiad*) between 776 B.C and 394 A.D (Fig. 1.6). These Games were considered great events and were looked upon as symbols for peace. The Olympic Games were forbidden in 394 A.D. and then reinstated in 1896, when the modern Olympic Games era was initiated. The first modern games, held over a couple a weeks as we know them today, was the Olympic Games in Stockholm in 1912. The Olympic Games today generate great public interest and have stimulated many individuals to become more physically active.

The first use of therapeutic exercises to treat illness and injury is credited to Herodicus from around 500 B.C., who recommended strict diet, constant physical activity and regular training to maintain good health. He also introduced the use of massage. Herodicus is considered by many to be the 'father of Sports Medicine'. He was the teacher of Hippocrates (469–399 B.C.), who is considered to be the 'father of Medicine'. Hippocrates postulated that an athlete's injury should not be regarded as an effect of the disgrace of the Gods, but was instead related to athletic activity. Galen (129−199 B.C.) was a prominent surgeon during the second century B.C., and his works on anatomy and of the relation of the body and mind were highly regarded for many years. He was also a team physician for the gladiators and was called upon when there was an injury.

It was not until the Winter Olympic Games in St. Moritz in 1928 that Sports Medicine formally was formed. At this meeting a decision to form the Federation Internationale Medicine de Sport (FIMS) (International Sports Medicine Organization) was made and the term Sports Medicine was coined.

The First International Congress of Sports Medicine was then held at the Summer Olympic Games in Amsterdam. FIMS is still active. In 1954 the 'American Chapter' of FIMS was founded and their name was changed the year after to the American College of Sports Medicine (ACSM). After a deadly doping case during the Rome Olympic Games in 1960 the International Olympic Committee (IOC) formed a Medical Commission in 1962 and it has been increasingly active since then.

During the 1970s and later, a number of sports-related international medical societies were formed, most notably the International Society of Arthroscopy, Knee surgery and Orthopedic Sports Medicine (ISAKOS), which was founded in 1995 as a merger of the International Society of the Knee (ISK) and the International Arthroscopy

Figure 1.6 The Olympic arena in Olympia in Greece, where the ancient Olympic Games were held, starting in 776 B.C and continuing until 394 A.D., when they were forbidden for religious reasons. The picture shows the shot put final on the 192 m long running track during the Athens Olympic Games in 2004.

Association (IAA). ISAKOS is today the leading international orthopedic Sports Medicine organization with very active and related continental and regional partners.

National Sports Medicine organizations started to be formed during the 1920s in countries such as France, Netherlands, Belgium, Italy, Germany and Poland. In 1953 the British Association of Sport and Medicine was formed and has recently changed its name to the British Association of Sport & Exercise Medicine. As mentioned above, ACSM was founded in 1954 and is the largest national Sports Medicine & Exercise science organization in the world, with more than 45,000 members. The American Orthopedic Society for Sports Medicine (AOSSM), founded in 1972, is an organization of orthopedic surgeons and other allied health professionals dedicated to Sports Medicine. Essentially every professional and collegiate team in the USA has a team physician, who is a member of AOSSM. The Canadian Academy of Sport and Exercise Medicine (CASEM) was founded in 1971 and is an organization of physicians committed to excellence in the practice of medicine as it applies to all aspects of physical activity.

During the early 2000s there was a strong move in many countries towards encouraging people to become more physically active and also to use physical activity as a treatment method. To reflect this paradigm shift, the specialty itself in some countries has rebranded from Sports Medicine to 'Sports & Exercise Medicine', including the national Sports Medicine societies in countries such as Great Britain, Australia and Canada. In Sweden the name has changed to 'Physical Activity and Sports Medicine'.

It should also be mentioned that the Medical Commissions of the International Sports Federations in sports such as football/soccer, ice hockey, handball, basketball, athletics etc. have lately become increasingly active in prevention of sports injuries, as their financial situation is much improved and sports injuries constitute a growing problem.

Components of Sports Medicine and Sports & Exercise Medicine

Sports Medicine has long been a specialty that focuses on prevention, treatment and rehabilitation of injuries and illnesses related to sport and physical activity. Sports & Exercise Medicine is focused on all medical problems that can occur during sport and physical activity and also on the benefits generated by physical activity and exercise. Since the late 20th century, Sports & Exercise Medicine has gained increasing interest and is now regarded as an integral part of healthcare. Sports include in general a strong competitive component and therefore the management of injury and illnesses is expected to be optimal and the recovery to full activity, at the same activity level, to be speedy and successful.

There are aspects of Sports & Exercise Medicine present in most medical disciplines; Sports & Exercise Medicine is multifactorial or a cross-over specialty in a wider sense. This can mean that many persons with different knowledge are involved in treating one athlete with one injury or illness. Besides a physician, a physiotherapist/athletic trainer, a nurse and sometimes 'complementary medicine' practitioners (e.g. osteopathy, naprapathy and chiropractic) may be part of the Sports Medicine team.

In the first half of the 1900s general physicians dominated Sports Medicine, but since the 1970s orthopedists have gradually become more dominant although other aspects have also developed. Today many 'non-orthopedists' are very active in Sports & Exercise Medicine, including physiologists, family practitioners, cardiologists, etc. There are also other important related areas such as internal medicine, pediatrics and gynecology, as well as other sports scientific areas, e.g. biomechanics, technology, sociology, psychology, history, education and other paramedical specialties.

Sports Medicine involves athletes at all levels, not only top level athletes. This is very evident from the experiences of all the mass running events available today with tens of thousands of participants. In the media the Sports Medicine physician is portrayed as the physician who only takes care of the top level athletes, but this is not the case. The majority of the problems a professional athlete is subjected to is also common among recreational athletes, who constitute the overwhelming majority of people visiting the physician's office. The top level athletes are few and they are often taken care of by a few medical super-specialists.

Sports injuries

Athletes may sustain injuries in the same way the general population can get injured in daily life. Sports injuries can be divided into two types: the acute traumatic injuries and so-called overuse injuries. Traumatic injuries can happen to anyone, for instance through vehicle accidents, at work or similar. One main difference is that sports injuries are sustained by individuals with good muscle strength, often during motion, with much power and high motion energy involved. This may result in more extensive and severe injuries in athletes compared with non-athletes (Fig. 1.7). On the other hand, the athletes are mostly young, healthy individuals with good healing capacity, which means that an injury may well heal well and normal function be restored in the injured body part.

Tip

Athletes not only want to be fully recovered from their injury to enable them to return to work – they also demand and expect to be healthy and recovered from the injury so they can return to sport and function at the same level as before the injury.

The athlete's demands for rehabilitation and speedy return to sport are greater than those required by non-athletes. Because of this the Sports Medicine physicians and physiotherapists have needed to develop and refine diagnostic and surgical techniques and create quicker and safer rehabilitation methods. This has resulted in disciplines such as Sports Traumatology and Orthopedic Sports Medicine having been instrumental in generating new knowledge and experiences, for the benefit of Orthopedics in general.

Prevention

There are many risk factors contributing to the large number of sports injuries. These may be part of the anatomy, i.e. intrinsic risk factors such as malalignments of different kinds, for example 'knock-knees', where the knees angle in (genu valgum) or 'bow-leggedness', where the leg is bowing outward in relation to the thigh (genu varum, tibia vara), too high arches of the foot (per cavus) or flat feet, in which the arch of the foot collapses (pes planus). Risk factors can also be extrinsic or environmental factors, e.g. running on hills or canted roads, too much running, too much jumping on the toes, etc.

Tip

Risk factors must be identified as far as is possible. This can be done by studying the injury incidence (injuries/number of activity hours), the injury mechanism and its severity.

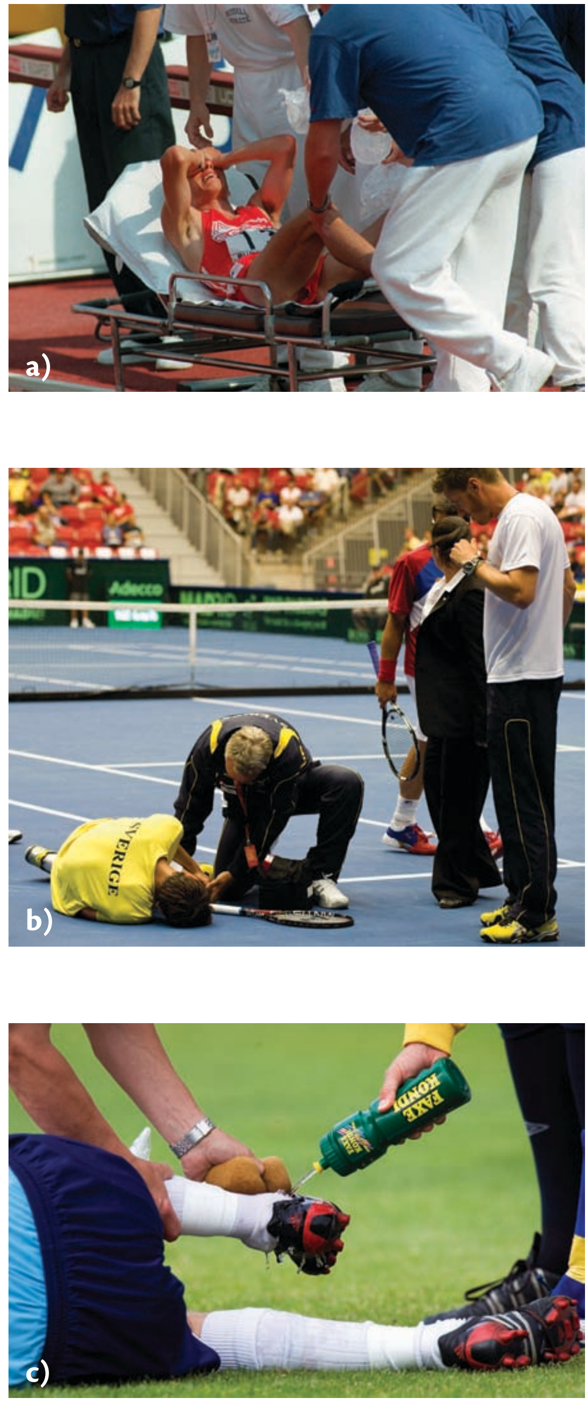

Figure 1.7 Acute and early management of an injury or illness is important. **a)** Early care after a long distance running race; **b, c)** experienced medical personnel are available for speedy management on site. (With permission, by Bildbyrån, Sweden.)

An injury pattern related to a certain activity may then result in the development of an injury prevention program. This can then be tested in the sporting activity involved to ensure that the program is effective. Preventive orthotics and taping may reduce the number of injuries and their severity (Fig. 1.8).

Figure 1.8 Orthosis/braces of the ankle can be very efficient in supporting the bone and the soft tissues during healing.

Sports traumatology includes overuse injuries. They are the result of too much loading carried out with normal frequency, with normal load too often (too high frequency) or, in worst case scenarios, too high load with too high frequency. Overuse injuries can also be the result of too high frequency activity in spite of low load. The specific problem with overuse injuries is that physicians who are not regularly managing these injuries often misinterpret the symptoms for something else.

An important part of injury prevention is participation in preseason examinations, identifying common risk factors including biomechanical changes such as maladaptations. Knowledge about warming up, stretching, strength and conditioning exercises, preventive orthotics and padding, sports equipment such as shoes and turfs, rules changes, etc. are very important.

Unfortunately it has been very difficult to generate financial support for injury preventive research, despite the fact that many studies show that large sums can be saved in healthcare and thus for society by introducing adequate injury preventive measures such as instituting the preventive programs available.

Injury prevention through physical activity and exercise

Sports and other types of physical activity can reduce the risk for many illnesses and injuries throughout life. Physically inactive people have a greater risk for conditions such as cardiovascular disease, diabetes, osteoporosis, depression, as well as colon and breast cancer.

- Regular moderate physical activity – such as walking, cycling, or participating in sports – has significant benefits for health.
- Physical inactivity is the fourth leading risk factor for global mortality according to the World Health Organization (WHO).[4]

Fracture in the elderly because of osteoporosis is very common. Prevention is provided by physical activity during childhood and adolescence, which results in increased bone density especially during the first 30 years of life, but also has positive effects throughout the full life span.

Sports Science

Sport Science can be said to include some subdisciplines such as sports and exercise physiology, biomechanics, psychology and behavioral sciences, sports history and some other allied disciplines. Sports and exercise physiology can be said to be the study of the long-and short-term effects of training on athletes, including strength and conditioning and nutrition. Applied sports and exercise physiology increases our understanding of how the healthy person functions, not least by also studying top level athletes.

Tip

Anatomy is about structure, whereas physiology is about function.

Sports and exercise physiology, the science of conditioning, fatigue, strength, muscle composition and muscle function, has been groundbreaking for many sports. Sports and exercise physiology is continuously developing and now includes studies in health sciences and genetics, which will have enormous impact in the future for Sports Medicine, not least when planning conditioning, strength training and recovery. Genetics seem to have a large influence over strength, muscle size and muscle fiber composition and to some extent, endurance. Possibilities will open for identifying genetic factors behind types of different injuries and illnesses.

The internal medicine component of Sports & Exercise Medicine

This part of Sports & Exercise Medicine includes illnesses and diseases associated with sports activities. An athlete can succumb to a 'cold' or a virus infection just like any individual. These diseases are usually not caused by the sport itself, but the sporting activity as such can make the symptoms more obvious. An illness that does not affect regular work (such as a cold) can make sporting activity not possible. It is therefore important to know what requirements different sporting events may have on the participating athletes in order to be able to decide if the illness or its symptoms require withdrawal from participating in the sport at that time.

Physical activity and exercise is furthermore used as part of the rehabilitation process as well as treatment of many illnesses. Physical activity is beneficial and important in conditions such as diabetes, obesity, rheumatoid diseases, vascular disease in the extremities (intermittent claudication), high blood pressure (hypertension) and chest pain (angina pectoris) or similar problems. Physical activity and exercise has been shown to be effective in the management of asthma and is of great importance for the individual's adjustment to a normal life. It is therefore of value to be aware of the consequences of having had an illness, but it is also as important to know what loads and potential problems different sporting activities may generate for the individual. This will decide which activities an individual is capable of participating in and what type of activity is suitable after having had a certain illness.

Sudden death is unusual but may occur during participation in sport. A limited number (2/100,000 cases a year) of sudden deaths occur during sporting activities. Guidelines are available in most countries. They include directed heart examinations of top level players and a number of risk groups.

It is impossible for a physician to cover all disciplines of medicine. There is, therefore, a need for practitioners with specialist knowledge in areas of Sports Medicine, such as sports traumatology, internal medicine, cardiology, exercise physiology, etc. These specialists need to cooperate to try to form a broad team taking care of the athletes.

Sports & Exercise Medicine as a specialty

In many countries Sports & Exercise Medicine physicians are specialists who have completed medical school, residency training in a specialty such as orthopedic surgery, family medicine, internal medicine, etc. and then continued to complete additional fellowship training in Sports & Exercise Medicine. These specialists not only treat and prevent injuries such as muscle, ligament, tendon and bone problems, but also may treat illnesses that can affect physical performance, such as asthma and diabetes.

Sports Medicine is a specialty in its own right only in some countries. In a European summary investigation in 2010 by the European Federation of Sports Medicine Associations (EFSMA), Sports Medicine was a basic specialty in 21 countries and a subspecialty in 15 countries, with a total of >20,000 specialists.

In many countries Sports & Exercise Medicine is still a subspecialty. Most physicians first study a basic specialty for 5–7 years and then they may add a subspecialty such as Sports Medicine with 3–12 months of basic education/training in this subspecialty. There seems to be an increasing need for physicians specializing in Sports & Exercise Medicine, especially in areas such as prevention and rehabilitation. In physiotherapy Sports & Exercise Medicine is a specialty in its own right.

Requirements of a practitioner in Sports & Exercise Medicine

It is essential to have a good basic medical education, not only within a specialty but also in related topics.

Tip

A physician with good knowledge and experience of a specific sport has a great advantage when it comes to understanding the risks and problems to be expected during activities in that sport.

There is also a need for understanding of what it means for an athlete to be sick or injured and why the expectations and requirements for a quick and speedy management and rehabilitation are so strong. The expectation for optimal management is very high from the sporting community, as instructions to 'stop being active in sport' are unacceptable. Problems should, if possible, be solved and not only accepted.

Ethical considerations in Sports & Exercise Medicine

Physicians, physiotherapists/athletic trainers and all others involved in Sports & Exercise Medicine must have some basic knowledge of the ethical 'rules' in this area. Ethics in Sports & Exercise Medicine are largely the same as medical ethics in general, such as the physician's main goal must be to protect the health of the athlete, never do harm and that the physician must not let his/her authority influence the individual's right to make his/her own decisions.

Tip

The main goal for a Sports Medicine physician must be to protect the health of the athlete.

The maintenance of complete and accurate medical records is a requirement for all types of healthcare providers, and personnel active in Sports & Exercise Medicine are no exception.

Participation in sports, especially top level sport, is never free from risk as the athlete is challenging his/her ability to the extreme. On the other hand, this does not mean that sport in itself is dangerous, but mostly gives many positive effects for good health. This means that persons active in Sports & Exercise Medicine, regardless of whether a physician or a physiotherapist, need specialist knowledge of the topic. Besides the basic medical knowledge there is also a need to recognize the special physical and psychological requirements put on the athlete, as they vary from sport to sport.

- Participation in sport gives so many positive health and social benefits that far outweigh any potential problems such as injury, doping (illicit drug use) scandals, etc.
- Being physically active is good for everyone!

If the athlete is a child or is elderly there are additional challenging risk factors to consider. The persons working in Sports & Exercise Medicine should share their knowledge with parents and responsible adults about the very special circumstances, advantages and potential risks that exist during training and competition for different ages.

A Sports & Exercise Medicine specialist should forcefully counteract methods and techniques used that are not in agreement with medical ethics or with science and evidence-based medicine.

Tip

It is unethical to participate in and support 'doping' of any kind. Doping is cheating.

The physician should not help to cover up pain so that the athlete can return to sport; with increased risk the injury will get worse or not heal. There are no strict rules covering appropriate use of injections, but in general anesthetizing a weight-bearing joint should be avoided. Pain killing injections are banned in sports such as rugby, but most sports governing bodies leave it to the discretion of the treating team physicians. No strict rules cover appropriate use of injections, but sound medical principles should be used to guide decisions without consideration of the specifics of the game or contest.

Sports under discussion

It is well recognized that boxing provides benefits for participants, including exercise, self-discipline and self-confidence. On the other hand professional boxing encourages and rewards deliberate blows to the head and face and therefore the boxers are at risk for head injuries, including neurological injuries.[5] Scientific evidence shows that nerve cell breakdown occurs in boxers who have been subjected to a knock-out. A physician's main goal is the protection of the athlete's health as mentioned above. Boxing should therefore not be allowed in its present form, according to Sports Medicine ethical rules. Some countries have therefore banned professional boxing, especially for children and adolescents.

Some countries have recently accepted mixed martial arts (MMA) as a public sport. It is a sport that allows kicks against the head and allows 'strangling' of the opponent until unconsciousness. The match physician and the referee have the obligation to stop the match when unconsciousness occurs, but at their own discretion as to when that occurs. Recently there are some regulatory changes, which may help making MMA a safer sport (Fig. 1.9).

Figure 1.9 Boxing is today a sport under discussion as there is an increased risk for brain injury. **a)** In professional boxing headgear is not used; **b)** amateur boxers do use headgear, which can decrease the risk for brain injury; **c)** mixed martial arts is a sport with some risks for injury. (With permission, by Bildbyrån, Sweden.)

Concussion has also developed into a serious problem in some other sports such as football/soccer, ice hockey, etc. Some preventive steps have recently been agreed in these sports; for instance in football/soccer FIFA Medical Committees have decided to monitor on-field head injuries and cases of potential concussion as follows:

- "In the event of a suspected concussion the referee stops the game to allow the injured player to be assessed. This should take no more than 3 minutes. If there is a serious incident the player will be treated on the field of play or immobilized on the field for immediate transfer to hospital.
- Any player suffering a head injury that requires assessment for potential concussion will only be allowed to continue playing after the assessment, on specific confirmation by the team physician to the referee, of the player's fitness to do so."

Trauma against the head will result in increased risk for brain damage. Mild traumatic brain injury or concussion is common in many sports. Repetitive head trauma is a risk factor for Alzheimer's disease and is the primary cause of a syndrome of global brain dysfunction (chronic traumatic encephalopathy).[6] It has recently been shown that education may have a protective effect against cognitive deficits following various forms of brain insult. These problems are now being studied in the Professional Fighters Brain Health Study of active professional fighters (boxing and MMA) and can hopefully be developed as a model for assessing the impact of cumulative brain injuries on cognition and brain health.[7] Neuropsychological evaluation is recommended in the monitoring of a concussion and in return-to-play considerations.[8]

- All athletes must be treated with the highest ethical standards and with respect.
- From an ethical point of view it is not acceptable to cause brain damage actively in any sport.

Respect and authority of Sports & Exercise Medicine personnel

A prerequisite for licensed healthcare personnel participation in Sports Medicine is that their authority as medical experts is recognized and is sustainable. The balance between the expert role of the medical personnel and the individual athlete's rights to his/her own decisions requires careful and well-thought through reflections. The physician and physiotherapist must try to understand the athletes' reactions to the requirements of the sport *per se* and to the pressures put on the athlete (Fig. 1.10).

Figure 1.10 One of the responsibilities of the team physician is to be responsible for the medical management both in the short and long term. **a)** The team physician evaluates the injured on the field; **b)** the therapist takes care of the athlete on the field. (With permission, by Bildbyrån, Sweden.)

Tip

The physician and the therapist must always make an independent medical assessment of an injury regardless of the opinion of other participants in the sport such as active players, coaches, trainers and leaders.

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2 Risk Factors for Sports Injuries

Individual risk factors

Athletes can suffer injuries in the same way as non-active people can in everyday life. Sports injuries often affect individuals with good muscle strength, often during movements with high force and high kinetic energy. This means that athletes' injuries are often more extensive and severe than the injuries that non-active individuals suffer. On the other hand, sports injuries often affect individuals who are healthy and young and have good healing abilities, which means that the injury can often be repaired so that the injured body part returns to normal function.

Figure 2.1 a, b) The risk for injury is increased in some contact sports. (With permission, by Bildbyrån, Sweden.)

Tip

An athlete requires not only full recovery and return to work but also recovery and return to full activity/play at the same level he/she had before the injury.

An athlete's requirements for management, rehabilitation and return to sport are higher compared to a non-athlete. This has resulted in pressure on Sports Medicine physicians and Sports physiotherapists/trainers and others to improve and refine diagnostic methods, develop safer and more sophisticated surgical techniques as well as more efficient rehabilitation to secure an earlier and safe return to sport. Orthopedic Sports Medicine (sports traumatology) has thereby contributed new knowledge and experience to general orthopedics and traumatology.

Risk for injury – multifactorial model for principal causes (etiology) of injury

In order to understand why injuries occur it is vital to understand the injury mechanism and the risk factors (Fig. 2.1). To do this we need to study injury epidemiology so that we can develop an effective prevention program. This is a complex event. This means that the athlete and his coach need to try to understand the main risk factors that exist in the sport and how the injuries occur. Meeuwisse developed a model in 1994 that involves both, internal – intrinsic – risk factors such as age, gender and body composition, as well as external – extrinsic – risk factors that may affect the athlete, such as weather, playing surface, rules and equipment.[1] At some point a 'triggering event' may develop for the athlete, causing an injury. This can be biomechanically related, but also related to the sport in question (Fig. 2.2).

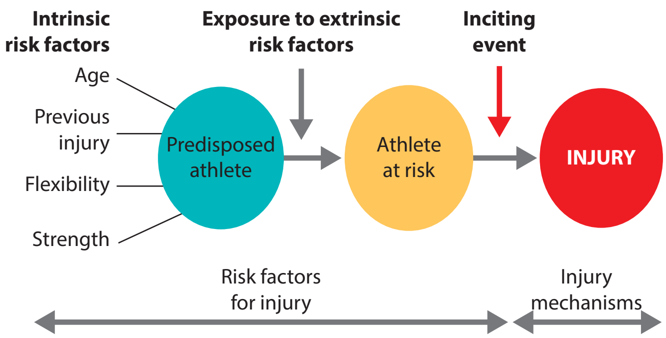

Figure 2.2 Risk for injury – a multi-factorial model for the cause of injury and analysis of possible failure mechanisms. (Modified after Meuwisse 1994.[1])

It is the internal factors that prepare the athlete for a given situation. External factors such as a competitive situation and the athlete's behavior contribute to an occurrence of an injury. The connection between different factors puts the athlete in a risky situation in which an injury may occur. More recent research emphasizes the importance of a more dynamic model in terms of the etiology of an injury.[2] This should also include the impact of repeated participation in sports, both with or without injury.

Effective prevention depends on good information on risk factors and injury mechanisms in terms of both mechanics and sports-specific considerations.

Internal (intrinsic) risk factors

The internal (intrinsic, body-related) factors, in addition to general ones such as gender, age and body weight, include various anatomical abnormalities such as cavus foot, excessive pronation of the feet, knock-knees or bow-leggedness (genu varum or valgum), side differences in anatomy, balance, muscle weakness, muscle tightness and general joint laxity. The greatest risk factor today is considered to be a previous injury, inadequate rehabilitation and too early return to sport.

The internal (body-related) factors can be divided into basic, primary and secondary (acquired). The basic internal factors include sex, age, body growth, weight and length. Important factors are the primary internal malalignments, leg length, muscle imbalances and insufficient strength, as well as reduced flexibility and neuromuscular coordination. Secondary acquired factors such as impaired function in the kinetic chain and previous injuries, are also important.

Basic/fundamental factors

Gender: gender and age are not particularly significant in terms of predicting sports injuries in general. The musculoskeletal system is dimensioned differently in women, who have 25% less muscle mass per kilogram body weight, lower bone density, wider pelvis and more mobile joints than men. These factors may make women more susceptible to 'female prone' injuries, such as stress fractures in the pelvis (p. 374) and patellofemoral pain syndrome (p. 446) (Fig. 2.3).

Over the past 20 years it has emerged that young girls aged 13–18 years have 2–4 times more anterior cruciate ligament (ACL) injuries than boys of the same age in team sports such as soccer, basketball, handball and the like (Fig. 2.4). This is discussed in detail in Chapter 19 on knee injuries (see p. 401) and in football/soccer injuries (see pp. 112–5).

Age: the changes in the musculoskeletal system to do with age consist of decreasing bone density, muscle strength, fluid content, metabolism and collagen in the tendons. Older people have a greater degree of degenerative changes in the tissues, resulting in decreased shock absorption and thereby increased risk of injury (Fig. 2.5). There is no evidence of any increased incidence of running injuries with age as a primary factor.

Body growth: young people aged 12–15 years often have an imbalance in muscle leverage, tightness, joint mobility and coordination. The muscle–tendon complex is relatively shorter at this age. There are some diagnoses that are age- and growth-related, such as Osgood–Schlatter's disease, injuries to the apophyses and some avulsion fractures.

Figure 2.3 a, b) Women in, for example, long distance and jumping activities are more susceptible to "female prone" injuries. (With permission, by Bildbyrån, Sweden.)

Figure 2.4 a, b) Young female players in sports such as basketball, football/soccer, team handball, and the like have an increased risk for serious knee injuries (e.g. ACL injuries). These often occur during landing after jumps. (With permission, by Bildbyrån, Sweden.)

Figure 2.5 a, b) Being physically active and participating in sports activities is beneficial for health at all ages, but especially for the elderly. (**a**) With permission, by Bildbyrån, Sweden.)

Weight and length: although obesity is sometimes seen as a potential problem for distance runners, no correlation between body weight and running injuries has yet been found.

Primary internal factors (see Chapter 6)

Malalignments of the foot can be divided into pes planus (flat feet) and pes cavus (cavus foot, high arch), each of which occurs in about 20% of the population. Pes planus leads to an excessive pronation during the stance phase. Pronation is discussed on p. 540. Excessive pronation can be physiologically induced, but can also be a secondary consequence of bow-leggedness (a tibia varus position). The probability to sustain an injury seems to be low if the total varus position is less than 8°, while the incidence of running-related injury increases if the varus position exceeds 18°.

Figure 2.6 Active hyperextension in the knee joint even without body contact can be a risk factor, such as in football/soccer. However, it can be compensated for by a good muscle strength especially in the main muscles of the thigh such as the quadriceps and hamstring muscles. (With permission,by Bildbyrån, Sweden.)

Figure 2.7 Cavus foot, characterized by a high foot arch.

Various malalignments can be combined. The ‘miserable malalignment’ syndrome (p. 451), which occurs in some runners combines anteversion (forward tilt) of the femoral neck with internal hip rotation and knees angled externally, a so-called valgus deformity at the knee, with the distal part of the leg deviated laterally. This can be combined with or without hyperextension of the knee joint (Fig. 2.6), different patella tilting angles, excessive Q-angle, varus position of the tibia, functional equinus and compensatory foot pronation (see Chapter 6, pp. 90–1).

Cavus foot (Fig. 2.7) can also be linked to sports injuries (Fig. 2.7). High arches have been found in approximately 20% of a group of injured runners. Athletes with cavus feet have reduced mobility in the subtalar joints (below the talus), which may result in a load on three areas (heel, big toes and the little toe’s footpads), reduced flexibility of the midfoot and excessive rearfoot varus. In the mid stance phase the heel remains in varus, the longitudinal arch is maintained and the foot does not disengage. The tibia remains in external rotation (see Chapter 6, p. 91, Chapter 22, p. 539 Fig. 22.6).

A functional leg length discrepancy may occur by running on canted roads.

Functional shortening can also be a result of impaired function of the sacroiliac joint, unilateral excessive pronation, muscle pain in the lower back or contractures or imbalances of the muscles. The leg length discrepancy can cause a pelvic tilt to the short side, functional lumbar scoliosis, increased hip abduction, excessive pronation, increased genu valgum and external rotation of the leg (Fig. 2.8). Leg length can be linked to injuries such as iliotibial band syndrome, trochanteric bursitis, acute lumbago and stress fractures. A leg length discrepancy that is not accompanied by other orthopedic disorders

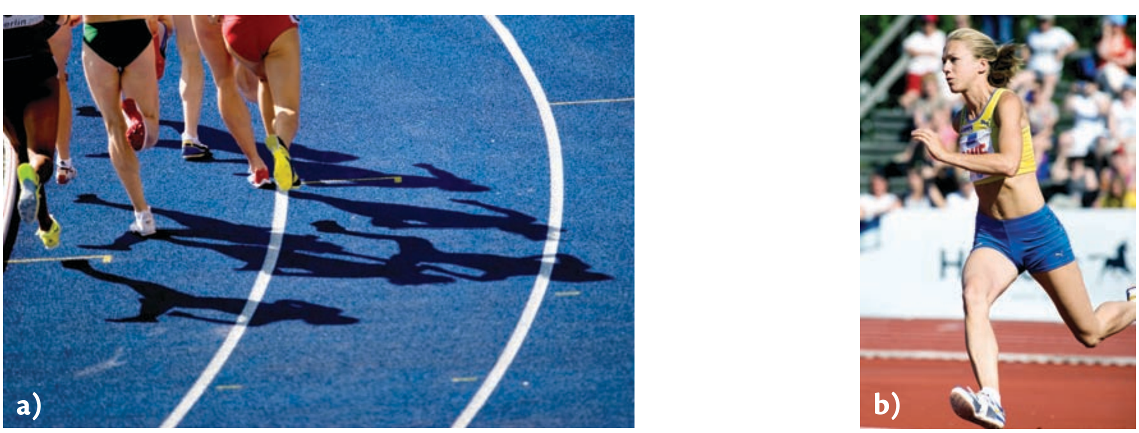

Figure 2.8 Functional length discrepancy may be caused by curve running and running on the road **a)** and can increase the stress on the lower limbs; **b)** during high jump running up to the bar there is often a rotation of the foot in relation to the lower leg. (With permission, by Bildbyrån, Sweden.)

usually does not need to be compensated for (see Chapter 6, p. 92).

Structural variations may contribute to the susceptibility to injury. A large protruding process (osteophyte) on the calcaneus may cause Achilles tendinopathy and /or inflammation in the bursa located behind the calcaneus. A large os trigonum (an extra bone posterior to the talus) or a protruding posterior process of the talus can cause posterolateral (rear outer) ankle pain. Tarsal coalition of various types can cause abnormal pain associated with loading. Tarsal coalition is an abnormal fusion-like bridge of tissue, that connects two normally separated bones in the rear to midpart of the foot. An accessory (extra) navicular bone (os naviculare) can cause medial midfoot pain (see Chapter 22, p. 549). This bone can be prominent on the inside of the foot and may lead to difficulty with proper fitting of footwear.

Good flexibility is emphasized by many as an important factor in preventing running injuries (Fig. 2.9). Running results in contracture of the hamstrings and calf muscles. Such reduced local flexibility can contribute to injuries. There seems to be no correlation between stretching habits and incidence of injury. It may be pointed out that there are reports that stretching may negatively affect the running economy, which includes many physiological and biomechanical factors that contribute to running performance.

Muscle strength: the muscles stabilize the lower extremities and absorb forces to the joints and bone during running. Because of the important role of the muscles in terms of both stability and shock absorption, muscle weakness can increase the susceptibility to stress fractures.

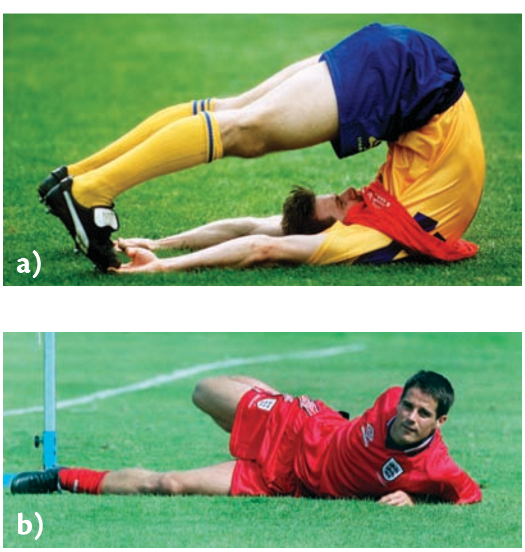

Figure 2.9 a, b) Flexibility. Stretching and mobility exercises are an important part of the warm up. (With permission, by Bildbyrån, Sweden.)

Neuromuscular function – coordination: disruptions in terms of balance and motor control can make a runner more susceptible to injury. Any kind of lack of proprioceptive ability (joint position sense, i.e. movement control without the aid of sight) can lead to functional instability in the ankle, for instance, which in turn makes the athlete more prone to injury.

Ligament laxity: general laxity of ligaments at excessive pronation may increase the risk of injury.

Secondary or acquired factors

In the kinetic chain the lower extremity is considered as a series of movable segments and links that enables the forward drive during gait. The kinetic chain is closed when the foot is in contact with the ground during the stance phase and is open when the foot is lifted and moves forward. Anything that disturbs the normal pattern and the mechanics of the force transmission can lead to changes in gait and compensatory movement patterns at other segments in the chain. In athletes with recurrent or previous injuries, it is particularly important to draw attention to the disrupted function in the kinetic chain. Since the kinetic chain function is very complex it often becomes overlooked as a primary cause for running injuries.

The role of the secondary or acquired function disturbance as a cause of injury is still controversial. Such impairments are usually a result of increased or decreased flexibility of a segment in the kinetic chain after an injury. Each impaired function of the kinetic chain can lead to compensatory changes in posture and gait, which in turn may cause micro-trauma, tissue damage and visible damage.

Mechanical dysfunction: changes in sacroiliac joint position and movements are quite common. Although the sacroiliac joint is mostly stable, with limited movements, it has been argued that movements can occur with anterior subluxation and rotation, which can lead to asymmetry of the pelvic ring structure. The dysfunction is characterized by locking or reduced mobility in the sacroiliac joint. The main symptom, pain, is usually localized to the sacroiliac joint, but may also radiate to the buttocks and the groin region. In order to identify dysfunction in the sacroiliac joint, it is important to be aware that this condition exists and know the biomechanics of the joint. A thorough assessment is in place when treating patients with recurrent injuries.

Recurrent injuries and previous injuries: recurrent and previous injuries are the most common risk factors for sustaining a new injury (Fig. 2.10). A hamstring injury is a recurrent injury in 30% of cases. A recurrent injury may be defined as 'an incident of the same type and at the same site linked to an index incident and which occurs after an athlete's return to full function and participation ('full recovery') from the index recordable incident'.[3] Recurrent conditions should be subcategorized into re-injuries and exacerbations. A re-injury is a repeat episode of a fully recovered index injury. An exacerbation is a worsening in the state of a non-recovered index injury or illness.

Most injuries will heal sooner or later, but they may leave a scar in the tissue. In humans magnetic resonance imaging (MRI) has shown evidence of scar tissue for up to 1 year after an athlete's return to sport. The presence of such scar tissue can alter the muscle transmission pathway and lead to a modification of deformation patterns in the muscle tissue adjacent to the fibrous scar. Such scars may have a different elasticity than normal tissues and can cause weakness in the area with increased risk of recurrent injuries. Scientific evidence shows that neuromuscular training (+ balance board training) and strengthening programs are effective and result in reduction of hamstring injuries.

Figure 2.10 It is important to prevent injury recurrence such as recurrent adductor and hamstring injury. **a)** Stretching of the adductor muscles in the groin is a natural integrated part of modern warm up exercises; **b)** recurrent hamstring tears are common and must be prevented with adequate warm up. (With permission, by Bildbyrån, Sweden.)

Multiple and recurrent injuries can be a sign of dysfunction in the kinetic chain. Previous injuries can lead to fibrosis, with adhesions and reduced mobility and function of the joint. Prolonged joint injuries can lead to chronic instability, or even a small effusion; it can also result in a reflex inhibition of muscles with altered gait patterns as a result. Reduced mobility of the knee, ankle or subtalar joints increases the load in other areas. Instability of the joints causes a regression of muscles and increased compensatory stress on the joint surfaces, and other structures.

External (extrinsic) factors

External factors include environmental factors such as climate, surface, equipment and level of competition. External factors are the cause of 60–80% of all reported running injuries. Most of these are due to improper training.

Improper training

The most common errors are sudden changes in the training program, such as extended running distance or intensity (see Chapter 6 p. 87).

Running terrain

Too much running downhill can cause problems in the knee joints, as the body weight is mainly located behind the knee's vertical axis, which requires large loads on the quadriceps muscle to protect the knee. Downhill running can cause painful symptoms, such as anterior knee pain or 'runners knee' (iliotibial band syndrome) (Fig. 2.11).

Running surface

Running surface may be of importance in relation to injury (Fig. 2.12). Some surfaces may triple or quadruple the frequency of injuries in certain types of sport. Running on hard surfaces, such as asphalt or concrete, causes mechanical stress and overloading of the joints and tendons, and can be linked to higher incidence of running injuries (see Chapter 6, p. 88).

Figure 2.11 Running on hilly and uneven terrain may be strenuous on the knee joints. Competition uphill may take its toll. (With permission, by Bildbyrån, Sweden.)

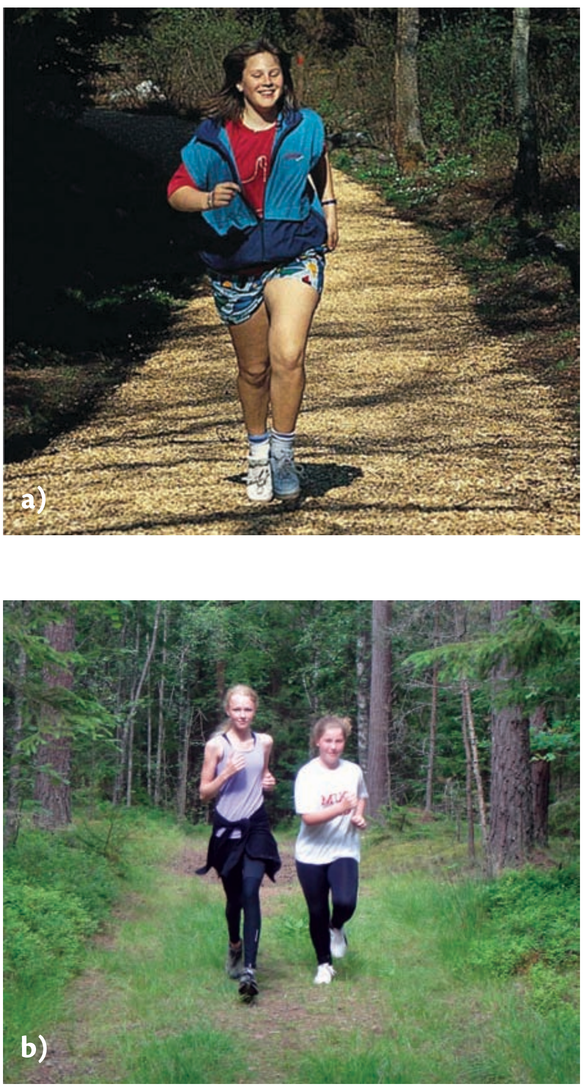

Figure 2.12 a, b) Running in the woods on prepared trails with woodchips or on soft trails is as a rule very lenient on the lower leg tissues.

Running on uneven or artificial surfaces or on slippery roads can also cause injuries. Running on slopes or on canted roads in the same direction can cause abnormal stress on one side of the body.

Running shoes

A bad choice of sports shoes could cause sports injuries, because shoes can change the forces in certain anatomical structures by more than 100%. The shoes can also affect sports injury localization, type and frequency.

Inappropriate or worn out shoes can cause increased stress and strain. It is not good to use tennis or basketball shoes during regular running (see Chapter 6, p. 88).

Techniques in sports such as running and jumping

Movement patterns vary from one sport to the other (see Fig. 3.2). Repeated poor running or jumping technique almost always results in overuse injuries.

General risk factors and preventive measures

General risk factors can include improper training, exercise without warming up, repeated monotonous training, incomplete rehabilitation and return to sport too soon after injury. Other general risk factors include exercise despite infection, improper sporting techniques, poor equipment, no adjustment of training surface and inadequate equipment for training and competition.

Knowledge of the sports specific requirement profile can be of value. Every sport has its unique requirement profile, which means that it is beneficial to analyze the demands on the athlete in a particular sport. The basis of a requirement profile includes physiological qualities like aerobic and anaerobic requirements, together with strength, speed, agility and good technique (Fig. 2.13). Mental qualities can be qualities such as a so-called 'winning mentality', good pain tolerance, sense of sporting tactics, etc.

General measures for injury prevention include adequate competition and training environment, following the established rules, climate adaptation, adequate equipment, adapted skill, good warm up, individually tailored training even in team sports, etc. Physical activity itself may have a preventive effect. Sport and exercise can reduce the risk of a range of diseases and injuries that can affect human life. Fractures in the elderly due to osteoporosis are extremely common. Prevention against this is established during childhood and adolescence through physical exercise, which leads to an increased bone density, especially during the first 30 years.

Figure 2.13 a, b) Optimal technique is best learned at a young age. (With permission, by Bildbyrån, Sweden.)

Tip

The human body is built for physical activity, not rest.

Humans have always had to work hard because the struggle for existence has demanded it. Today, we spend most of our lives sitting or lying down, even though our body systems are designed for physical activity. The human heart pumps 4–5 liters of blood per minute at rest; during work the volume can increase to 10–40 L/min. During normal breathing at rest a person inhales about 6 liters of air per minute, but the volume can be increased to over 100 L/min and a fit athlete can inhale up to 200 L/min.

There are many indications that even very moderate physical activity is valuable when it comes to preventing cardiovascular disease. Chest pain and abnormal fatigue during sports are serious warning signs. When they occur, it is vital to discontinue sports activity immediately.

Sports competitions should never be carried out in extreme cold, or when it is very hot. In cold weather, contestants are always given the opportunity to start with a proper warm up. Sports should be performed regularly, and exercise and intensity should increase gradually.

Infections

Airways – respiratory tract

The common 'cold' is in everyday speech a designation for a number of infectious diseases in the airways. These diseases are spread generally through direct contact or through the air, such as when the sick person sneezes.

When a cold or upper respiratory infection is about to break out the person may feel cold, get a little feverish and feel tired and generally unwell. Muscles may feel sore, as if after working out, and the person may get a headache. A running nose, sore throat, coughing and sneezing are frequent symptoms, together with fever at 38–39 °C and usually last for 3–4 days when due to a viral infection. During this time the sick person should stay at home in peace and quiet and rest. The fever can be kept down with paracetamol (acetaminophen) or an acetylsalicylic drug (e.g. aspirin).

The athlete should be without fever (afebrile) for 1 week before returning to normal sporting activity. There is a need to consult a physician for evaluation and possible treatment if:

- Symptoms and fever last more than about 4 days.
- Fever has gone down but rises again.
- Pain occurs during deep breathing or a feeling of exercise-related transient abdominal pain.
- There is a productive cough with pleghm.
- Severe pain over the sinuses, ears, etc.

When any of the above symptoms are present, a bacterial infection may have started, and treatment with an antibiotic may be needed. If the sick person shows signs of tonsillitis with swollen, red tonsils, often with a white coat and tender lymph nodes around the throat, a physician should be contacted. Tonsillitis must be treated, as severe complications such as inflammation of the heart muscle, kidneys, joints, etc. otherwise could occur.

Infections with heightened body temperature are often ignored. However, there may be a simultaneous cardiac involvement in the form of cardiac muscle inflammation. This can proceed with minor symptoms that are the same as for a general infection – fatigue, malaise, etc. There may also be chest pain and palpitations. The symptoms may be so modest that the athlete or coach does not find any reason to call off the training and competition. Cardiac muscle inflammation can lead to serious complications, including sudden death.

Urinary tract infection

Urinary tract infections include infections of the urethra, bladder, ureter, renal pelvis and kidneys. The symptoms are a searing pain and a frequent need to urinate and sometimes fever (especially with renal pelvis inflammation; back pain often occurs with this). Those who suffer a urinary tract infection should immediately contact a physician for diagnosis and treatment.

In men, the tissues of the prostate gland can become inflamed (prostatitis). The symptoms are dull pain over the bladder, urgency to urinate, and intensive pain and sometimes fever. Physicians should be consulted for diagnosis and treatment. It is important to avoid getting cold if you have a urinary tract disorder.

An athlete should never exercise or participate in any sport with physical exertion during infection with fever. The training should not be resumed until the athlete has been fever-free for at least 1 week. There is no place for the misguided 'heroism' that the public sometimes can read about in the newspapers.

Women and sport

Cardiovascular exercise and sporting activities are beneficial in many ways for both women and men. However, there are a group of disorders, a syndrome, with interactions that can only affect women. The syndrome ('the female triad') contains three symptom groups: eating disorders (anorexia and bulimia), loss of menstruation (amenorrhea) and osteoporosis, and the risk of it is highest during adolescence (Fig. 2.14).[4] It affects young girls in several sports but is especially common in sports such as long-distance running and artistic sports, such as gymnastics, diving, figure skating and ballet. The syndrome is related to the athlete's age at the training debut, the sport, nutrition and the amount of stress the young athlete is experiencing.

Eating disorders (anorexia and bulimia)

There is a tendency in modern society to glorify slender bodies. Some women feel that there is a pressure and that there is a requirement for them to lose weight. For female athletes this demand can be external, e.g. from the coach, who wants to improve training and competition results or appear in sports such as figure skating, gymnastics, swimming and running. The internal and external pressure can generate harmful eating habits, so-called eating disorders. This concept includes everything from fasting and using laxatives, appetite suppressants and diuretics to the fully developed conditions of anorexia and bulimia. The disorders can also occur in long-distance runners if they do not provide the body with the nutrients needed for the high energy-demanding activity.

Figure 2.14 Elite female runners are at risk of the 'female triad'. (With permission, by Bildbyrån, Sweden.)

Absence of menstruation (amenorrhea)

Amenorrhea can be defined as a missed period for 3–6 consecutive menstrual cycles. The reason may be incomplete nutrient intake, which in itself can lead to an increased amount of musculoskeletal injuries. If menstruation has been absent for more than 6 months (and pregnancy has been excluded), the athlete should consult a physician for an hormonal investigation, complemented with a bone mineral measurement.

Bone loss (osteoporosis)

Osteoporosis is one of our most widespread but least recognized major diseases. Every woman and every fourth man is expected to have a fracture some time in their lives related to osteoporosis. Osteoporosis is a bone disease characterized by a decrease in bone mass, a reduction in bone mineral density and changes in the bone structure (Fig. 2.15). This reduces the bone strength and leads to an increased fracture risk. Osteoporosis can be seen as a part of the biological aging process, but varies between individuals. The World Health Organization (WHO) has proposed a definition of osteoporosis based on bone density measurement with dual energy X-ray absorptiometry (DXA) on the hip, lumbar spine or

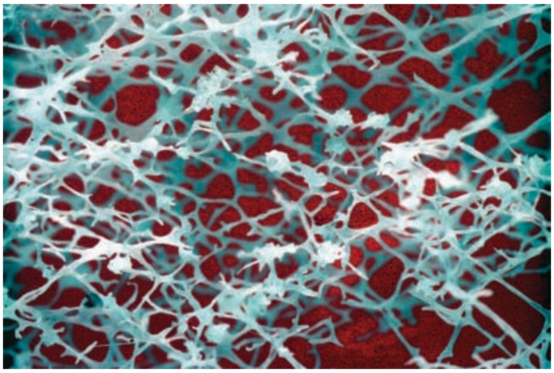

Figure 2.15 Osteoporosis. Osteoporotic trabecular bone (cancellous bone) has larger empty bony spaces and is thinner and has sponge-like bone at the ends of long bones and vertebrae. (Courtesy of Prof. Tommy Hansson, Sahlgren Academy, Gothenburg University, Göteborg, Sweden.)

forearm in women after menopause. A reading more than 2.5 standard deviations below the mean for young adults in the same population is considered osteoporosis.

An individual's bone mineral density normally peaks at 25–30+ years. There is then an age-related decrease in bone mineral content by 0.5–1% annually. In women, this is accelerated in connection with the menopause and in the following years losses can be 2–4% per year to reach 40–60% bone loss at the age of 80 years. In men there is a similar but smoother bone loss due to declining sex hormone levels. After age 65 years, the bone loss is similar between the sexes.

The areas most commonly affected are the most distal part of the radius, vertebral bodies of the spine and femoral neck. The primary form of osteoporosis may have genetic or hormonal causes, but it may also be related to factors such as diet and lifestyle (e.g. cardiovascular training). Secondary osteoporosis can be caused by an underlying disease. The condition can also be a reaction to certain drugs.

The more risk factors, the greater the risk. The strongest risk factors are advanced age, female gender, corticosteroid medication for over 3 months and non-traumatic fractures. Important risk factors that are not modifiable include advanced age, female gender, previous fracture and heredity. Risk factors that are modifiable include physical inactivity, low weight, smoking, alcohol consumption, tendency to fall, impaired vision, low sun exposure and cortisone treatment. Advanced age and previous fracture is considered to be the risk factors that are most relevant.[5]

Osteoporosis-related fractures are an international public health problem and this problem is most common in Scandinavia. The risk for a middle-aged Swedish woman to suffer one or more osteoporotic fractures at some point during their lives is about 50%, and for a Swedish man 25%.

Sometimes amenorrhea occurs after intense sporting activities, and decreased ovarian hormone production can lead to osteoporosis. The bone loss that affects young women with amenorrhea matches the 2–6% reduction of bone that occurs after menopause (when menstrual periods have ceased). Bone mass does not recover by itself. Women with amenorrhea should take calcium tablets to maintain the body's calcium balance, but calcium supply alone cannot prevent bone loss. The goal is for menstruation to start again by itself. Otherwise, hormone therapy (with ovarian hormones) could be initiated to prevent further bone loss. The athlete can aid in this by increasing their weight by 2–3%. Extreme workouts should be avoided. Instead, training should be adjusted to well-being.

A healthy person increases bone mineral content in adult life only marginally through vigorous exercise, diet, calcium or vitamin D supplements. Physical activity is the basis of the treatment of these conditions and has a clear positive preventive effect on bone density at any age, especially among children and youth. This applies to all ages and can mainly be done by performing a customized muscle strength and balance training. This training, especially in the elderly, should be combined with measures against the risk of falls in the home, including reducing medication. A shock absorbing hip protector is available to reduce the risk of hip fracture after a fall in the elderly.

Tip

It is advised to be physically active throughout life.

According to reports from the USA, amenorrhea occurs in 40% of female athletes and 60% of female gymnasts with eating disorders. Prolonged amenorrhea should be monitored by a physician. The triple syndrome described above, besides causing long-term problems, can cause conditions such as dehydration, salt disorders, irregular heartbeat, depression and increased risk of injury, including stress fractures. Since these disorders are often hidden or denied, they can be difficult to detect. The earlier the syndrome is diagnosed and treated, the more favorable the prognosis.

Tip

The triad syndrome of eating disorders, amenorrhea and osteoporosis, should always be investigated in female athletes with stress fractures.

Pregnancy

A normal pregnancy is not negatively affected by physical activity, but such activity should be adjusted after the development of the pregnancy. Good physical condition can facilitate both pregnancy and childbirth. Most active female athletes stop competing in the fourth or fifth month of pregnancy and adapt to more appropriate intensity training. Caution is advised, especially regarding contact sports like soccer, and in connection with activities that can cause elevated core temperature (body temperature).

Pelvic floor muscle dysfunction may cause urinary and fecal incontinence, pelvic organ prolapse, pain and sexual disturbances. There is some scientific support that pelvic floor muscle training may be used to prevent and treat these pelvic problems and women should be encouraged to start training their pelvic floor muscles during the first 8 weeks after giving birth. Other training and competitive sports can be resumed gradually. Bleeding after birth may last up to 2 weeks after which there is a whitish discharge for 2–6 weeks. When this has stopped and the uterus has regained its normal size the athlete may start returning to sport activity.

Making the decision to breastfeed a baby is a very personal matter and the decision is made by the mother. Breast milk provides the ideal nutrition for infants. Breastfeeding lowers the baby's risk of having asthma or allergies. Breastfeeding has been reported to lower the mother's risk of breast and ovarian cancer. The milk production may be influenced by hard physical training. During the breastfeeding period the breasts are relatively larger than normal and can be easily affected by physical activity.

Way of life and living habits

The musculoskeletal system consists of the skeleton, joints and ligaments, muscles, tendons, nerves and blood vessels. This musculoskeletal system is subject to major quality changes in response to physical activity and inactivity.[6–8]

Skeleton

The adult human skeleton consists of 206 bones supported by ligaments, tendons, muscles and cartilage. The bone is decalcified in athletes who for some time have been inactive or have not been training. This results in reduced strength and increased risk of fractures. When bone is not loaded, e.g. immobilization with a cast, there is a bone loss from bone resorption (accounting for 30%) and reduced bone formation (accounting for 70%), leading to osteoporosis. The bone loss is less if weight bearing is allowed when casted compared with non-weight bearing. If the bones are loaded regularly, e.g. through physical training, they will adjust to the increased demands and gets stronger. However, the parts of the bones that are unloaded get weaker and a break-down starts. The re-building may take place relatively slowly, but is important in rehabilitation after injury, and – above all – after prolonged, repetitive training of children and adolescents (see Chapter 23), where it can cause permanent changes in the skeleton.

There is a correlation between different degrees of stress and tissue quality: during exercise it adapts faster and better the lower the load was in the initial stage; during periods of inactivity, for example bed rest, the decalcification will occur faster and becomes more severe the higher the load was in the initial stage. The reverse is true in both cases.

Cartilage

Changes in the articular cartilage tissue occur after even a short period of inactivation. The tissue's water and proteoglycan (see p. 159) content decreases and the metabolism increases, especially in those parts exposed to pressure. The cartilage surface is softened and fragmented, more and more chondrocytes (cartilage cells) die, the collagen fibers split and break up and the subchondral bone under the cartilage layer is decalcified. These early events are likely reversible and cartilage/bone integrity can return by itself. Research has shown that 8 weeks of inactivity can cause permanent changes and that the vicious cycle that leads to osteoporosis has begun. Injuries to the cartilage result in inactivity. Cartilage tissue has no blood supply, which affects its capacity to heal after injury (Fig. 2.16).

Tip

Cartilage has a poor capacity to heal after injury to the cartilage tissue.

The central parts of the joint surfaces can withstand stress better and therefore loading the joints in the periphery of the joint surfaces should be avoided. Some activities such as sitting squatted or doing the splits should be avoided if the ability to perform these loaded movements in extreme positions has not been developed by the athlete over time. The most gentle type of exercise to maintain cartilage quality consists of unloaded or low resistance movements. Any unilateral, extreme load can cause damage.

Tip

Training with low to moderate intensity is a safe and effective treatment for cartilage injuries – even in incipient osteoarthritis. This can include strength training, flexibility training, walking, cycling, water training, etc.

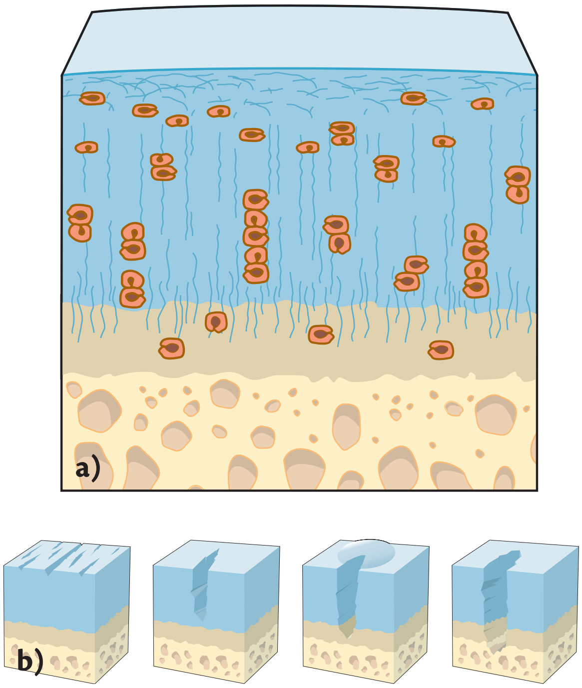

Figure 2.16 a) Healthy cartilage structure; **b)** injury to the cartilage from the surface to the deep layers anchored to the bone.

Muscles

A reduction and weakening of muscle tissue starts already after 1–2 weeks of inactivity and decreased use of muscles. The degree of hypotrophy (reduction of tissue) depends on factors such as:

- Duration of inactivity: the longer the period of inactivity, the greater the regression.
- Muscle tension level during inactivity: tense muscle tissue regresses to a much lesser extent than relaxed muscle tissue.
- Condition before the injury: trained athletes who are forced to rest seem to lose more muscle mass than untrained.
- Slow and fast twitch muscle fibers seem to contract in different ways during inactivity.
- Age and gender may have some impact on hypotrophy.

Muscle loss is proportionally less than the functional impairment, but muscle mass decreases more during inactivity than the girth (circumference) of the extremity. After a complete immobilization for 6 weeks a typical reduction of 30–40% of the isometric or concentric strength of quadriceps muscles will occur, while a cross-section of the muscle in computed tomography (CT) or MRI shows 20–30% reduction and the thigh's girth measured with a tape shows a reduction of 10–20%. The functional impairment of the muscle is larger than its cross-sectional reduction, which probably is related to the nerves in the area, i.e. the nerve supply to the muscles is impaired. Rest and inactivity also damages the mechanisms of the muscle–tendon complex, particularly in terms of strength and elasticity.

After regular exercise the athlete's muscle mass will increase (hypertrophy). With increasing age the limb retains its volume, but its strength decreases, since some of the muscle fibers are replaced by fat. Exercise causes muscle mass to increase and the regression is postponed. In a working muscle, the external load on the joints is reduced, because the forces are distributed in a better way.

Tendons

Inactivity and rest causes also regression of tendon tissue, albeit more slowly than is the case with muscle tissue. The tensile strength, the elastic stability and the total weight of the tendon tissue decrease; the collagen fibers included in the tendon become thinner and less aligned, and transverse bridges between the tendon fibers (cross-links) can become fewer and smaller.

With regular exercise the athletes can maintain connective tissue strength and delay degeneration, which some call 'changes with age' (Fig. 2.17). Training also improves the tendon's mechanical properties (material properties) and its structural properties (tensile strength) (see Fig. 20.2).

Ligaments

Ligament is fibrous tissue connecting bones to other bones. Inactivity causes ligaments and joint capsules to weaken.

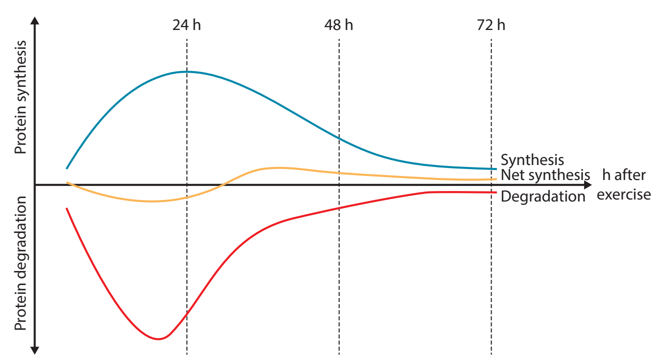

Figure 2.17 Diagram depicting collagen synthesis and degradation after acute exercise in humans. The first 24–36 hours after exercise results in a net loss of collagen. However, 36–72 hours after exercise, a net synthesis of collagen follows. Hence, repetitive training without enough resting time in between may result in a net catabolic situation with degradation of the matrix and can lead to tendinopathy.[9,10]

In some cases, ligaments can retract and shorten, which may result in decreased mobility and improper loading of the joints. The collagen tissue content generally decreases. It has been shown in animal experiments that the ACL loses 25% of both its tensile strength and elastic stability by inactivity. Regular exercise improves both the mechanical properties (material properties), and the structural features (the cross-sectional area increases) of the ligament.

The internal soft lining of the fibrous joint capsules, the synovial membrane, is very sensitive to overload and friction–compression forces, causing irritation. It can react by forming more joint synovial fluid than usual, and the result will be an effusion in the joint.

Tip

The consequences of inactivity and complete unloading can be devastating. There is a need for more research and education on how these adverse effects should be limited.

Different tissues of the musculoskeletal system have recovery times of varying duration, e.g. cartilage and bone have the longest, tendon and ligament tissue shorter, while muscle has the shortest recovery time. This is due to the tissues having different turnover times.

Rehabilitation and reactivation

Different tissues are affected differently by rehabilitation and reactivation. In general, it takes a considerably longer time for the positive effects of rehabilitation to affect a person than for the negative effects of inactivation. The skeletal muscle's functional properties can be greatly reduced for years after a trauma causing a period of healing and long-term unloading. It is still unknown whether the significant changes in the muscles are permanent and, if so, what effect these changes have on the functional recovery when the muscles are loaded again.

The bone responds positively to reactivation if the length of the inactivity period does not exceed 6 months. In other cases, osteoporosis is then more or less an irreversible fact.

Behavioral issues

Anti-doping activities

Doping is a health hazard, and all doping increases the risk of injury.

Tip

Doping is not only dangerous and illegal, doping is cheating.

The World Anti-Doping Agency (WADA) prepares an annual doping list of prohibited substances and methods. Two of the following three criteria must be met for a substance or method to be put on the list:

- It is potentially performance-enhancing.
- It affords a potential health risk.
- It is contrary to the ethics of sport.

In addition, a substance or method to mask the use of other prohibited substances or methods could be prohibited. WADA also has provisions for exemptions and stay statements. The Swedish National Sports Confederation, which is responsible for the work with anti-doping in Sweden, follows these rules. The international sports federations are responsible for anti-doping in their respective sport. They have all accepted the World Anti-Doping Code and adhere to it (Fig. 2.18).

If an athlete takes medications for asthma or drugs with cortisone, special rules for exemptions apply. The athlete and coach must always check with his/her physician to be safe. If an athlete is required to take medication to treat an illness or condition that falls under the WADA Prohibited List, a therapeutic use exemption (TUE) may give that athlete the authorization to take the needed medicine. The purpose of the International Standard for TUEs is to ensure that the process of granting TUEs is harmonized across sports and countries. An example of this is systemic treatment with cortisone, i.e. pills or suppository as well as injection into the bloodstream or muscle, which requires an approved TUE. Topical treatment with cortisone on skin, anus, ears, eyes, nose and mouth is permitted and can be used without an exemption. Likewise, injection in the joint, tendon attachments or bursa is allowed.

Tip

Note: There is a high risk of doping when taking dietary and bodybuilding supplements.

Nutritional supplements, health foods or various 'natural' products are not considered drugs. However, there is a clear risk that such products contain agents that can give positive doping tests, though it is not declared in the contents list. Scientific studies have shown that about 15% of analyzed nutritional supplements from different countries contained anabolic substances such as testosterone and nandrolone, which were not declared on the product label.[11] These contaminations may cause an unintended positive doping result.

Figure 2.18 Doping tests are carried out at all major competitions with rigorous control. **a)** The urine for the doping test is collected in a bathroom with several mirrors so that the urination can be controlled by an observer; **b)** skilled anti-doping experts control the whole procedure. The urine is sent for analysis to a specially accredited doping laboratory; **c)** the fight against doping requires the involvement of strong and knowledgeable leaders.

Tip

- An athlete is responsible for what enters the body.
- An athlete cannot blame anyone else if he/she tests positive in a doping test!
- WADA apply 'strict liability'. This means that the athlete is found guilty of doping, even if he/she did not intend to take the banned substance.

Alcohol and sport

Alcohol habits are strongly age-related. The largest proportion of heavy drinkers is found among males and young adults and is becoming less common in middle and old age.

There is a 50% genetic contribution to alcoholism. Alcohol abuse mostly leads to medical, psychological and social problems.

Tip

Alcohol intake impairs performance and significantly increases the risk of injury.

Sport and alcohol do not mix. Even at low concentrations, alcohol in the blood will impair coordination skills and reaction time is extended. This will obviously affect many sporting achievements and occurs long before the athlete exhibits intoxication symptoms. In Sweden it is a criminal offence to drive with a blood alcohol concentration of 0.02%, or 20 mg of alcohol in 100 ml of blood; in other countries the limit varies between 0.05 and 0.08% (50–80 mg of alcohol in 100 ml of blood). Even at this level, which corresponds to a consumption of one glass of wine or a beer, symptoms such as memory loss occur and a noticeable worsening of reaction time.

The breakdown of alcohol in the body occurs at a constant speed and is not affected by exercise and taking a sauna. It is essential to point out that it takes a long time to break down alcohol, but also that alcohol consumed with food is absorbed more slowly, because it spends a longer time in the stomach. After absorption from the stomach and the small or large intestine the alcohol passes to the liver via the blood stream, whose volume is fairly similar between small and large bodies. Ethanol disappears by about 1 ml per hour, regardless of body size. The only known substance that can increase the rate of metabolism of alcohol is fructose.

Alcohol may contribute to obesity. This is due to the fact that alcohol contains a lot of calories, almost as many as pure fat, i.e. 7 calories per gram. Common beverages such as beer are high in calories and a glass of wine can have the same calories as four cookies. Calories from alcohol have no nutritional value, they are 'empty calories'. Drinking alcohol reduces the amount of fat the body burns for energy and therefore our systems want to get rid of it.

Alcohol has a causal relationship to sports-related injuries with an injury incidence of about 55% of those who drink alcohol compared to about 24% in non-drinkers ($p < 0.005$). Intake of alcohol at least 12 hours prior to skiing increases the risk of accidents during skiing. It is believed that this may be related to the effects of a hangover, which is caused by the intake of alcohol or related to an effect of the residual alcohol in the body, of which fatigue may play a role. Research has shown that a hangover may reduce performance by about 11%.

A low consumption of alcohol may have a small (but in principle no) negative influence on the training effect. A high consumption will on the other hand decrease the ability to build muscles by training, as the muscle building hormones may be inhibited after intake of alcohol.

Although alcohol has left the body, there are still effects the day after that will negatively affect the performance. Because alcohol has a blood sugar lowering effect it can sometimes further worsen the performance. As alcohol is broken down so slowly in the body, all forms of alcohol intake, even beer drinking, should be avoided on the day of a sports competition.

Tip

- Alcohol and sports do not mix. Alcohol impairs not only performance but also coordination, concentration and reaction time.
- Physical performance may in some cases be reduced for more than 60 hours after intake of alcohol!

Overweight and obesity

Obese people are usually less active than people of normal weight and will thus have a weakening of the muscles and bones. In combination with the increased load, this increases the risk of injury and can accelerate the deterioration of articular cartilage.

Obesity is a risk factor (although a weak one) in the development of diseases of the heart and blood vessels. The body's adipose tissue can be evaluated by the so-called body mass index (BMI) based on an individual's weight divided by the square of their height:

$$\text{BMI} = \frac{\text{Body weight (kg)}}{\text{Height (m}^2\text{)}}$$

BMI estimates the body fat amount, even if it does not measure the exact percentage of adipose tissue.

The cause of obesity is almost always that the body takes in more calories than the body consumes. Only in exceptional cases is obesity a medical disorder. Caloric excess is converted into fat tissue.

A person who has a sedentary job and does not exercise uses about 8,000–10,000 kJ (kilojoules) per day (2000–2500 kcal per day). A healthy well-balanced diet depends on several factors such as the age, lifestyle, weight and height of the person. According to Britain's National Health Service, a western man needs around 10,500 kJ (2,500 kcal) a day to maintain his weight, and a woman around 8,400 kJ (2,000 kcal) a day.

Tip

- Overweight/obesity can be solved by:
- Eating small amounts of food and making sure that the diet is of good nutritional value.
- Raising the metabolism through exercise and other physical activity.
- A combination of these two methods is preferable.

Liquid

Sweating and fluid loss and intake

At physical exertion the body's internal temperature (core temperature) increases. Since the body is not cooled sufficiently by the wind and by thermal radiation and heat conduction (transfer of heat energy), the body begins to sweat and water evaporates from the skin. An athlete starts sweating after 1.5–3 minutes of exercise and this increases linearly to reach a steady level after 10–15 minutes. At higher humidity this takes longer.

The human body is composed of 70% water and most of the water is located inside the cells. When an athlete sweats the water will mainly be collected from the cells and this affects their metabolism. Fluid loss therefore leads quickly to impaired performance, and this is usually evident at a fluid loss of only 1–2% of body weight.

If the fluid loss reaches up to 4–5% of the body weight, the athlete's working capacity will be reduced by 50%. Further fluid loss increases the risk of collapse, particularly in prolonged exercise in hot weather such as in some competitions (Fig. 2.19).

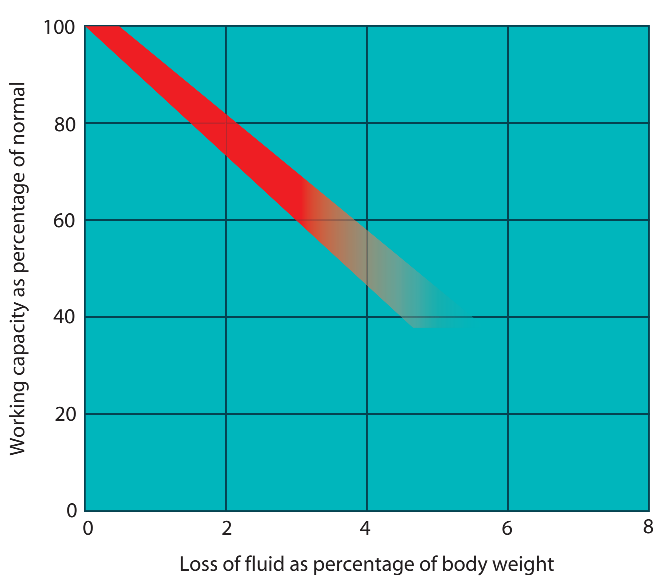

Figure 2.19 Graph of the connection between loss of fluid and decrease of working capacity.

Hydration

In order to be able to maintain the physical work capacity during prolonged exercise, it is essential to supply the body with fluid. In sports where competition times are long and the athletes' fluid loss is large, it is almost impossible to replace all fluid lost during the competition. Therefore, an abundant fluid intake during the day before the race is to be preferred. Arm and leg muscle cells must be hydrated from the night before.

The athlete should not eat carbohydrates or snacks an hour before a competition such as a match. There is a risk of a low blood sugar due to residual insulin effect. Usually a liquid supplement is suggested before the start of the race, but only after the warm up has started. The insulin response then becomes small. If the competition time is less than 30 minutes, the athlete usually does not need any fluid intake during the competition.

During a race it is recommended to have a water intake every 20 minutes with a little sugar in it in hot weather. Salt is not a problem until the athlete reaches a water intake that corresponds with the sweat loss, which does not occur in an elite competition. Coffee can be consumed.

Thirst sensation is not an appropriate measure when it comes to replacing the amount of fluid lost through sweating. An athlete who only quenches his/her thirst has generally only taken in half the amount of liquid needed. An athlete who is engaged in hard physical exercise mostly has a larger water intake than he/she considers they need to prevent dehydration.

The fluid supplied to the body should be composed in such a way that it replaces what the body loses during hard physical work. The main substance is the water itself, but also the consumption of sugar should be replaced. The sugar is absorbed into the bloodstream through the intestinal tract and transported to the working muscles, the brain and nervous system. If blood sugar drops too low, below the normal value, the performance will decrease. The athlete may then feel dull, dazed and hungry, and may collapse. The risk of injury increases when judgment and alertness are affected.

A fluid intake with excessively high sugar content (higher than 6–8%) may have negative effects, because sugar in high concentration is taken up slowly by the body. If the sugar concentration is too high, the fluid stays abnormally long in the stomach and feels uncomfortable. The uptake of fluid in the body is independent of the intensity of work (except in very hard training), so there is no limitation whether the body is at rest or in hard work. The speed at which the stomach empties is, however, a limiting factor. High work intensity lowers this speed and if the athlete drinks liquid during hard physical work with excessive sugar the gastric emptying may almost stop, which means that the liquid does not transfer to the intestinal tract, which otherwise would be expected. It is therefore essential that athletes drink liquid during low intensity periods of competitions. Plain water is good to have nearby when training in very hot environments.

The drink supplied to the body during training and competition should be tasty (flavored with lemon as an example) and kept at 25–30°C temperature. Since it is difficult to drink more than 3–4 dL of liquid at a time, fluid intake should occur at short (15–25 minute) intervals. Access to drinking in sports such as orienteering, trail running and Nordic skiing, should therefore be available at intervals of 5–6 km (Figs 2.20, 2.21). The warmer the weather, the more often the athlete should be drinking,

Figure 2.20 a, b) Intake of fluid and nutrition during long competitions is important; blueberry soup is nutritious and effective. (With permission, by Bildbyrån, Sweden.)

Figure 2.21 a, b) The Vasa race from Sälen to Mora in Sweden is over 89 km; very long racing times require extensive fluid intake. (With permission, by Bildbyrån, Sweden.)

even during training sessions, in order to get used to the regime for during competitions, as well as keeping a good pace, which is equally important. In any workout lasting more than 20–40 minutes the active person should be drinking water repeatedly with or without dissolved sugar. The sugar solution can be mixed by the athlete or the coach themselves by dissolving 25–75 g common sugar, or glucose, in one liter of water. The sugar concentration is then 2.5–7.5%, i.e. as in most of the sports drinks which are currently available. During sporting activity the active person should drink sugar solution frequently and regularly. In the winter the sugar solution should be 5–15% and in the summer from 2.5–5%. The weight can be checked every morning, because weight changes are often due to fluid balance.

After a prolonged sporting activity, it is important that both carbohydrate and protein are consumed, e.g. 60–100 g of carbohydrates and a maximum of 10 g of protein. The subsequent meal should contain 300–400 g of carbohydrates and 40–50 g of protein. Some salt intake is needed especially in warmer countries, but also in Sweden the recommendation is to add some salt. Fluids that contain sugar and salt (e.g. juice) should be taken. The athlete can also drink 0.5–1 liter extra fluid 1–2 hours before bedtime.

Nutrition

In order to be able to accomplish muscle work, energy is required. This is produced by the energy-rich substances that are stored in the body and digested and used. The energy is used to maintain body temperature at 37°C and to maintain the internal organs vital functions. During muscle work the metabolism will be 50–100 times greater in the muscles than when at rest.

Fat tissue is the body's main fuel storage. An obese adult male has about 8–10 kg and an obese woman 10–15 kg fat tissue (fat cells plus connective tissue), which is localized in different parts of the body. Combustion of fat tissue produces about 36 kJ/g (9 kcal/g).

Carbohydrate (such as in bread, rice, potatoes) is stored as glycogen in muscle and liver. Normally there are 10–15 g glycogen/kg muscle mass in the body. Burning glycogen produces about 17 kJ/g (4.1 kcal/g). Muscle and liver glycogen totals approximately 400–500 g and can thus have a total turnover of 6600–8300 kJ (1500–2000 kcal); this corresponds to the energy metabolism of an elite skier or cyclist working at hard competition speed for around 1.5 hours. Glycogen is therefore a limited energy depot.

The choice of fuel

Glycogen is the storage form of glucose (or carbohydrates) that the body holds in reserve in muscle and liver. The body releases 21 kJ (5.1 kcal) and 20 kJ (4.7 kcal) per liter of oxygen consumed when burning carbohydrate and fat, respectively. In competitions where the work demand is so high that athletes' oxygen uptake is near or close to maximum, glycogen is the fuel that is burned first. Glycogen is the main fuel for athletes during competitions, whether racing time is long or short. An athlete can store about 2 hours' worth of glycogen to use for high-intensity training. When glycogen runs low the body will gradually use fat and thereby decreases in efficiency. Glycogen deficiency has been decisive in the result in several competitions.

The body fat is also a storage for fuel. Fatty acids are equally good fuel as carbohydrates. Fat is recruited for fuel during exercise, when the brain senses that glycogen stores are becoming depleted. The more trained the muscles are, the more fat is burned. At rest and during moderate muscle work with a small load on oxygen transporting organs, the body mainly uses fat as fuel. As the tempo of muscle work rises to more than 75% of the maximum, glycogen will become the body's predominant energy source.

Normally glycogen stores are sufficient for races lasting up to 1 hour. Carbohydrate loading can be recommended when competitions last longer than that.

Short duration races: carbohydrate loading is not needed when competitions last less than 1 hour, as the glycogen stores of the body are normally sufficient. An excessively high intake of carbohydrates may result in gaining weight because quite large amounts of liquid are bound in the muscle and liver as deposition of glycogen (1 g sugar binds 3 g water). At least 3–4 hours before each race the athlete should eat an easily digestible meal.

Long duration races: before competitions lasting 1–3 hours the athlete should spend some time on the diet preparations. In tough endurance sports, e.g. walking, running, orienteering, cycling, skiing or canoeing, the risk is high that the glycogen stores will run empty during competition. On days before a competition meals should be composed of carbohydrate-rich food. It takes about 2 days to fill the glycogen stores. During this period, too long or too hard training should not be conducted, since the glycogen stores that have built up would then become depleted.

Very long duration races: in competitions lasting more than 3 hours, such as the Vasa ski race (89 km) or bicycle race around Vättern (300 km), the end result is to some extent dependent on the body's glycogen content at the start.

Tip

Empty glycogen stores and hypoglycemia impair both physical and mental performance and increase the risk of injury.

Training and competition abroad

If training and competing abroad is to be as successful as expected, the athlete and his/her team should consider many aspects in the different countries to be visited beforehand. It is important to be well prepared.

When planning a trip abroad the athlete and the team should obtain information about the general weather and humidity conditions at the destination during the visit time. Furthermore, they should find out about potential altitude problems at the destination and the time difference from home. From these data the time of departure can be adjusted to accommodate the need for acclimatization. It is also important to acquire information on the local population's standard of living, hygiene standards, which diseases particularly occur in the area and how good the medical care is. Before major competitions the team physician should visit the competition area in good time to make on-site preparations for the team's arrival and visit.

Jetlag – altered circadian rhythm

Jetlag is caused by disruption of the circadian rhythm, which is generated from within (endogenously), but affected and modified by external cues such as sunlight and temperature and travel across time zones. For large time differences between departure location and destination there is an interference in the body's circadian rhythm, so that sleep, body temperature, heart and blood circulation, mental performance, appetite, bowel habits and certain hormonal factors are affected. Signs of jetlag may include fatigue, insomnia, confusion, dizziness, nausea, headache, etc.

Symptoms depend on the number of hours the circadian rhythm is shifted:

- Sleep disorders leads to apathy and lethargy. Flying in a westerly direction, e.g. from Europe to the USA, the circadian rhythm is shifted 5–9 hours and 2–4 days are needed before sleep patterns becomes normal. There are no clear statistics on the type of disruption that is most troublesome. This varies probably between individuals.
- Acclimatization time is shorter for younger people. For some people, this transition is very demanding.
- Changes in body temperature influence metabolism and can potentially affect performance; concentration can become impaired and can sometimes last 4–6 days.
- Changes in eating habits and loss of appetite can also cause changes in bowel habits, so that bowel emptying is faster or slower than normal.
- Hormone balance is restored only after 4–10 days, during which performance is likely to be impaired. In women, menstrual cycle changes can occur, with loss of or earlier menstruation than usual.
- The hormone melatonin may reduce the effects of jetlag. Since the experience of jetlag varies between individuals, it is difficult to evaluate the effectiveness of these products.
- Jetlag usually clears up within 1 week even on long distance trips. The recovery is much shorter for shorter trips.

Tip

As a rule, the symptoms of jetlag persist for 1 day for each hour of shift of the circadian rhythm.

The problems that result from disruption in circadian rhythms can be prevented through a program of circadian shift by 2 hours per day during the course of 1 week prior to departure. If the adjustment instead has to occur at the destination, the athlete and the team should arrive in plenty of time before the competition; for example at least 6–10 days before the competition day if travelling between Europe and the USA.

Disease prevention

It is important to find out in good time which vaccinations are advised for a chosen country and which ones are mandatory. Vaccinations against certain diseases, such as typhoid and cholera, must begin long before departure to allow time for the body to build up the necessary protection. In the case of malaria, the athlete must take preventive medicine against the disease before, during and after the stay in an area where there is risk of infection. Before a trip to less developed areas, protection against epidemic jaundice is advised. In the past it was common to have a gamma globulin injection before the athletic team set off abroad, which provided protection for 2 months. Nowadays, there are vaccines that provide many years of protection.

When staying abroad the athletic team may be exposed to novel bacterial and viral environments and thus may be susceptible to gastric, intestinal and respiratory tract infections.

Tip

It is therefore important that during a stay abroad strict personal hygiene is followed.

Tap water in many countries is not suitable for drinking for temporary visitors and bottled mineral water must be consumed instead. If hygiene is questionable the athletic team should eat hot, cooked or baked dishes and avoid cold dishes, salads, pastries and desserts – in some places even ice cream. Ice in drinks should be avoided. All fruit should be peeled before eating. If this is not feasible, the fruit should be washed in mineral water. Drinks should be mineral water, soft drinks (used with caution), pasteurized milk or boiled beverages such coffee and tea.

With outdoor swimming pools it is important to determine if the water is clean enough to swim in. In the hotel the athletic team should shower rather than take a bath if the hotel standard is not adequate. If someone in the athletic team falls ill, he/she should be isolated and a physician should determine the nature of the disease.

Tip

The Swedish Institute for Protection against Infection (Smittskyddsinsstitutet) states:

"After access to clean water vaccination is the most effective way to save lives and promote health".

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3

Prevention of Injury and Preparation for Sport

Sports injury prevention

Injury prevention has historically generated limited interest and it has therefore been difficult to obtain financial support. A major shift started during the 1990s and the interest grew dramatically after the millennium. To prevent the occurrence of injuries should be at least as important as taking care of an individual that already has suffered from an injury. Successful injury prevention is important both for the individual as well as from a socio-economic perspective.

General risk factors and preventive measures

General risk factors can include improper training, exercise without warming up, repeated monotonous training, incomplete rehabilitation and too soon return to sport after injury. Other general risk factors are, exercise despite infection, improper sporting techniques, poor equipment, no adjustment of training surface and inadequate equipment for training and competition (see Chapter 2). Knowledge of a sports-specific requirement profile can be of value. In some sports, the equipment has become an important part of the injury prevention as well as compliance of rules.

Tip

Every sport has its unique requirement profile, which means that the demands on the athlete in a particular sport are carefully analyzed., thus facilitating the creation of an overall prevention program.

The base of a requirement profile includes physiological qualities like aerobic and anaerobic requirements together with strength, speed, agility and good technique. Mental qualities include having a so-called 'winning head', good pain tolerance, tactical sense, etc.

General measures for injury prevention include adequate competition and training environments, following the established rules, climate adaptation, adequate equipment, adapted technology, good warm up, individually tailored training even in team sports, etc. Physical activity itself may have a preventive effect. Sport and exercise can reduce the risk of a range of diseases and injuries that can affect human life in the later stages. Fractures in the elderly due to osteoporosis are extremely common.

Tip

Prevention against osteoporosis is established during childhood and adolescence through physical exercise, which leads to an increased bone density especially during the first 30 years, but if continued will last the whole life span.

Individual-related risk factors

There are many risk factors which contribute to the occurrence of injury. Risk factors for injuries should be identified as far as possible. These may include internal (intrinsic) and external (extrinsic) factors (see Chapter 2) (Fig. 3.1).

Internal risk factors, include gender, age and body weight and also include various anatomical abnormalities such as cavus feet, hyperpronated feet, knock-knees or bow-leggedness (varus or valgus knees), side differences in anatomy, balance, muscle weakness, muscle tightness, and general joint laxity. The greatest risk factor is considered today to be a previous injury, inadequate rehabilitation and too early return to sport.

External risk factors may include environmental factors such as climate, surfaces, equipment and sporting level.

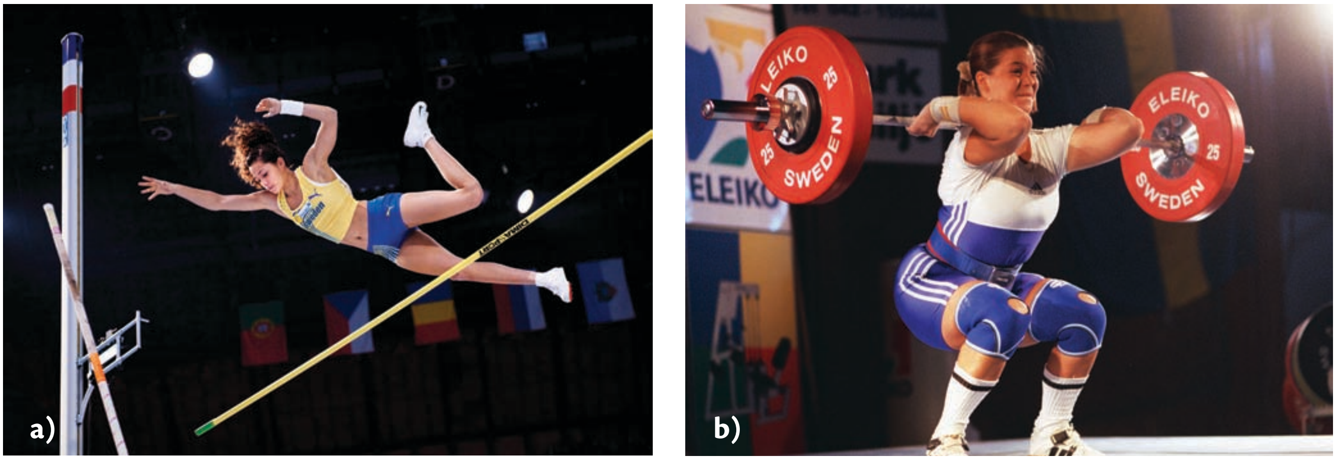

Figure 3.1 a, b) Examples of sports with multiple risk factors. (With permission, by Bildbyrån, Sweden.)

'Sequence of prevention'

Epidemiological research on the etiology of sports injuries requires a conceptual model. Willem van Mechelen and coworkers from Holland developed the 'sequence of prevention' in 1992 (see Fig. 3.2).[1] This model facilitates the understanding of the extent of the sports injury problem that must be identified and described in order to create a preventive program. This is especially true if the injury assessment is based on the results of epidemiological research. It is imperative therefore, that there are clear definitions of what a sports injury is, and this has been defined in recent years.

Analysis and establishment of incidence (injuries/number of activity hours) and prevalence can be expressed as the number of cases per 10,000 or 100,000 people. 'Point prevalence' is the proportion of a population that has the condition at a specific point in time. Incidence or prevalence of an injury can be studied by carrying out epidemiological studies related to the specific sport in relation to the degree of activity level, i.e. number of hours of training and competition. The next step in this context is to establish the severity of the injury. The extent of the sports injury should be specified with sports injury incidence, which can be expressed in the number of injuries per activity session as per 1000 hours of activity in the actual sport. This should be done because it enables various research results to be compared.

The factors and mechanisms causing the injury must be identified. This can be done using the athlete's own story. Pictures or video taken at the time of injury will help to understand the injury mechanism. A recent review on the risk factors for lower extremity injuries demonstrates that our understanding of the causes of injury is limited.[2]

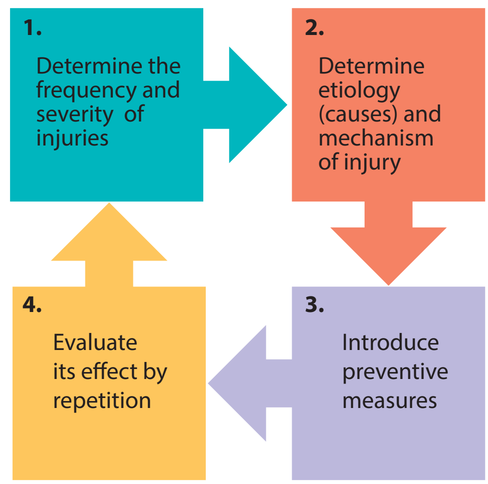

Figure 3.2 An overview of how prevention can be studied and managed. Sequence of prevention – a model of sport surveillance developed by Willem van Mechelen *et al.*[1]

Thereafter measures to reduce the risk and severity of the sports injury are introduced. This is based on the results of step 2. Finally the effect in step 3 is assessed through repeating step 1.

By studying the incidence (injuries/number of activity hours) of an injury, the injury mechanisms and injury severity help in developing a functioning injury prevention program. This should then be tested in the sporting activity of interest to ensure the program's effect. An example of this could be the use of preventive protection equipment, so-called orthotics, which can reduce the number of injuries and injury severity, and the like.

This model has been further developed by other authors. The model of Meuwisse and colleagues includes the importance of repetitive activities, whether these

Research requirements	Research process
1. Count and describe the injuries 2. Understand why injuries occur	Injury surveillance Prospective studies to determine the underlying causes and injury mechanisms Basic mechanical and clinical studies
3. Develop 'potential' preventive measures to identify what can be done to prevent injuries 4. Understanding what works in 'ideal/perfect' conditions	Controlled studies to investigate 'effects' such as randomized clinical trials (RCTs) Ecological studies to understand implementation
5. Understanding intervention implementation with respect to personal, environmental, societal and sports factors that may strengthen or be a barrier 6. Understanding what works in 'real' conditions	Studies in real sports environments to investigate the effectiveness (in natural, non-controlled environments)

Figure 3.3 Carol Finch's new model, Translating Research into Injury Prevention Practice, or TRIPP.[5]

cause adaptation, maladaptation, injury or complete/non-complete recovery after an injury.[3] If possible, future studies on injury prevention should have a strategy of methodology and analysis, which includes the cyclical behavior of changing risk factors for creating a dynamic picture of etiology.[4]

Carol Finch has presented a new model, the 'Translating Research into Injury Prevention Practice' framework, or TRIPP (Fig. 3.3).[5] This research is based on the fact that only research that can prevent injury will be accepted by athletes, their coaches and sports organizations and sports clubs, and must be directed toward understanding how injury prevention can be implemented in the sport and continue to improve. Future research on prevention should follow the technique that TRIPP proposes to ensure its success.

Tip

- Prevention of injuries is one of the most important areas in sports in general.
- Research on prevention must be given much better support than is the case today.
- Have respect for this field as research on prevention of injury and its implementation can be very challenging.

Figure 3.4 a, b) Preparation for training and competition. It is important to make sure that all equipment is in place and is optimal. (With permission, by Bildbyrån, Sweden.)

Preparation for sport

Preparing for competition

Behind good athletic performance lies extensive training over a long period of time. The athlete builds up muscles, strengthens joints and bones and improves overall neuromuscular function. Active training will, with time, improve the foundations for good performance (Fig. 3.4). A generally healthy lifestyle with proper nutrition is also an important prerequisite to achieving good results.

It is important that tissues that are subjected to heavy loading during training are given the chance to rest and recover. The harder the workout, the longer the rest required for full recovery. Training with large and repeated loading requires 1–5 days of recovery before the next similar workout. Training with less strain and stress/intensity may be conducted each day. Athletes who have taken a long break in their training or who are not trained well cannot benefit greatly from the training if it is carried out every day. These athletes should instead start with 2 or 3 working-out days a week during a break-in period to get adequate rest between training sessions.

In setting the goals in selected sports the demands of these should be analyzed by the athlete and the coach. In addition to the sports-specific techniques, there are other factors that affect the athlete's performance. An analysis should be the basis for the detailed planning of training and such analysis can be done on the basis of the following questions:

- What factors affect performance in my sport?
- Which of these factors can I, through exercise, affect and improve?
- How should I train to influence the individual factors effectively?
- How much time should I invest in training to influence each factor, and when should the training be carried out?
- How should I, with these factors taken into account, exercise to reduce the risk of injury to a minimum?

Tip

Intensity and load during exercise and recovery should be adjusted:

- To the athlete's current fitness level.
- So that performance is optimized.
- So that the risk of injury is minimized.

Basic conditioning

A good basic fitness is crucial for avoiding injury. Both traumatic and overload injuries are more frequent among athletes with poor than with good basic fitness.

A period of inactivity will result in a marked reduction of the individual's maximal oxygen uptake. In a research project from the 1960s five healthy subjects were asked to stay in bed for 20 days, during which time they did not engage in any physical activity. This relatively short period of inactivity caused the subjects' maximum oxygen uptake to decrease by 20–45%. This and other similar experiments show that the body quickly adapts to the physical demands placed on it. When the demands get lower, the heart's ability to pump blood reduces. Muscle fiber numbers decrease (hypotrophy) and blood volume decreases. Inactivity reduces the body's ability to transport oxygen and thus the muscles' ability to convert nutrition into energy.

A good basic fitness can be achieved through conditioning and comprehensive physical activity all year round. The training program should increase gradually in intensity and load. The exercises should be carried out slowly, especially for the elderly. During the build-up phase after illness, injury or a fitness break or the like, improvement in basic fitness should be targeted before resuming competition.

Warming up

The purpose of warm-up exercises is to ensure that the body's tissues and functions are ready to embark on the sporting activity (Fig. 3.5).

Tip

A good warm-up has two main functions:

- It should prevent injury.
- It should be performance-enhancing.

As long as the athlete is at rest, the blood flow to the muscle is relatively small and many of the small blood vessels in the muscles are closed. When athletes start physical work the blood flow increases to muscles, because the small blood vessels open. In a person at rest 15–20% of the blood flows to muscles, while the corresponding figure is 70–90% when the person has engaged in hard exercise for 10–12 minutes. When all the blood vessels of the muscles have been opened and filled, optimal muscle performance is possible. The muscles need energy obtained by burning fats and carbohydrates, which produces heat, the amount of which is related to the amount of work the muscles perform; the blood supply brings the fuel to the muscles and removes the waste products.

A gradual warming up leads to a markedly reduced risk of injury and performance is increased. At the same time there is some psychological preparation for the ensuing exercise. Warming-up exercises should begin with the large muscle groups because the blood is mainly redistributed to them. After this general warming up, the more specialized warming up begins. Runners, for example, should focus their warming up on the lower limb muscles and joints.

Stretching of muscles and joints is essential, but heavy loading at the outer limits of motion in the joints should be avoided (see Fig. 3.6).

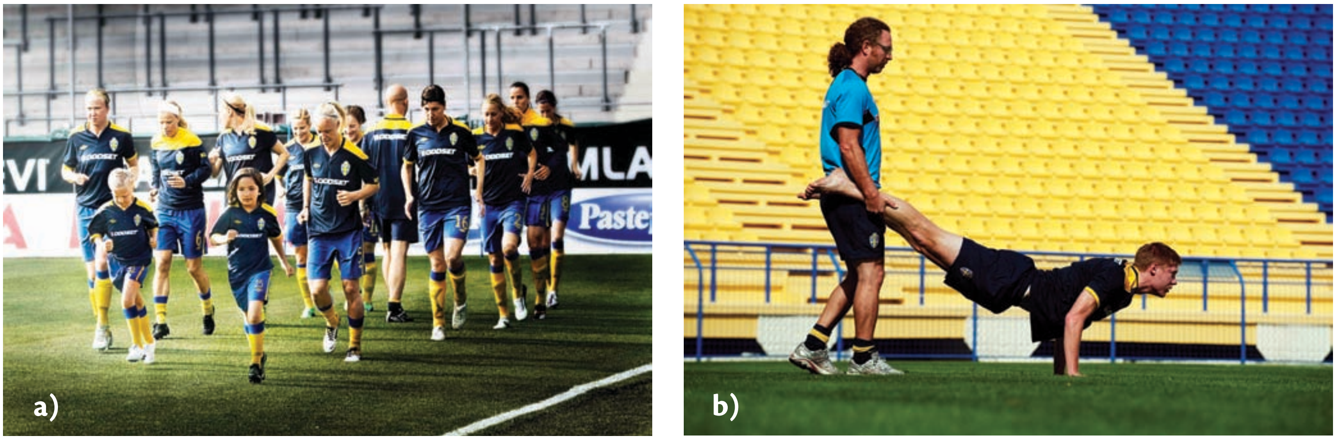

Figure 3.5 Warming up should be thorough but can be executed in different ways. The age and needs of the athlete need to be considered. **a)** Warming up in a group (with permission, by The Swedish Football Association); **b)** warming up individually (with permission, by Bildbyrån, Sweden).

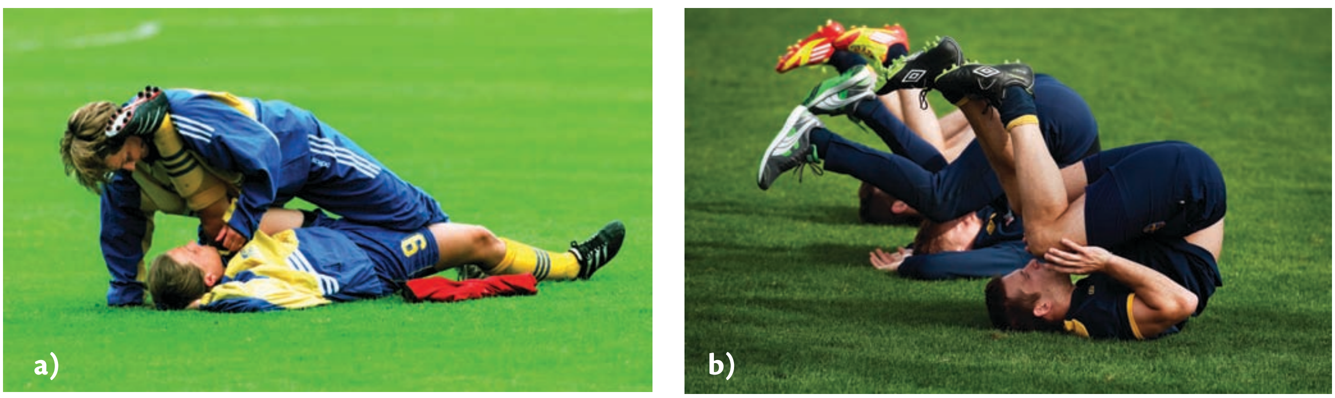

Figure 3.6 Warming up should vary and include different types of movements. **a)** Passive stretching should be done carefully by experienced people; **b)** proper warming up should include the whole body. (With permission, by Bildbyrån, Sweden.)

Should stretching be a integral part of warming up?

- Good flexibility is valuable in injury prevention and is needed for successful participation in sports and aims to increase the range of motion.
- Static stretching is considered to be an effective and popular technique whereby the muscle or muscle groups are slowly stretched to their end-range. The stretched position is maintained for 10–60 seconds (typically 20 seconds).
- Regular stretching can improve muscle strength and jumping ability but does not affect running efficiency.

The last step includes technique and skill training, e.g. controlled onset in long jump and high jump, neuromuscular exercises and the like. The tempo in the exercises can be increased gradually. Warming-up exercises should last at least 10–30 minutes, depending on the sport.

After warming up the athlete should change the shirt next to the skin, because otherwise the muscles will quickly cool down again when the sweat evaporates. Furthermore, it is strongly recommended to put on a track suit or similar to keep warm. The effect of the warming up decreases after only 10 minutes, so the pause between warming up and competitive element should not be longer than that.

Tip

Warming up should be carried out for training and competition and is an integral and crucial part of injury prevention and performance enhancement measures.

After training and competition the athlete should start with cooling down exercises, e.g. by jogging at a slow pace. Light stretching should also be included in the cool down. Stretching after activity contributes to increased agility and flexibility when stretching warm and relaxed muscles.

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4

Equipment in Sports – Principles

Evolution of sport is very rapid, exemplified by the continuing breaking of world records in sports such as athletics. Reasons include factors such as more talented people have access to sports and exercise, athletes are active at an earlier age and compete longer and that athletes can train harder, not least as professionals. Training methods are developing and are currently characterized by periodization and new techniques. However, the most important factor will always be the human mind. As this is happening, sports injuries are not decreasing and are more serious.

Technology is increasingly important as it can fine-tune an athlete's technique. New material is being developed. In some sports events new material and new designs have contributed to development of new techniques. An example of this is shown by the dramatic changes in both technique and technology in pole vault. Pole vaulting involves the transfer of energy from the vaulter to the pole, and finally back to the vaulter as he/she jumps. The evolution of materials from hardwood, to bamboo, and finally to fiberglass and carbon fiber, demonstrates the strong influence of material properties on the success of the vault. The bamboo pole was used by Cornelius Warmerdam, USA in 1942 when he set the 'unbeatable world record' with 4.77 m. With the development of the fiber glass pole in 1956 the record is currently 6.16 m set by Renauld Lavillenie, France in 2014.

Another example is the development of scientifically advanced materials used for swimwear in competitive water sports. Materials of this type are normally spandex and nylon composite fabrics, with features to reduce drag against the water. Some claim that their lineup will increase swimming speeds by 3–7%. The use of high-technology suits made from plastic derivatives, such as polyurethane is now banned by FINA.

Another example of effective equipment design is the development of the clap skate, which is a type of ice skate used in speed skating. Clap skates have the blade attached to the boot by a hinge at the front. This allows the blade to remain in contact with the ice longer. Dutch research has shown that the speed improves by using the clap skate because the point of rotation is moved from the tip of the skate to the hinge. This facilitates the transfer of power to the ice. This equipment became very popular in the mid-90s and dominates today. The design has, however, been banned from use in short track speed skating.

In this chapter the commonly used equipment in sports will be discussed. There will also be a discussion of the principles of protective equipment.

Shoes

Great demands are placed on ankles and feet, which are carrying the weight of the body and move it. In sport, these requirements are higher than usual, and in most sports shoes are the most important piece of equipment. Their mechanical properties and structure are thus of great importance for the prevention of injuries.

Different sports have different functional requirements and demands on the protective effects, i.e. injury prevention. It is important to use the correct shoe for the correct purpose (Fig. 4.1)! When choosing shoes the athlete should take several factors into account, including design of training program, the surface properties, foot anatomy, previous injuries and the sport and its demands, for protection and prevention of common injuries. A football/soccer player who trains on asphalt for example, should not use shoes or boots with cleats.

Figure 4.2 Athletic shoes should be adjusted to the sport they are used to participate in. **a)** Shoes for high jump must contribute to stability (with permission, by Bildbyrån Sweden); **b)** the stability of a shoe can change over time.

Figure 4.1 Sports shoes. **a)** Shoes in sprint running; **b)** clay shoes in tennis; **c)** shoes with cleats. (With permission, by Bildbyrån, Sweden.)

Athletic shoes and their structure and design

The sole of the shoe is essential for shock absorption and an athletic shoe should be built up of layers with different properties. The outsole should insulate from cold and be water resistant and durable with pattern and friction fit for the sport. The wearing surface also determines the shoes durability. Worn soles change the load conditions and give poor friction to the surface (Fig. 4.2).

The midsole should have shock absorbing properties, primarily in the heel, and also be designed to distribute the load on the foot and support the arches. The insole should be of soft material but reinforced and designed so that it participates in the dynamic support for the arches. The surface of the insole should be soft and skin friendly. One advantage is if the insole is replaceable and can be washed or replaced if needed. In the end, the three layers act as one unit.

The heel of an athletic shoe should be of a solid material, cover the entire heel area and fit closely to the heel. A well-fitting heel cup should provide increased lateral stability, so that the movements of the joints under the ankle joint are limited and the shock absorption of the heel supported. There are specially designed shoes for most sports.

Tip

- The most important piece of equipment in many sports are the shoes.
- Consideration should be given to stabilizing and supportive qualities when choosing them.
- Good, well-constructed and well-fitting shoes are a good investment.

Equipment and rules

The rapid technological developments in sports has been both good and bad for athletes. The results are often improved at the expense of increased injury risk. An example of this is modern downhill skis; current ski boot design has resulted in injuries now affecting the lower leg and knee, rather than the region just above the ankle as previously.

Technological developments have also contributed to improved track and field results such as in pole vault, where the development of new poles and materials has enabled changes in jumping technique.

Tip

When new equipment and tools are to be designed, it is of great importance that medical aspects and considerations are reflected during the development phases.

If the designer adopts medical aspects into the design from the outset, they will not be faced with an unexpected increase in the number of injuries. If there are some elements of risk, protective equipment should be coordinated with the tools. A change in one type of equipment can affect the function of another type; for example, the underside of a ski boot can have an impact on the function of the ski binding. Furthermore, the openings in an ice hockey goalkeeper's facemask should be adjusted to the design of ice hockey sticks.

Safety recommendations include:

- Protective equipment shall be subject to the safety rules and policies.
- Equipment and tools may cause serious injuries, especially if the rules for their use are not followed. It is imperative that every athlete and sports leader respects the rules.
- If the current rules can be considered as contributing to increased risk of injury the rules should be changed.
- When new rules are introduced, the potential risks of injury they may cause should be considered before the rules are approved.

Protective equipment

Protective equipment should prevent or mitigate injury to the body in both the short and long term. This is achieved by alleviating the body part from the force of the injury mechanism, and distributing the force over as large an area as possible. The protective equipment should not hamper the athlete's activity or technique. Human ability to adapt is very strong. Some movement limitations may occur when the athlete first starts using the protective equipment, but will be overcome quickly thanks to this adaptability.

Both the standards of how the protective equipment should be designed as well as product declarations are lacking in several areas. It is therefore up to each individual athlete to assess the effectiveness of the protective equipment.

Tip

Improperly designed protective equipment gives a false sense of security that can have unfortunate and unexpected consequences.

Athletes and spectators often have preconceived ideas about how athletes should look. If this attitude can be steered by comprehensive and objective information on how important protective equipment is, such equipment would be used to a much greater extent and may spread into other sports, thereby further reducing the number of injuries.

Head protection /helmet

A helmet aims to protect the head from injury. The requirement for using head protection varies from sport to sport, but is always used by boxers, hockey players, bandy players, cricketers at the wicket, baseball players, cyclists, horse riders and those engaged in motor sport. Head protection is sometimes used by other athletes such as skiers, football/soccer players, etc., when it is up to the individual athlete to decide whether to use head protection. Significantly higher demands are placed

Figure 4.3 Protective equipment must be tested, approved and of highest quality to be effective, as in protection for the main parts of the body in ice hockey.

on the head protection's effect in downhill skiing and motorsport because of the large amounts of energy that it must attenuate (see Chapter 14 for head injuries).

The head should be protected from contact with other players, the surface and objects in the environment and blows from equipment such as hockey sticks, pucks and balls (Fig. 4.3). Head protection equipment, most often a helmet, usually consists of a hard outer shell, which is kept separate from the cranium (skull) by a softer interior shock absorbing material. The use of helmets is debated. Some consider that they may create a sense of invulnerability and that no helmet can stop the brain from taking lots of small blows.

Every sport has special needs and design should reflect these; for example baseball batting helmets have an expanded protection over the ear to protect the jaw from injury, mixed martial arts helmets have ear pads and water polo helmets have ear-cages to prevent burst eardrums. The scrum cap made of soft sponge is a form of headgear used by rugby players to protect the ears in the scrum, possibly helping to prevent developing 'cauliflower ears'. A ski helmet is a very important piece of protective ski equipment. If the skier is racing a special ski racing helmet should be used as it protects the skier from not only high speed crashes but also from gates.

In American, Canadian and Australian football helmets are a requirement at all levels of organized activities in these sports. Although these helmets are well designed with good protective effect, players can and do still suffer head injuries, such as a concussion. Football helmet manufacturers are working hard to develop safer products. Current football helmets are regularly tested and given a yearly rating. Playing with a helmet is considered to be so important that play without a helmet is deemed to be against the rules and play ceases immediately a helmet comes off. In rugby hard helmets are not allowed.

When head equipment is exposed to violent blows the energy is transmitted to the softer interior. If the outer shell is softer, as is the case in hockey helmets, this may partially get deformed without coming into direct contact with the bones of the head. The energy of the blow is then reduced. The remaining energy is distributed over a larger area due to the soft interior and is further suppressed when the soft interior is compressed. The volume and weight are also important issues, since higher volume and weight may increase the injury risk for the athlete's head and neck.

Tip

An important prerequisite for head protection to really play its role is that it is securely fixed so that it does not fall off or fall down and obscure vision.

In sports where the use of head gear is mandatory serious head injuries have become rare, and the injuries that have occurred despite head protection have often not been severe. However, it should be pointed out that repeated mild head injuries can cause permanent damage. There are standards for design of helmets in some sports, such as hockey and bandy.

Safety standards for helmets

There are strict standards on how bicycle, ski, hockey and bandy helmets are designed. Helmets sold in the European Union (EU) must be CE-marked, which means that a helmet fulfills the requirements in the European Economic Community (EEC) Directive,

Figure 4.4 Head protection/helmets. **a)** Head protection in ice-hockey function reasonably well and are properly tested; **b)** Head protection in alpine skiing speed events; **c)** In horse riding helmets for youngsters must be of the highest quality. (With permission, by Bildbyrån, Sweden.)

89/686/EEC. This is a mandatory directive, thus helmets must be CE-marked if they are to be sold anywhere in Europe. This means that they must meet the EN CE 1078 standard bicycle helmets for adults, or EN CE 1080 for impact protection helmets for young children, i.e. if the cyclist hits the ground at 20 km/h the force will correspond to that if a pedestrian trips and falls on his/her head.

In the USA helmets must be tested by the ASTM International, formerly known as the American Society for Testing and Materials (ASTM). ASTM is a globally recognized leader in the development and delivery of international voluntary consensus standards. The relevant ASTM helmet standard for action sports helmets are used in sports such as bicycling, skateboarding, downhill mountain biking, BMX, skiing and snowboarding (Fig. 4.4).

Bicycle helmets

Studies from hospitals show that bicycle helmets have a large protective effect on both the face and skull. Cyclists who attend hospital without head injuries wear helmets to a higher degree. According to the Cochrane Review on helmets for preventing head and facial injuries in bicyclists, the helmet can reduce the risk of head injury by 63–88% and facial injuries (upper and middle face) by 65%.[1] A response to this study has been made which concludes: "A Cochrane Collaboration insists that its reviews should be based on reliable data, normally obtained by randomised controlled trial. It is concluded that the review above takes no account of scientific knowledge of types and mechanisms of brain injury. It provides, at best, evidence that hard-shell helmets, now rarely used, protect the brain from injury consequent upon damage to the skull."[2]

Australia became the first country in the world to introduce legislation on wearing bicycle helmets in 1990. From January 1st 2005, there is a law in Sweden that everybody under 15 years must wear a bicycle helmet when riding or is given a ride on a bicycle. Children without a helmet can be stopped by the police but not fined. Adults who transport a child without a helmet can be fined.

The Swedish National Road and Transport Research Institute (VTI) found in 2009 that 27% of all cyclists wore helmets. 54% said that they have always ridden *without* a helmet. VTI also found that 1,300 cyclists in Sweden each year are admitted to hospital for head injuries. The average length of hospitalization is 1.7 days.[3]

In Great Britain every year around 19,000 cyclists are injured in reported road accidents, including around 3,000 who are killed or seriously injured. The majority

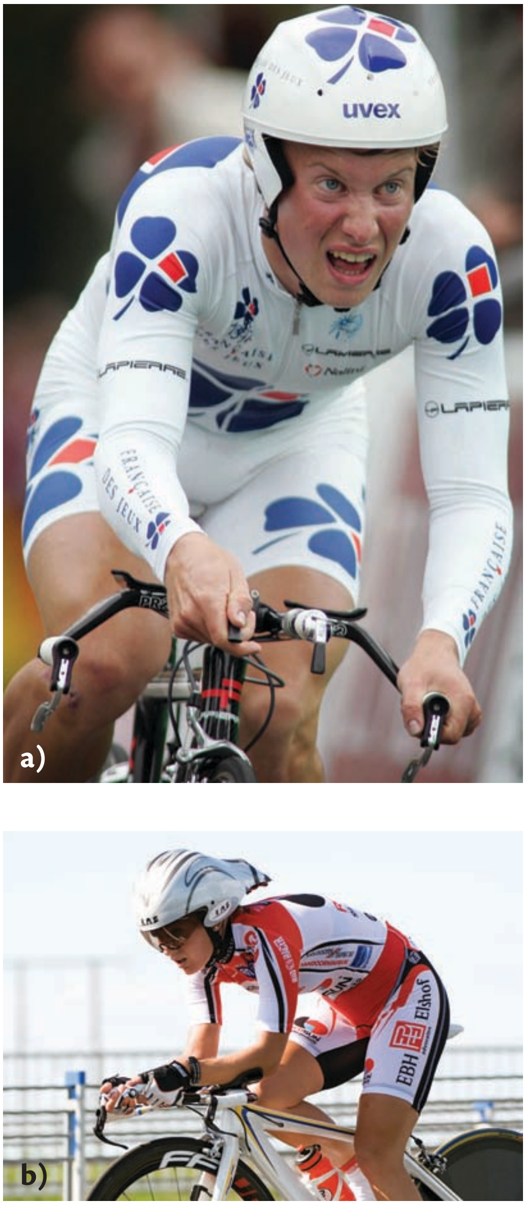


Figure 4.5 a, b) Elite bicyclists with specially constructed head gear. (With permission, by Bildbyrån, Sweden.)

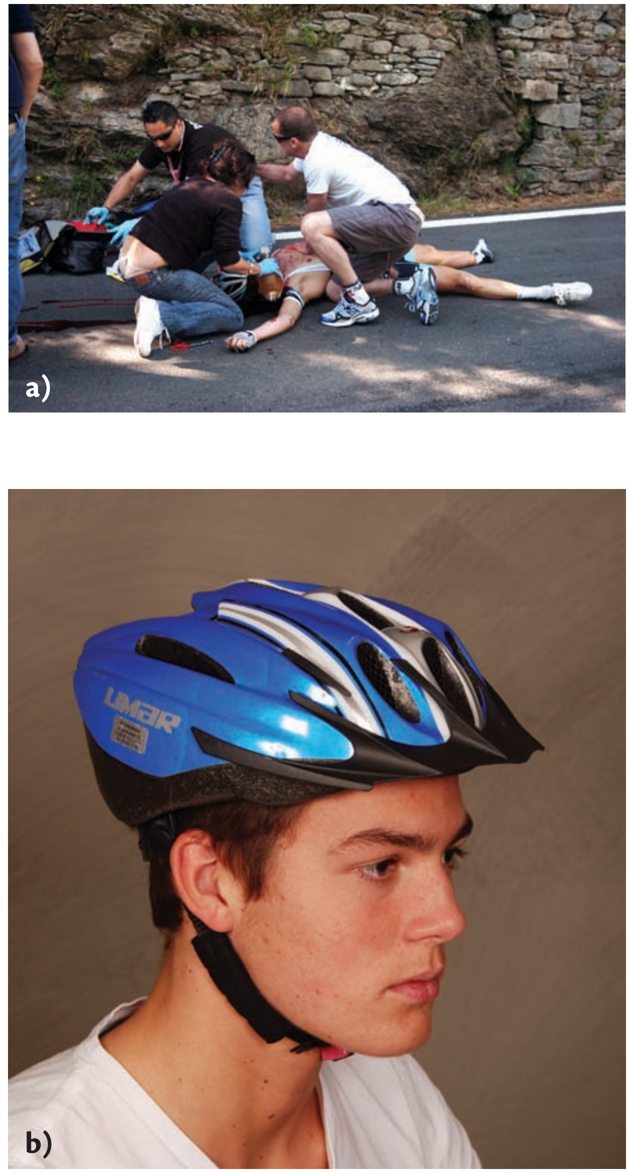


Figure 4.6 All cyclists should use a helmet. **a)** Cycling requires a helmet of highest quality if an accident occurs (with permission, by Bildbyrån, Sweden); **b)** A cycling helmet for the regular cyclist.

of cyclist casualties are adults, with less than one-fifth being children. Cycling accidents increase as children grow older, with 10–15-year-old riders being more at risk than other age groups, including adults until about the age of 60 years. Half of cyclists killed are over 65 years. 40% of fatal accidents could have been avoided by wearing a helmet (Figs 4.5, 4.6).

Common cycling accidents include motorists emerging into the path of a cyclist, motorists turning across path of cyclist, cyclist riding into the path of a motor vehicle, often riding off a pavement, cyclist and motorist going straight ahead, cyclist turning right from a major road and from a minor road and child cyclists playing or riding too fast.

Head injuries, ranging from fatal skull fractures and brain damage to minor concussion and cuts, are very common injuries to cyclists. Hospital data show that over 40% of cyclists, and 45% of child cyclists, suffer head injuries.[4]

Bicycle helmets are considered by many to be sufficient protection when a skateboard, rollerblades (inlines) and roller skates are used.

Tip

A well-designed bicycle helmet that meets current standards should be used by all cyclists.

Face protection

Face protection is used primarily by ice hockey and bandy goalkeepers, fencers and downhill skiers. Injuries to the face are caused by direct trauma, such as blows from sticks, puck or ball and through collisions with objects in the environment and opponents. It is essential that the facial protection is designed in relation to the appearance and size of the equipment used in each sport. There are standards on how facial protection for hockey goalkeepers is designed.

Tip

Face protection prevents eye injuries, which can cause permanent damage, lacerations and fractures and also dental injuries.

It is mandatory for ice hockey and bandy junior players up to college level to wear face protection. They should however, be mandatory at all ages and for field hockey. Among the athletes who wear full-face protection there are virtually no facial injuries. Visors are translucent Plexiglas (Perspex) and cover the upper half of the face. A visor protects primarily against eye and nose injuries as well as injuries to the temporal bone (Fig. 4.7).

Alternatively, a grid consisting of wire covers the face completely or partially. A comprehensive full-face grid protects against eye injuries, fracture of facial bones, facial lacerations and dental injuries (Fig. 4.8).

Figure 4.7 a, b) Head protection with a visor for ice hockey and bandy.

Protective eyewear

Protective eyewear or protective frames are essential for downhill skiing and squash and other racquet sports. Goggles are a valuable protection against blows, snow, sun and wind (Fig. 4.9).

Figure 4.8 A face guard gives full and efficient protection for the face and should be used by everybody playing ice hockey and bandy and is mandatory for young, junior and college players as well as for female athletes of all ages.

Mouth guard

Dental injuries are serious and costly. It has been reported that 13–39% of all dental injuries are sports-related, with 2–18% of the injuries related to the maxillofacial area. Males are traumatized twice as often as females.[5–7] The American Academy of Pediatric Dentistry recommends a mouth guard for all children and youth participating in any organized sports activities.

Since the loss of a tooth can affect the jawbone development, a dental injury should be considered serious if it affects a young, growing individual more than if it affects an adult. In boys and junior hockey and bandy as well as boxing, it is mandatory to use mouth guards.

Figure 4.9 a, b) Goggles are essential wear in snow and bright sun. They are needed during all types of skiing especially downhill, and also in racquet sports such as squash. (A, with permission, by Bildbyrån, Sweden; B, photo by Kerstin Samuelsson.)

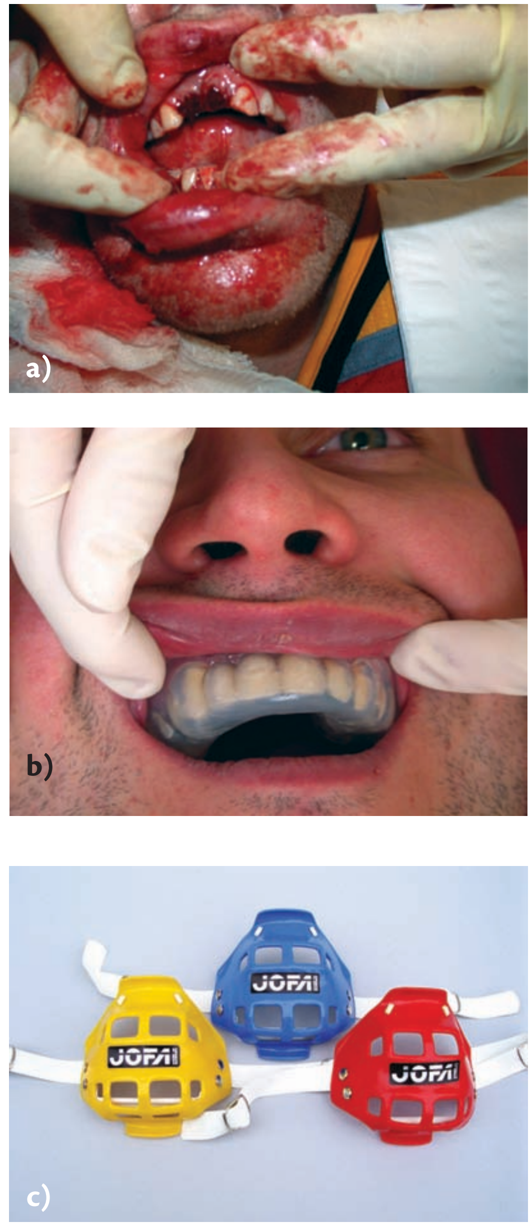


Figure 4.10 Injuries to the teeth should be prevented in sports such as ice hockey, American football and boxing, especially in growing individuals. **a)** Acute serious dental injury in ice hockey; **b)** intraoral mouth guard after molding the upper row of teeth (courtesy of Paul Pincininni, Ottawa, Canada); **c)** extraoral mouth guard worn outside the mouth (courtesy of Reebok-CCM).

Mouth guards can be constructed in two different ways:

- Intraoral mouth guards consist of a cast of the upper teeth and are worn inside the mouth.
- Extraoral mouth guards are worn outside the mouth.

The best protection against dental injuries should be through the use of both types of protection in combination (Fig. 4.10).

Standards are elaborated for extra oral mouth guards.

Ear and hearing protection

Those involved in shooting sports should always use effective ear defenders to avoid permanent hearing loss from damage to the inner ear (Fig. 4.11). It should be noted that hearing protection for hunters in the trade are not enough for a sports pistol shooter. A pistol shooter needs more damping than a hunter needs (see Chapter 14 and Fig. 14.9)

Figure 4.11 Passive hearing protection is necessary for noise suppression in shooting events. (Courtesy of Peltor/3M, Sweden.)

Neck protection

Neck guards can prevent serious, life-threatening injuries to the neck (Fig. 4.12).

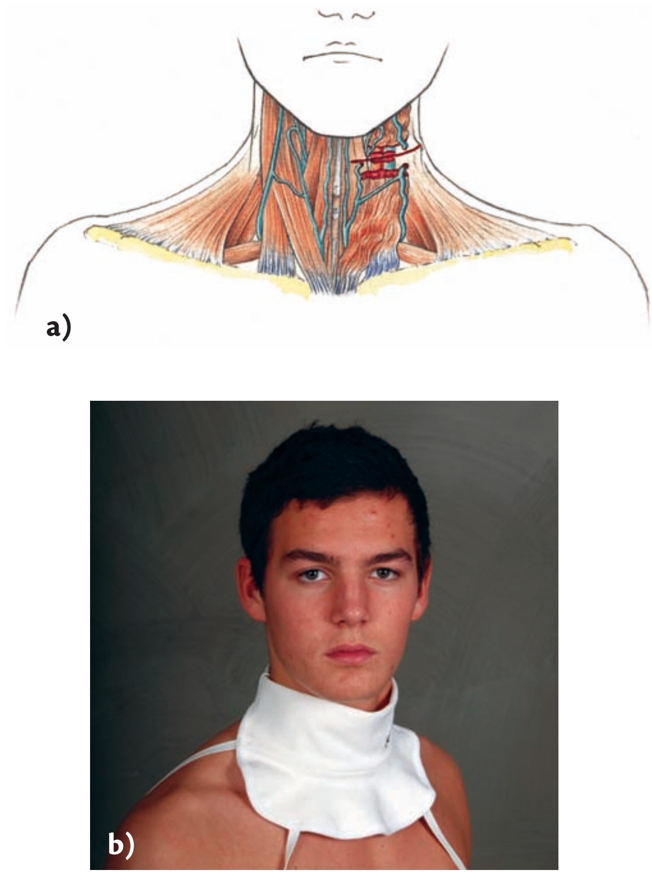


Figure 4.12 **a)** Diagram of the anatomy of the neck; **b)** neck protection against penetrating injuries.

Safety and protective vest (torso protector) in equestrian/horse riding

The rate of serious injuries per hour is higher for horseback riders than for motorcyclists and automobile racers. 70,000–100,000 people are seen in US emergency rooms due to horse-related injuries each year.[8]

Safety and protective vests are heavily padded and help protect the rider's torso if there is a fall. These vests help prevent injury to the internal organs, spine and ribs. The vests are usually lightweight (Fig. 4.13). They are commonly worn by long distance riders, in jumping and by pleasure riders, but also by rodeo riders.

There is one study showing an association between wearing a torso protective vest and protection from torso injuries, probably due to confounding. An effective vest should not only protect the thorax and abdomen, but also the cervical and the lumbar spine.[9]

Shoulder protection

Shoulder pads are used by American football, ice hockey and bandy players and in motorsport. Similar protection should ideally also be used in other sports, such as equestrian, cycling, downhill skiing and ski jumping, where injuries in the shoulder region often occur (see Chapter 10). Shoulder protection particularly protects the wearer against trauma to the shoulder from the front and outside (Fig. 4.14).

The pads should protect the shoulder joints, and distribute the force to the surrounding, more durable tissues. The most common causes of shoulder injuries are falling with the outside of the shoulder towards the ground or tackles made shoulder against shoulder or shoulder against the ice or the board. Injuries sustained by these mechanisms can often be prevented with shoulder pads. Tackling in American football usually hits the shoulder from above. The shoulder pads mostly protect parts of the shoulder region, but are often designed so that there is also a protective effect over the upper part of the chest. Shoulder pads can prevent many common injuries in the shoulder region from occurring. These are often difficult to treat and take a long time to heal.

Elbow protection

Elbow pads are used in sports such as American football, rugby, basketball, handball, volleyball, ice hockey and bandy. The most common cause of elbow injuries is in cases where the athlete falls towards the ground with the tip of elbow first (see Chapter 12). In basketball the elbow pads have the same color as the game shirt.

The elbow pad should completely protect and unload the tip of the elbow and prevent impact with the ground (Figs 4.15, 4.16).

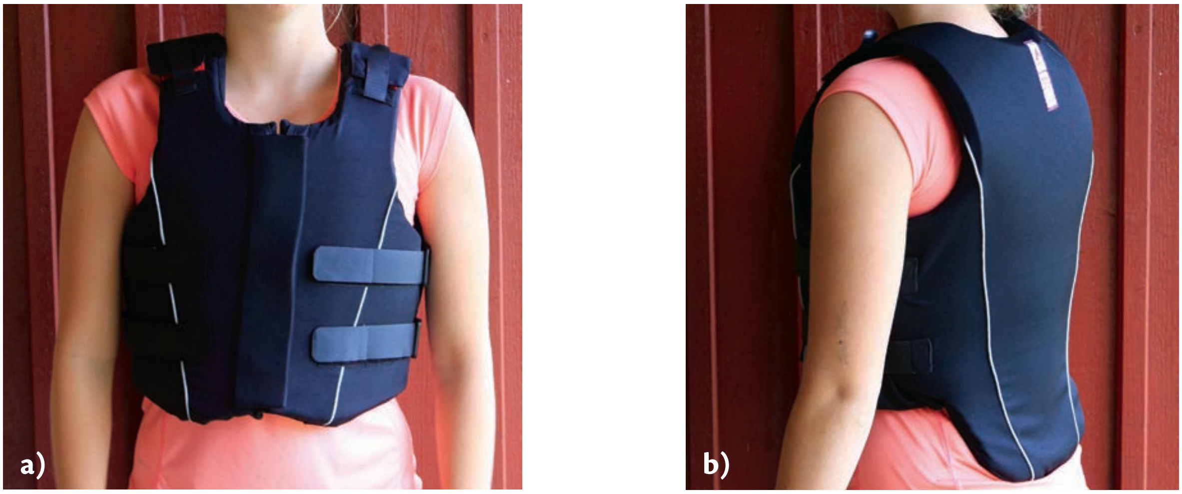
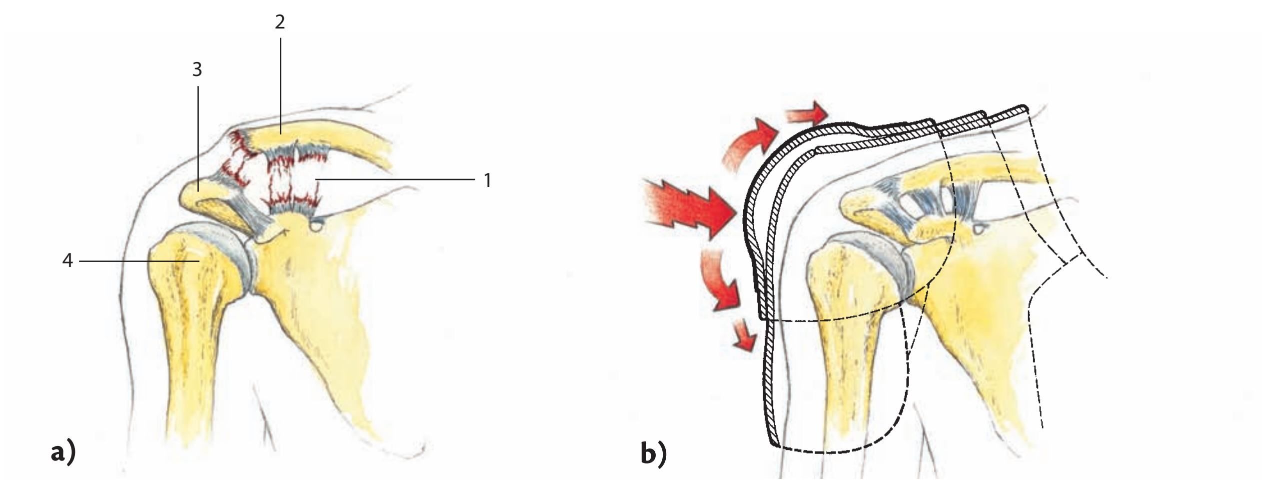


Figure 4.13 a, b) Safety and protective vest in equestrian/horse riding as well as downhill skiing can be very helpful if there is an accident. (Photo, Linn Samuelson.)



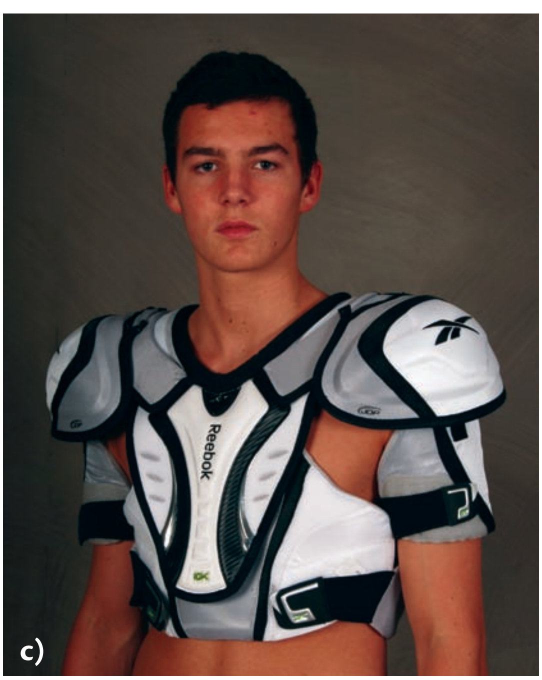


Figure 4.14 Shoulder protection: a common injury location is the acromioclavicular area. **a)** Diagram of anatomical landmarks, 1: acromioclavicular ligaments, 2: clavicle, 3: acromion, 4: humerus; **b)** Sketch of how in principle a shoulder protection pad should be constructed; when there is a trauma the forces are spread over a wider and more resistant area, protecting against injury to the acromioclavicular and humeroscapular joints; **c)** Effective shoulder pads (with permission Reebok/CCM).

Tip

Elbow pads prevent injuries to the elbow bursa and the tip of the elbow in the short term, and in the long term cartilage injuries in the elbow.

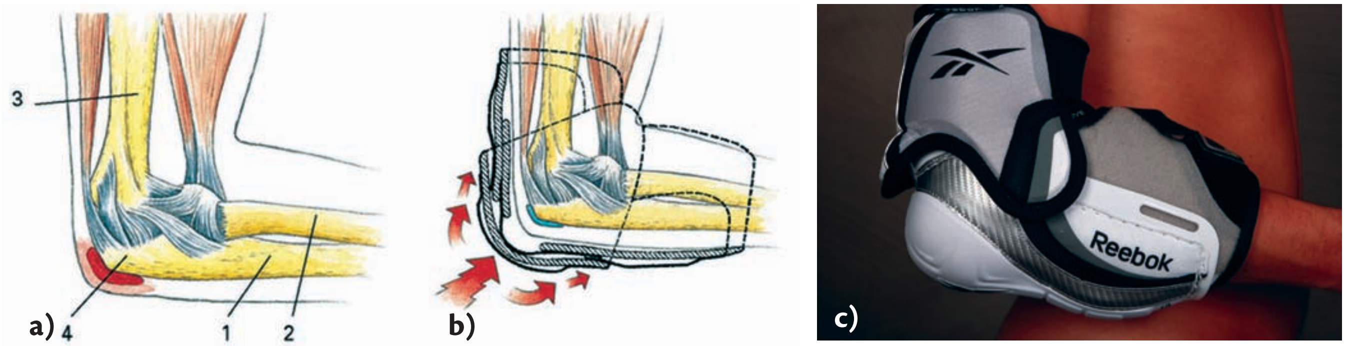


Figure 4.15 Elbow protective pads. **a)** Diagram of anatomical landmarks demonstrating olecranon bursitis (inflammation in the bursa behind the tip of the elbow), which is an area often injured; 1: ulna, 2: radius, 3: humerus, 4: olecranon; **b)** sketch of how in principle an elbow pad should be constructed for use in, for example, ice hockey. The pad is unloading around the tip of the olecranon and protects against direct trauma; **c)** example of an effective elbow pad used in ice hockey (with permission Reebok/CCM).

Figure 4.16 Elbow braces (orthoses) often used in many sports. **a, b)** Elbow brace with posterior padding used in sports such as volleyball (with permission from DJO, LLC. All rights reserved); **c)** Elbow pad used in volleyball and similar sports (courtesy of Otto Bock/ Rehband, Sweden); **d)** Elbow pad used in tennis for tennis elbow problems (used with permission from DJO, LLC. All rights reserved).

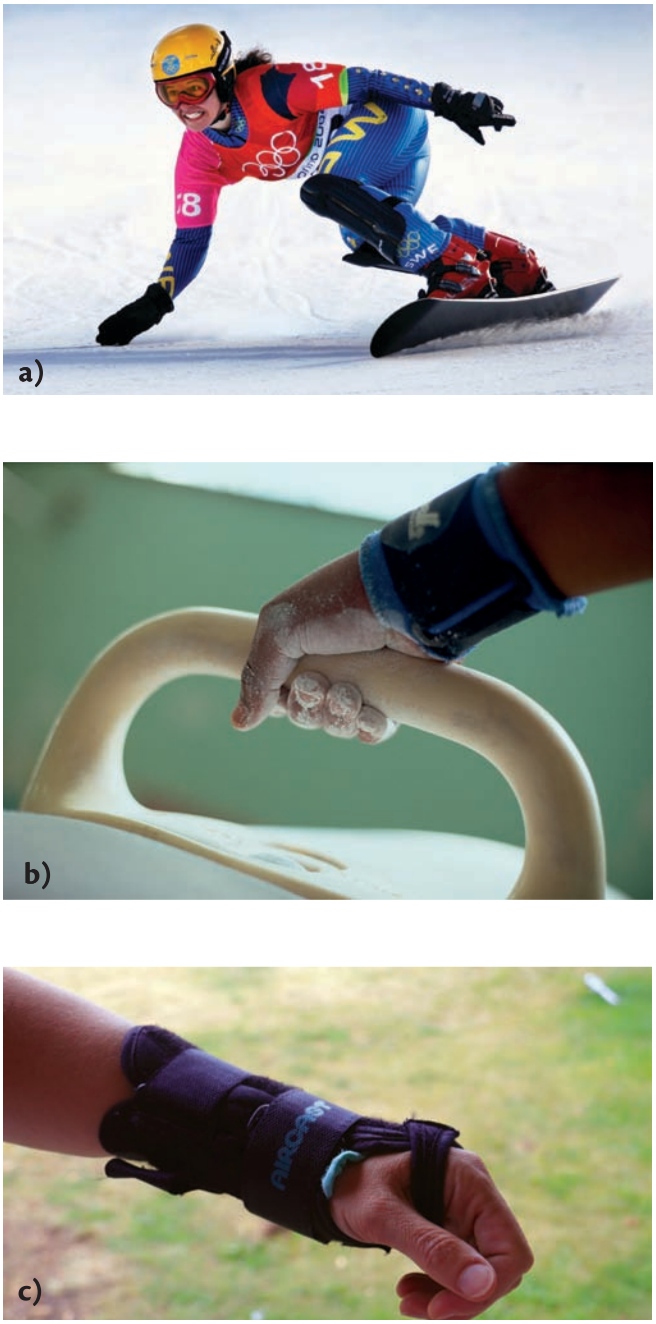


Figure 4.17 Wrist pads are often efficient and protective in many sports. **a)** Wrist injuries are not uncommon in snowboarding (with permission, by Bildbyrån, Sweden); **b)** a wrist support is often used in gymnastics (with permission, Bildbyrån, Sweden); **c)** wrist pads are often used in activities of daily living such as gardening (photo, Linn Samuelson).

Wrist protection

Wrist guards are used by inline, skateboard and snowboard riders (Fig. 4.17).

Wrist supports can also play an important role in everyday life including in the garden, in front of the computer, etc. Wrist supports usually have a good injury preventive effect. In addition, there are not any increased risks of injury to the forearm or shoulder when using them.

Most wrist injuries are usually the result of a low velocity fall (see Chapter 13). Wrist guards have a protective effect against the forces that are developed in this type of fall by absorbing and unloading the shock. In snowboarding, for example, is it possible to prevent injuries that are hard to heal such as wrist and scaphoid fractures.

Tip

Wrist guards generally have a very good injury preventive effect. They can and should be used in many sports.

Jockstrap/ suspensoir

A jockstrap is designed to support and protect the male genitalia during sports. A jockstrap should cover both the penis and testicles and protect them from direct trauma. Some jockstraps are designed for specific sports (Fig. 4.18). Some contact sports have optional hard cups, which may give additional protection. There are also more flexible and comfortable soft cups available for low contact sports.

The jockstrap provides in the short term protection against the severe pain, which is often triggered by direct trauma against the penis and testicles. Since these organs have a high vascular supply, trauma may more readily cause hemorrhage in the genital area, which may be difficult to treat and may cause permanent damage. In Thai boxing special protection is used, manufactured from cast iron strapped to the body with laces.

Hip guards

Hip guards are currently used by ice hockey, bandy and American football players and by goalkeepers in handball and field hockey, but they should have a wider range of applications. The hip guards available in stores are few and poorly developed. A hip guard should protect the upper end of the femur and thus the hip joint (see Chapter 17). It is often built into the pants used.

In the short term hip guards provide protection against the pain and hemorrhages that can occur when falling on the hip and when tackled by an opponent. In the long term the hip guard can prevent injuries to the cartilage in the hip joint by redistributing the force from the trauma.

Figure 4.18 Jockstrap in ice hockey (for jockstrap used in football/soccer etc., see Fig. 15.8). (Courtesy of Reebook/CCM.)

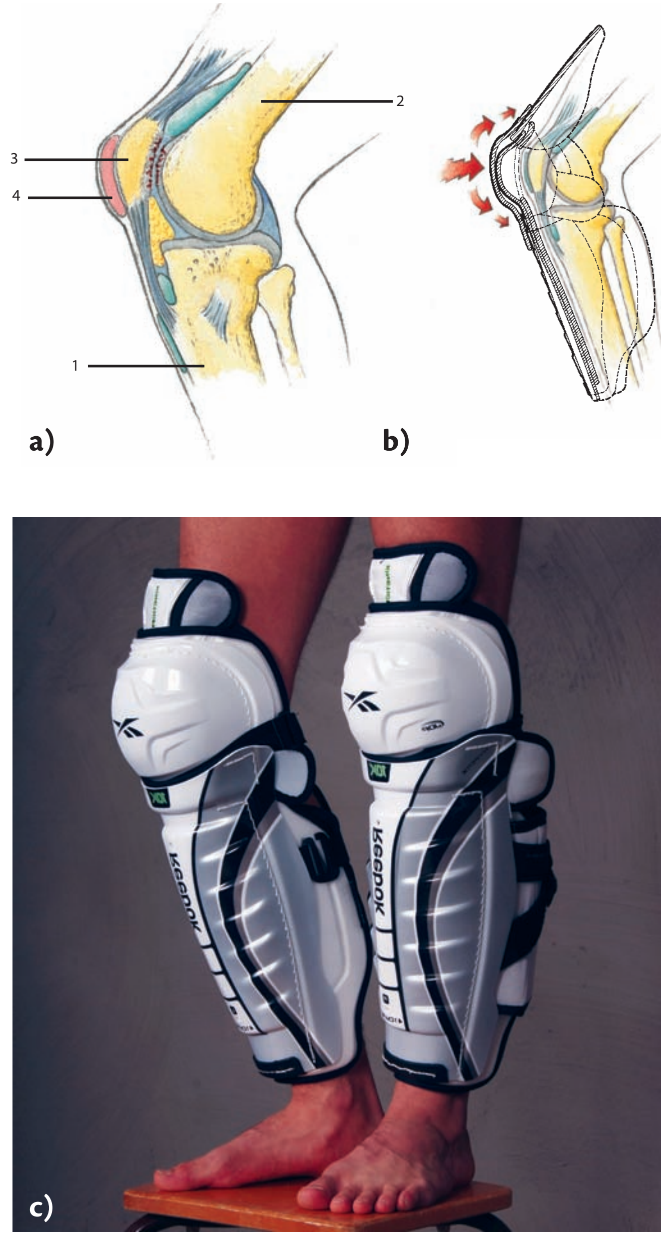


Figure 4.19 Knee and lower leg protective braces for use in ice hockey and bandy. **a)** Diagram of anatomical landmarks of the knee; 1: tibia, 2: femur, 3; patella, 4: bursa; **b)** sketch of how in principle knee protection should be constructed. The anterior area of the patella is susceptible to external trauma; **c)** in ice hockey and bandy braces that cover both the knee and the shin may be used (with permission Reebok/CCM).

Knee protective and preventive braces

The knee protective brace only protects the knee joints when falling on them, not when they are exposed to trauma from the side or pivoting, which can cause meniscal and ligament injuries (Figs 4.19, 4.20) (see Chapter 19). Combined knee and shin protective braces are used by ice hockey and bandy players, while separate knee preventive braces are used by basketball, handball and volleyball players, football/soccer goalkeepers, etc. Stabilizing preventive orthotics/braces and braces are described on page 56.

The protective braces should relieve the force from both direct trauma when falling as well as from traumas from blows and shots against the knee and lower leg. The patella is particularly fragile and should be completely protected from trauma. The forces from the trauma should be distributed to the surrounding tissues.

Tip

It is important that the sensitive areas are protected, especially in the knee joint, so that, for example, articular cartilage damage can be avoided.

Shin guards

Shin guards are used to protect the lower leg from kicks and other painful contacts with the environment (Fig. 4.21) (see Chapter 20). It is important that shin guards continue to develop and improve in their energy absorbing (shock absorbing) properties, in order to reduce further the risk of bone and soft tissue injury.

It is interesting that shin guards in basketball are supposed to have the same color as the game pants.

Tip

Shin guards should be able to prevent skeletal and soft tissue injury or at least reduce their severity through distributing the force of the trauma against the lower leg to a larger area. Shin guards must be used in sports such as football/soccer.

Figure 4.20 a, b) Knee braces with extra padding anterior to the patella are often used in handball and volleyball as the players often fall or throw themselves towards the floor. (**a)** with permission, by Bildbyrån, Sweden; **b)** courtesy of Otto Bock/Rehband.)

Foot and ankle braces

For many athletes shoes are of paramount importance since they provide protection against overload injuries and sprains. The development of athletes' footwear's protective properties has unfortunately been limited.

Figure 4.21 a, b) Shin pads in football/soccer for the young; shin pads, that cover the lower leg well are preferred.

Tip

The knowledge of important preventative and biomechanical parameters such as the relationship between surface, shoe and foot, as well as the importance of the shoe sole design in terms of the cleats, studs, striation, etc. is limited.

Bandy and ice hockey player's skates have a natural protection against injuries to the ankle and foot. The ski shoe offers downhill skiers similar protection. Skates and ski boots protect the ankle ligaments and bones. Regarding foot and ankle injuries, see Chapters 21 and 22 and see discussion of stabilizing ankle braces and orthotics on page 57.

Ski safety bindings

Although the equipment is constantly evolving, mainly based on good research, injuries in skiing are common. A type of protection of outstanding importance for the prevention of injuries in alpine skiing is the ski safety binding – provided it is properly designed and tuned (Fig. 4.22). The overall injury rates among skiers are directly related to the ski's safety binding. Some injuries occur because of an unsatisfactory release mechanism in the bindings, which results in the skis not being released or are released at the wrong time. In recent years the injuries related to the binding have decreased significantly; however, the most important factor for injury prevention in alpine skiing is still the development of more efficient ski bindings as about 30% of all ski injuries are still due to deficiencies in the safety binding's function.

Certain types of safety bindings have a multi-directional release mechanism, i.e. they release in any direction the skier falls, but many bindings still have a limited release mechanism, e.g. released by rotation or by lateral movement in the forefoot or forward tilt of the heel. Few bindings have more than these options. Skiers who are beginners and may fall frequently, should choose safety bindings that have a multi-directional release.

Safety bindings should be taken care of properly and the function should be checked regularly. The binding mechanism should be thoroughly examined and serviced at least once before each ski season. All equipment, ski boots, bindings and skis should be kept clean. The skier must always test the safety bindings in all directions before he/she embarks on the slopes (see a description of the ski binding importance at p. 110).

Figure 4.22 Ski bindings in alpine skiing are usually easily released if they are correctly adjusted. (With permission, by Bildbyrån, Sweden.)

Ski poles and gloves

The most common injury to the upper extremities of a skier is a rupture of the ulnar collateral ligament of the carpometacarpal joint of the thumb (base joint). This injury is to some extent related to the ski pole design. A ski pole should be designed so that it can easily come loose from the hand grip (Fig. 4.23). The skier can also avoid attaching the hand to the pole by the strap so that in an accident the pole can be dropped easily.

Gloves are used by skate- and snowboarders as well as ice hockey and bandy players, boxers, etc. Using gloves as protection may be of value in avoiding fractures to the bones in the hand and painful hematomas. Ligament injuries of the thumb and wrist can also be prevented (see Chapter 13).

Tip

It should be in every athlete's interest to protect themselves and prevent injuries.

Each athlete should form an opinion about relevant injury risks that exist in his/her sport and test the safety equipment that he/she plans to use. Injury rates in many sports may be reduced if all athletes would follow this advice.

Figure 4.23 The ski pole will distribute the forces of a trauma and should be easy to release in a fall.

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Braces and Taping Used in Sport

5

Support bandages

Different types of support bandage are used depending on the degree of stability required.

An elastic bandage is made of cotton and is more or less elastic. An elastic rubber bandage is made of cotton woven together with strands of rubber and is more elastic than a regular elastic bandage. It can be used for securing dressings or ice packs over injured areas and also provides compression in acute injuries, such as ankle sprains. The elastic bandage is flexible and stretches after use, which makes it unsuitable for long-term support. It has the advantage of being washable, and can be reused.

An adhesive elastic bandage is firm and flexible and its adhesive properties provide a strong hold. It is particularly useful for ligament injuries of the knee, ankle and wrist. Adhesive elastic bandages can also be used for taping as a preventive measure.

Self-adhesive elastic bandages consist of closely packed, unwoven polyester fibers. This type of bandage adheres to itself but not to the skin. It does not interfere with the normal functions of the skin, and is non-allergenic. It remains in place during bathing and dries quickly after getting wet. Self-adhesive elastic bandaging can be used as a preventive measure as well as during rehabilitation after an injury. It provides a stable but flexible dressing that is not bulky and even fits inside a shoe when applied to the foot. If the correct technique is used when applying the dressing and its elasticity is not overstretched, self-adhesive elastic bandage can be used as a semi-permanent support in ligament and other soft tissue injuries.

Kinesio tape is a new type of elastic therapeutic tape, which is a cross between the adhesive bandage and the inelastic sports tape, is water resistant and requires little space. The product is a breathable type of thin, elastic cotton tape with an acrylic adhesive and some claim that the tape is able to stretch up to 140% of its original length.

Orthoses and braces

An orthosis or a brace is an externally applied support with the aim to support or align the joint. Orthoses and braces are increasingly used in sports. They are mostly used for the ankle and knee, but increasingly are used for the shoulder, elbow, hand and wrist.

Knee braces, orthoses and support bandages for the knee joint

A knee orthosis (KO) or knee brace is a brace that extends above and below the knee joint and is generally worn to support or align the knee. Knee injuries are often serious. The risk of knee injuries is 6–22% each year for a college American football player and is increasing for young girls in football/soccer, handball and basketball. Support bandages of the knee joint/braces in one form or another are used in many cases during the treatment and rehabilitation period. Knee braces can be divided into three types: prophylactic, rehabilitative and functional.

Prophylactic knee braces

Prophylactic knee braces are designed to distribute applied loads away from the knee joint and, thereby, reduce the load on the medial collateral ligament (MCL) and perhaps also on the anterior cruciate ligament (ACL). Biomechanical studies indicate that there may be limited protection to the MCL and ACL when they are subjected to valgus loads. Research indicates increased resistance to valgus loads, with highest efficiency around 20°. The benefits have, however, been documented only for low non-physiologic loading. Prophylactic bracing in American football has not consistently been shown to reduce MCL injuries. There remains a lack of evidence to support the routine use of prophylactic knee bracing in uninjured knees. There is limited high-level evidence, bias in the available literature and confounding variables that limit the current literature.[1] There may however be a negative impact on performance, cramps in legs and fatiguing symptoms.

Rehabilitative knee braces

Rehabilitative knee braces are more effective than a plaster cast in treatment of MCL injuries, since they allow controlled early motion. They are valuable during the first weeks of conservative treatment of knee ligament injuries and may in a few cases be helpful after knee ligament surgery. Braces have many uses, for example, after ACL surgery, but the use of a postoperative brace has not been shown to affect outcome after ACL surgery significantly.

Tip

After MCL surgery a rehabilitation brace can be of value.

Functional knee braces

Functional braces are valuable in supporting the knee so that the joint can function without 'giving way' after an ACL injury. The brace operates by interacting with ligament, meniscus, and muscle function (Fig. 5.1). The functional knee brace offers support in the following:

- Varus/valgus (side-to-side): the brace has internal and external reinforcement, e.g. steel or hard plastic rails.
- Anterior tibial translation (tibia moves forward in relation to femur) by preventing hyperextension.
- Rotational control – this is extremely difficult to achieve and at present no brace can really control rotation.

Suspension is the most difficult part to control in these braces. The thigh muscles are very giving and conical and movements are difficult to control, giving the brace a tendency to slide down, so that the axis of movement of the knee joint does not coincide with the axis of movement of the brace.

Biomechanical studies show that functional knee braces can reduce anterior translation (movement forward–backward) at low physiological loads and during lifting. Clinical studies show that the athlete experiences positive effects from the brace, although many may continue to have some instability episodes despite brace wear.

Tip

- The braces have a verified positive effect on activities of daily living, but during physical activities benefits are not well documented. The stabilizing effects and other benefits may vary from individual to individual.
- A knee brace may be useful in the rehabilitation after an ACL injury that is treated conservatively.

Figure 5.1 Examples of functional knee braces (knee orthoses). **a)** Bauerfeind GenuTrain S Knee Support is a soft, light knee brace, which is proven to be effective in the management of ligament injuries in the knee joint; **b)** Albrecht´s ROM Stabil can be used as a brace after surgery (postoperative rehabilitation orthosis) and also functions well as a functional orthosis in tennis, running, alpine skiing (courtesy of Albrecht GmbH, Germany); **c)** the Defiance custom brace can be used in sports such as climbing and mountain biking as well as contact and non-contact sports. It is also used for moderate to severe anterior or posterior cruciate ligament instabilities and medial or lateral collateral ligament instabilities (©2014 DJO, LLC, used with permission from DJO, LLC. All rights reserved).

Braces for patella-femoral pain syndrome

Braces for use in patella-femoral pain syndrome (p. 446) are designed to prevent the displacement of the patella. They usually incorporate horseshoe-shaped lateral supports to stabilize the patella and prevent lateral subluxation. Medial straps may give extra stability (Figs 5.2, 5.3).

Some studies indicate that these braces improve the performance of these patients. Bracing seems to make it possible to include dynamic exercises in the rehabilitation program and to allow early return to recreational and athletic activities.

Figure 5.2 Examples of knee braces (orthoses) used for patella-femoral pain syndrome. **a)** This brace positions the patella optimally during the full range of motion; knee brace open (courtesy of Ottobock Scandinavia Rehband); **b)** Don Joy Reaction knee brace absorbs shock and shifts the peak loads away from the painful area of the knee. This dispersion of energy helps reduce the anterior knee pain and dynamically stabilizes the patella on all sides (©2014 DJO, LLC, used with permission from DJO, LLC. All rights reserved).

Ankle braces

Ankle injuries account for 15% of all athletic injuries. To reduce the incidence, athletic tape and bracing are used extensively to support the ankle joint (Fig. 5.4). Ankle braces do not, as a rule, significantly affect performance. There may be a slightly decreased performance in vertical jumping.

Biomechanical studies indicate that some support is provided by these braces, especially in the loading situation. Clinical studies show that braces decrease the severity of ankle sprains and also decrease their recurrence. In athletes with a previous ligament injury, the risk of re-injury is reduced through the use of an ankle brace. A brace or a support bandage provides a significant reduction in the number of ankle sprains in athletes of high-risk sports such as football/soccer, handball, basketball and volleyball. It has proven to be better to use some form of external support than nothing at all.

Tip

Ankle braces occur with both a fixed and a movable ankle joint; braces with a movable ankle joint are increasing in use.

Figure 5.3 Knee braces (orthoses) with reinforced shock absorbing brace anterior of the patella are used a lot in sports where the athlete is throwing themselves around and is often in contact with the playing surface, e.g. handball and volleyball. (Courtesy of Ottobock Scandinavia Rehband.)

The disadvantage of taping is, however, that the biomechanical protection is reduced with time. Skin damage can occur if the tape is applied directly against the skin. Using a protective dressing under the brace reduces the risk of skin damage, but at the same time decreases the biomechanical protection. Despite this, the taping of an ankle joint mostly gives a good effect. Taping is still a popular method because athletes do not consider that the tape interferes with performance capability compared with braces. Taping is widely used by elite athletes.

Ankle braces are also effective in ankle injuries and are widely used by all athletes, perhaps most of all by recreational athletes. As ankle braces are constantly improving in design, their use is likely to increase.

In the treatment of ankle ligament injuries a combination of tape/elastic adhesive bandage together with an ankle brace can often have a good effect.

Tip

- There is good scientific support for the use of the ankle brace in order to prevent lateral ligament injuries in the ankle.
- The use of ankle braces demonstrates better treatment results in terms of functional outcome.
- Individuals who have previously suffered an ankle sprain should be informed that the risk of future sprains can be reduced by using a brace.
- It has been proved to be better to use some form of external support than nothing.
- Ankle brace treatment is a more cost-effective method than using tape, so the use of braces after acute ankle sprains should be considered.
- It is important to improve the ankle's balance and proprioception using an ankle brace or tape.

Figure 5.4 Ankle orthoses are very efficient. **a)** Aequi 3-6 ankle brace (courtesy of NEA International); **b)** ankle brace (orthosis) used for injury prevention in tennis; **c)** an ankle brace (orthosis) is used in many team sports such as rugby (with permission, by Bildbyrån, Sweden).

Shoulder braces and support bandages

Surgery for anterior shoulder instability can be successful, but the use of bracing is controversial. A few shoulder braces are commercially available (Fig. 5.5). The aim of these braces is to limit abduction and external rotation, and prevent the shoulder from being placed in unstable positions. These braces are large and affect the performance of highly skilled athletes. They can be used by ice hockey players, for example, who do not perform overhead shoulder movements. No clinical or biomechanical studies have evaluated these braces.

Examples of shoulder braces include:

- A customary shoulder brace, which is designed to relieve pain and inflammation.
- A type of shoulder brace can create a pressure downwards and backwards to limit a dislocation of the acromioclavicular joint.
- A shoulder brace designed to relieve, for example, the rotator cuff and shoulders that have been dislocated. This can be used in motor sports such as motocross.

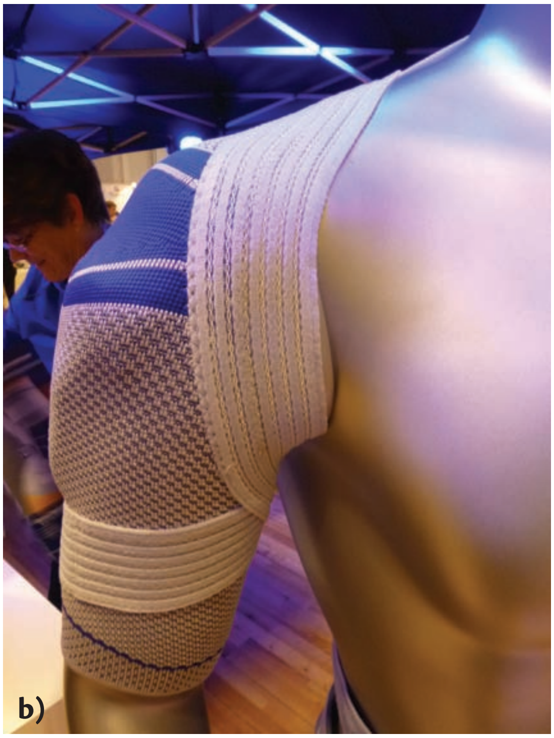


Figure 5.5 Shoulder brace (orthosis) can give some support. **a)** The Acro ComforT shoulder brace can be used for anterior multi-directional inferior and posterior instabilities, acromioclavicular separations, and muscle strains. The directional straps allow for individual restriction of the shoulder motion (courtesy of Ottobock Scandinavia Rehband); **b)** the Bauerfeind OmoTrain Shoulder Support protects against painful circular movements and provides support for movements, such as the lateral lifting of the arm, in order to strengthen the musculature. The full pain-relieving effect of the support is produced during movement.

Elbow bandages/braces/orthoses

Elbow braces are available for tennis elbow (see p. 268) or elbow hyperextension injuries.

Braces for tennis elbow are based on the counterforce principle. An elastic strap placed on the proximal portion of the forearm provides a counterforce to muscle contractions either by constraining full muscular expansion and thereby decreasing the potential force the muscle can generate, or by dispersing pressure from the area of injury, which lessens the stress at the lateral epicondyle. The counterforce brace thereby controls the muscle forces and directs the tension overload to healthy tissue. It can allow continued activity despite, for example, tennis elbow (Fig. 5.6).

Studies indicate that the counterforce brace decreases the electromyographic (EMG) activity in the proximal lower arm muscles. In athletes with tennis elbow, the counterforce brace may produce significant increases in

Figure 5.6 Braces (orthoses) can be used for tennis elbow, golf elbow, mouse arm and similar. It takes the strain off the irritated tendon attachment and provides pain relief while permitting movement in spite of inflammation and pain. (Courtesy of Ottobock/Scandinavia Rehband.)

Figure 5.7 Elbow braces (orthosis) with a shock absorption ability protect against trauma to the olecranon tip (posterior tip of the elbow) during a fall or jump and can be of great help in falls during wheelchair basketball. (With permission, by Bildbyrån, Sweden.)

wrist extension and grip strength, although no significant effect on perceived pain has been reported.

Traumatic hyperextension injuries may occur in contact sports such as wrestling. Braces are available that can prevent elbow hyperextension. The tip of the elbow (olecranon) sometimes needs to be protected in sports such as wheelchair basketball or when falling on the elbow is likely (Fig. 5.7).

Tip

Although scientific evidence is limited, these braces seem valuable in the management of tennis elbow.

Hand and wrist braces/ orthoses

There are several functional wrist braces/orthoses for ligament injuries of the wrist on the market. These are usually very effective.

Supporting bandages, orthoses and casts are also available for distal radius fractures and fractures of the scaphoid in the wrist (Fig. 5.8). Stener's lesion (see p. 303), which is an injury to the ulnar collateral ligament, can be treated by protective devices. These often have to be properly padded as the hard and non-yielding materials used are not allowed in many sports. Less severe cases can be treated by taping.

Tip

Wrist braces/orthoses are often well designed and are very effective to prevent and treat long-term wrist problems, not only in sport but also in everyday life as in gardening, painting, picking mushrooms, etc.

Figure 5.8 Wrist braces (orthoses) can be effective as they are adapted close to the underlying bones surrounding the wrist. They have an important injury preventive effect in sport, but also at work in the garden and similar activities.

When returning to sport or participating before full healing there are several protective options available, such as taping, custom-made splints, commercially available braces, soft casts and hard casts.

Casts, waterproof casts and splints

When there is a need for rigid support (e.g. in fractures and ligament injuries) or complete immobility (e.g. in acute peritendinitis), a plaster cast or splint is the best solution (Fig. 5.9). Depending on the nature of the injury, some activity, such as isometric exercises, can be allowed on the muscles encased in the cast. In principle, a plaster cast or splint should include the injured area and the joints above it, not those below it.

Firm casts can be made of many synthetic materials. Scotchcasts are composed of fiberglass impregnated with a plastic compound that hardens in cold water. The plastic cast becomes pliable 5–7 minutes after it has been dipped into cold water and can then be wrapped around the injured part of the body or applied as a splint. After 30 minutes it can withstand a certain amount of load. These casts are suitable as a temporary or permanent support for various parts of the body without the need for any restrictions on bathing, showering or swimming.

During the last few years there has been a rapid development of bandages made from plastic material. Various types with different properties (and colors) are available.

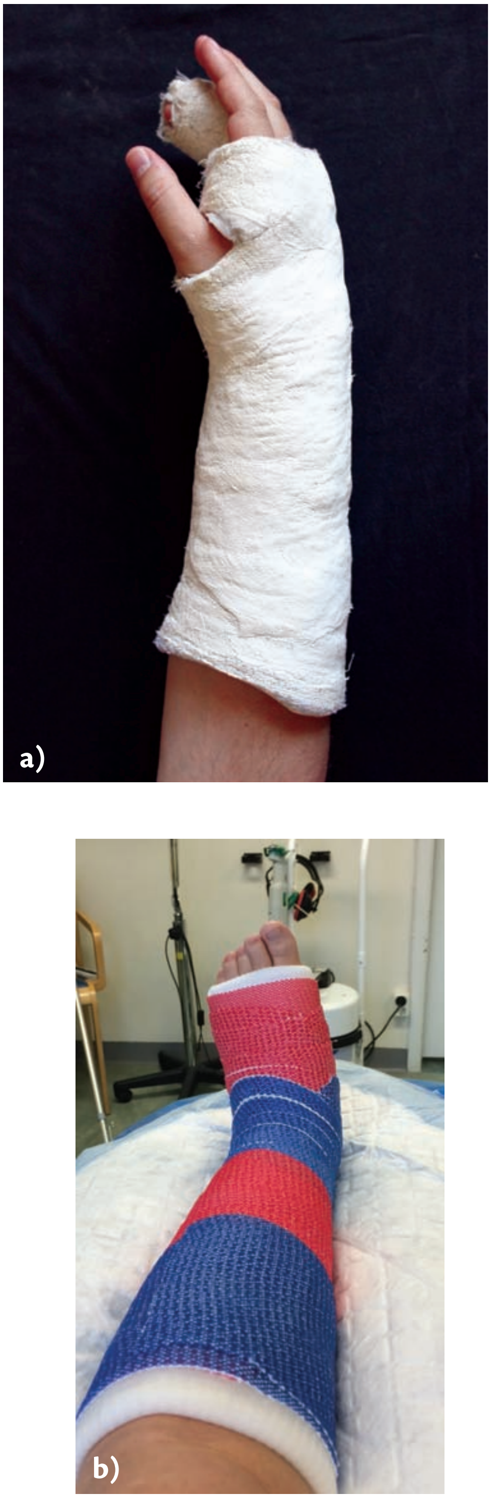


Figure 5.9 Casts are effective but as they cause muscle atrophy (the muscles decrease in volume and strength) they should be worn over as short a time period as is possible for healing and stability. **a)** Cast for a fracture in the middle of the hand fifth carpal bone; **b)** lower leg cast for injuries such as ankle and foot fractures or Achilles tendon problems. (Courtesy of Maja Uebel, Swedish Sports Confederation, Stockholm, Sweden.)

Taping

Tape was known to be in use in Egypt around 300 B.C. Tape is still extensively used, especially for ankle ligament injuries. Taping is mainly used for the protection of uninjured ankle ligaments, but it is also used after injury to prevent recurrence or worsening of the injury. After a recently healed ankle ligament injury, the ankle needs long-term rehabilitation to regain strength and nerve muscle function. The risk of recurrence during the rehabilitation phase should be lessened through a proper support, such as tape.

Taping here refers to the use of rigid/'inelastic' so-called sports tape, which of course can be combined with different types of adhesive bandages/kinesio tape to provide optimal support and range of motion, depending on the structure it is applied to.

Tip

The basic idea of taping is that the tape will support a weakened body part by preventing movements that negatively affect and further damage the weakened area.

Otherwise the tape should, if possible, not restrict the body part function. Such a goal, however, can be difficult to achieve, even when the tape is properly applied. The goal of a taping should be to:

- Reduce injury incidence without affecting the sports performance.
- Support the functions of an injured ligament, in for example, an ankle without affecting range of motion too much.

Indications for taping

The main purpose of taping is to provide a joint and/or surrounding tissues with a rigid support and avoid the injured/painful movement without affecting other movements. A perfect taping will mean that there is little or no movement restriction, i.e. it should feel like before the injury occurred (Fig. 5.10).

Tip

The tape has a stabilizing effect on mainly the joints and body parts that are surrounded by small amounts of soft tissues such as the foot and wrist, where the skin cannot move too freely around the joint.

The efficacy of the taping of, for instance, a thigh muscle strain is highly debatable, since the muscle is so extensive and variable. It is doubtful whether the

Figure 5.10 In most sports, including tennis, athletics and most team sports, well-positioned taping is of great value to the athletes. However, for top level athletes an expert needs to carry out these tapings. **a)** Taping of a top player in tennis (with permission, by Bill Norris, ATP World Tour); **b)** top level athletes in athletics need expert taping (with permission, by Tommy Eriksson, Swedish Athletic Association).

tape stabilizes such an injury. However, there may be a compression effect that may be of value.

Taping and performance

Taping an injured ankle will decrease its range of motion for 2–3 hours of physical activity. This time is shorter if a tape is used with poor adhesive properties. Correctly applied tape probably does not affect performance in sports very much. Biomechanically the support of tape is limited, but clinically it does seem to have an effect. Studies on tilt-boards indicate that taping has a proprioceptive effect on unstable ankles by activating a reflex system in the area.

Acute injury

It can be risky to use tape on acute injuries, and a constrictive taping of an area in which swelling and bleeding are occurring may cause serious impairment of circulation.

Tip

Taping of an acute injury should be performed by qualified medical professionals who are experienced in the area. Elastic tape should then be used.

Before taping an acute injury a detailed medical examination should be carried out, including a careful stability test. If there are any indications of a total rupture in ligaments in, for example, the ankle or knee, taping should not be used. The taping of an acute injury may unfortunately lull the athlete into a false sense of security, encouraging the resumption of or return to sporting activity, which will probably make the injury considerably worse.

Preventive taping

There has been some suggestion that taping healthy ankles as a preventive measure could, by changing mechanical conditions, increase the occurrence of knee injuries. Research has shown that this is not the case, and has confirmed that preventive taping may decrease the number of ligament injuries to the ankle. It is of particular value in sports in which the ankles are vulnerable to violent impact, e.g. soccer, team handball and volleyball.

Ligaments such as those around the ankle joint can be subjected to repeated impact and injuries with a result that they become weak and stretched. In such cases taping plays an important part in contributing to the stability of the joint. If, despite precautions, progressive instability of the joint is seen, surgery should be considered.

Tip

In cases of repeated trauma causing chronic instability taping is an essential treatment.

Taping during rehabilitation

Taping is most useful in rehabilitation after an injury has been treated surgically or has healed spontaneously. It is becoming common for athletes to use taping when they resume sporting activity after an injury, though the value of this practice has not been proven. Studies have shown that taping of the knee joint does not provide stability to any significant degree. In cases of medial instability of the knee, taping gives virtually no support after 5 minutes' hard physical activity. In these situations the use of an adhesive bandage, which can be expanded around the thigh and calf, may be of some value.

Tip

Correctly used, taping can be of value after an injury, but a taping should not be seen as a 'magic bullet' for a variety of injuries.

Types of tape

The tape in general use is non-elastic and is available in a range of widths: 38 mm (1.5 in.) and 50 mm (2 in.) widths are often used. The adhesive is often perforated to allow it to breathe and help remove sweat from accumulating on the skin. Some tapes have a serrated edge to make it easy to tear. By stretching the tape before application it is possible to achieve a firm restriction early in the range of movement and also reduce the risk of tightening the tape too much. In other words, the tape should be stretched, the right angle found and the tape placed on the body part in the correct position.

Taping technique

It is essential that the person who is taping has good experience and basic medical knowledge in the field and is aware of the various opportunities available to them. Research on taping techniques is limited. A study on a well-modulated foot and ankle model in the laboratory at the University of Vermont compared four different types of ankle taping. A mechanical test apparatus applied controlled loads and measurements could be taken when the tape failed. The results showed that the 'figure of 8' with three or more layers could best withstand the load (Fig. 5.11).[2]

Figures 5.12–5.22 demonstrate customary taping techniques of ankle, Achilles tendon, lower leg and knee.

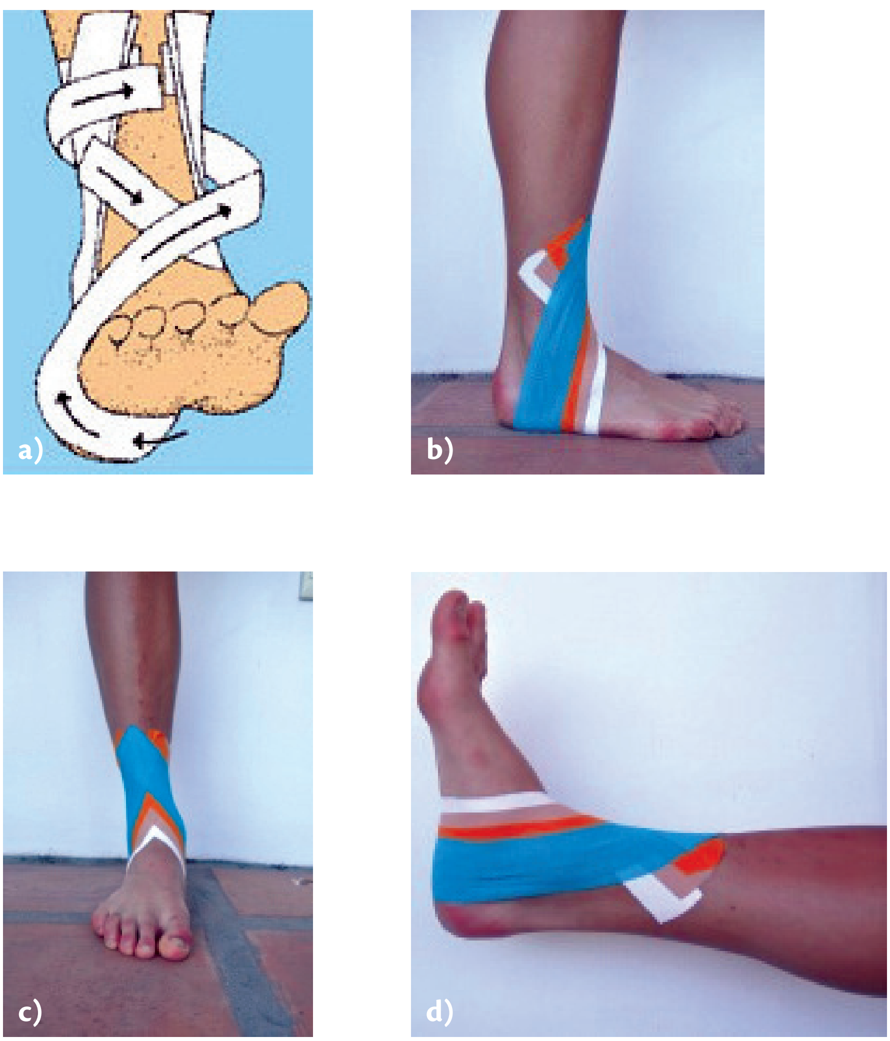


Figure 5.11 a–d) 'Figure of 8' technique with 3 or more layers has been shown to be the best method of those tested to resist load. Different colors have been used to demonstrate how the different layers are arranged: white tape, tan tape, orange tape and blue tape. (With permission, by Tommy Eriksson, Swedish Athletic Association.)

Stabilization – taping the outside (lateral side) of the ankle with tape

Materials: Non-elastic sports tape, kinesio tape or elastic adhesive tape (Fig. 5.12).

Joint position: The foot should be held at a 90° angle (0° anatomically) and slightly outward rotated.

Application steps:
A: Start with the first anchor (white tape) 2 fingers above the top of the malleoli, around the lower leg, angling the ends upward in front to get a good anatomical fit.

B: Add a second anchor with tape above and parallel with the first overlapping approxiamately 1 cm (0.5 in.).

C: Identify the base of the 5th metatarsal.

D: Support 1: From underneath the foot stretch a 'straight' piece of tape from the 5th metatarsal base using the front half of the tape (tan colored tape) to cover the base diagonally upwards towards the Achilles tendon and the anchors on the lower leg, finishing over the posterior midline.

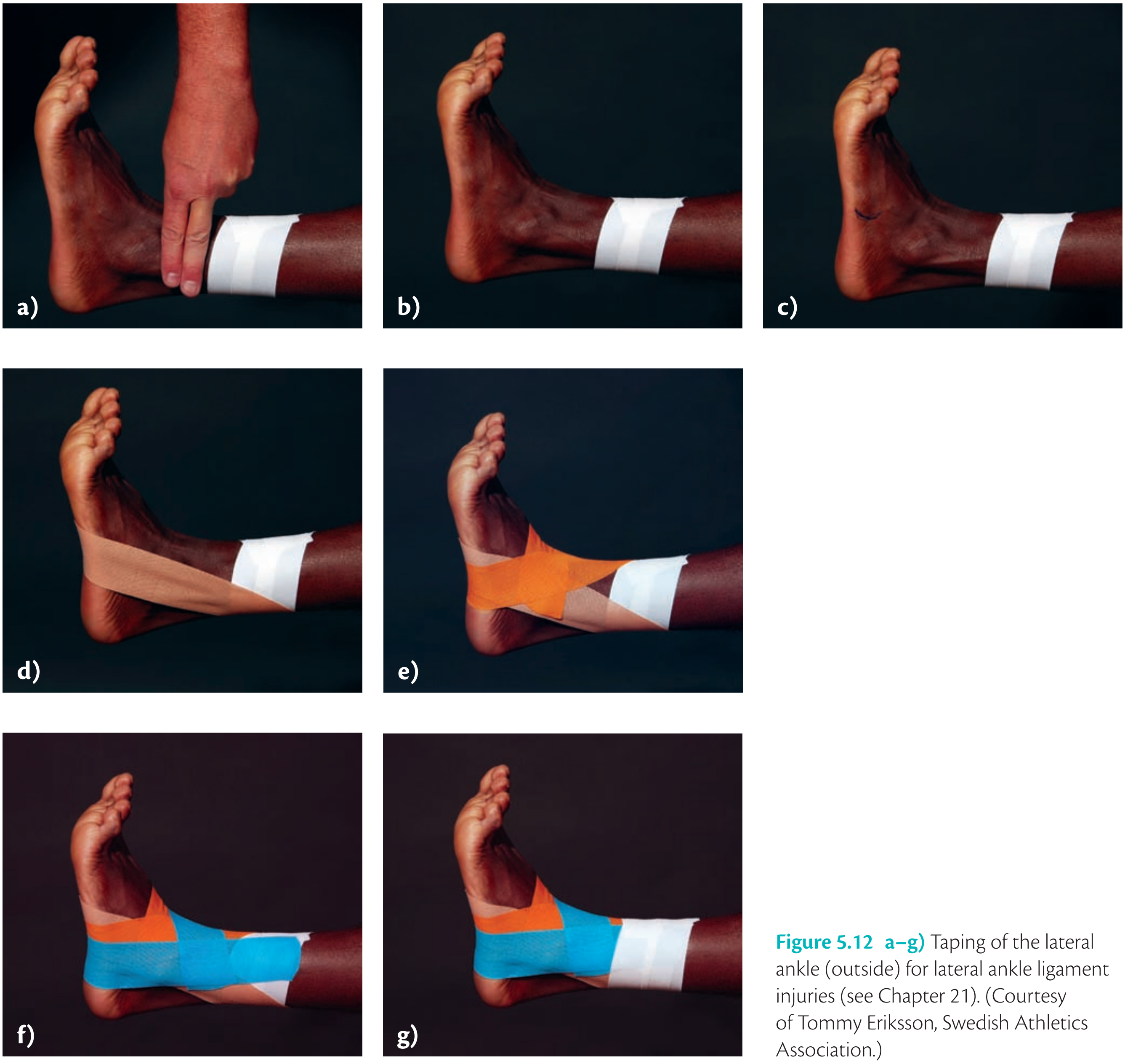


Figure 5.12 a–g) Taping of the lateral ankle (outside) for lateral ankle ligament injuries (see Chapter 21). (Courtesy of Tommy Eriksson, Swedish Athletics Association.)

E: Support 2: Start the support (orange colored tape) on the previous support on top of the lateral malleolus (there should be a small air space between the malleolus and the skin especially since it is so tense), looping around the foot medial side down in the arch over the tibialis anterior tendon straight and come up on the lateral side using the front half of the tape width on the 5th metatarsal and the other half behind. Stretch the tape diagonally upwards to the anchors on the medial of the lower leg, finishing over the posterior midline.

F: Support 3: Start the support (blue colored tape) above the lateral malleolus a little higher, about 1 cm (0.5 in.), than support 2, angling further back towards the heel. Continue the loop into the arch towards the heel and stretch the tape behind the 5th metatarsal and let the tape go straight up over the lateral malleolus to finish on the anchors.

G: Finish with another two anchors (white tape) around the lower leg as in the first step.

Tip

- When using elastic adhesive tape/kinesio tape instead of non-elastic sports tape for the support, stretch out the tapes to their maximum to make the tape similar to non-elastic sports tape.
- Steps C–E: From the start have some tension on the supporting tape pieces and as you get to the outside stretch the tape more forcefully.
- When using non-elastic sports tape stretch the tape, practice to find the right angle for application. A common error is the urge to overcorrect the position of the injured joint with the tape, which will result in a risk for excruciating, throbbing, foot pain.

Stabilization – taping of the outside of the ankle (lateral side) with an elastic bandage

Materials: Elastic adhesive bandage or kinesio tape (Fig. 5.13).

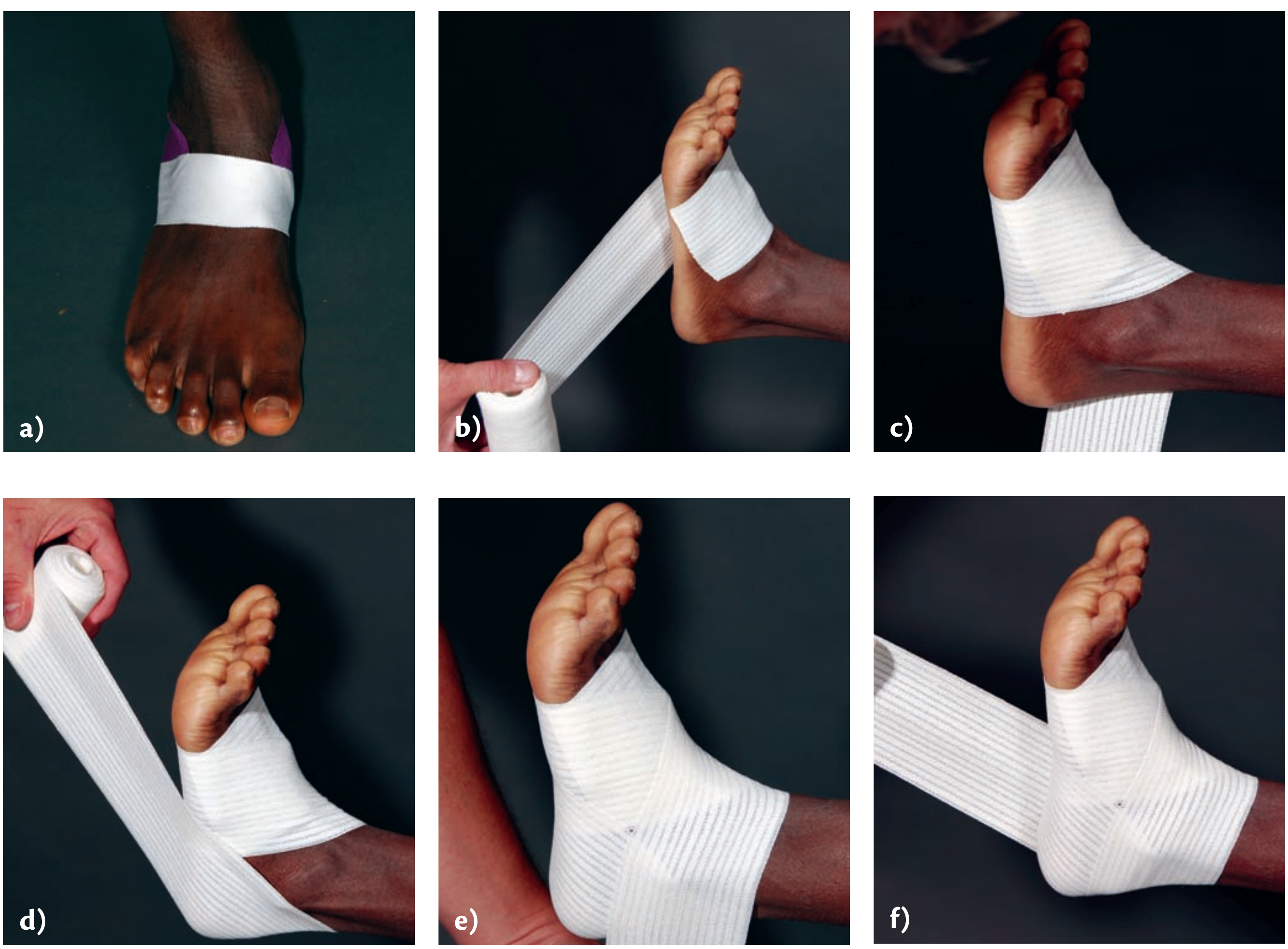


Figure 5.13 a–k) Taping of an injury to the lateral (outer) side of the ankle joint for lateral ankle ligament injuries (see Chapter 21) using elastic adhesive tape. (Courtesy of Tommy Eriksson, Swedish Athletics Association.)

Joint position: The foot should be at a 90° angle (0° anatomically) and slightly twisted outward and outside (lateral side) of forefoot upward.

Application steps:
A: Start with an anchor around the back part of the foot and just below the ankle joint (white tape).

B: Start the bandaging on the lateral upper side of the forefoot winding the tape medially towards the arch and around it, coming up on the lateral side.

C: Stretch the bandage on the outside (lateral side) of the foot, pulling it towards the medial side, continuing back around the Achilles tendon and diagonally down the outside (lateral) side of the heel bone (calcaneus).

D: The taping continues under the arch and up over the front of the ankle and the around the Achilles tendon.

E: It then goes diagonally down the inside (medial) side of the heel bone (calcaneus) towards the arch.

F: Pull the tape up on the outside (lateral side) of the foot just covering the base of the 5th metatarsal and over the front of ankle joint towards the medial mallelous.

G: Continue around the Achilles tendon a little higher than before on the lower leg.

H: Make a 'figure of 8' around the ankle pulling up on the outside of the (lateral) side of the hindfoot.

I: Finish the 'figure of '8' over the inside (medial) malleolus of the lower leg.

J: Complete the bandaging up around the lower leg.

K: The taping is complete.

Optimal ankle wrapping with elastic or adhesive elastic bandage or self-adhesive elastic bandages is to provide support primarily to the outside (lateral side) of the ankle with pressure placed around the malleoli, instead of just simple figure of 8 wrap, which does not provide enough pressure behind the malleoli.

Taping of a painful heel cushion using tape

Materials: Non-elastic sports tape or kinesio tape (Fig. 5.14).

Joint position: The foot should be at a 90° angle (0° anatomically).

Application steps:

A: The first anchor (white tape) is applied on the heel, continuing forward on both sides to just below and in front of the malleoli (make sure to keep the tape on the heel and not the Achilles tendon).

B: Pull the tape (tan colored tape) from the inside (medial side) of the upper anchor to the outside (lateral side) of the upper anchor.

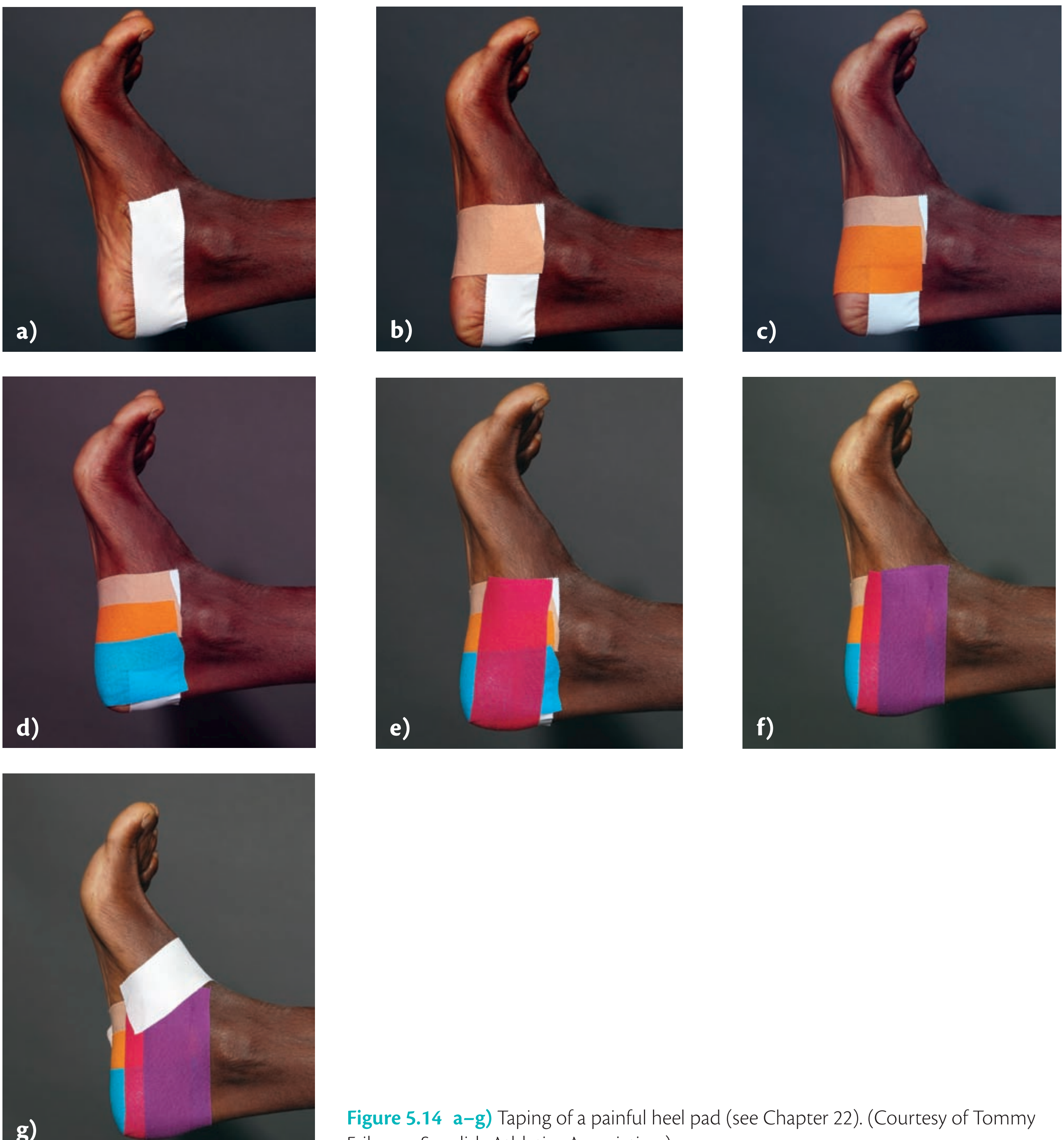


Figure 5.14 a–g) Taping of a painful heel pad (see Chapter 22). (Courtesy of Tommy Eriksson, Swedish Athletics Association.)

C: Overlap half the width of B towards the heel with a new piece (orange colored tape) as B, from the inside (medial side) of the upper anchor to the outside (lateral side) of the upper anchor.

D: Overlap half the width of C towards the heel with a new piece (blue colored tape) as C, from the inside (medial side) of the upper anchor to the outside (lateral side) of the upper anchor.

E: Add an anchor (red colored tape) on the heel pulling forward on both sides to just below and in front of the malleoli (make sure to keep the tape on the heel and not the Achilles tendon).

F: Add a another anchor (purple colored tape) a little higher than E but just below the malleoli, walk around the heel and finish ahead on the outside at an equivalent level.

G: Attach a piece of tape over the instep (white tape) that binds together 'the cup', formed by the previous steps, (be careful that it doesn't interfere with the upward bending [dorsiflexion] of the ankle).

Taping of plantar fasciitis

Materials: Non-elastic sports tape or kinesio tape (Fig. 5.15).

Joint position: The foot should be at a 90° angle (0° anatomically).

Application steps:
A: Start the support (white tape) on the inside (medial side) of the foot just behind the 1st metatarsal head, then

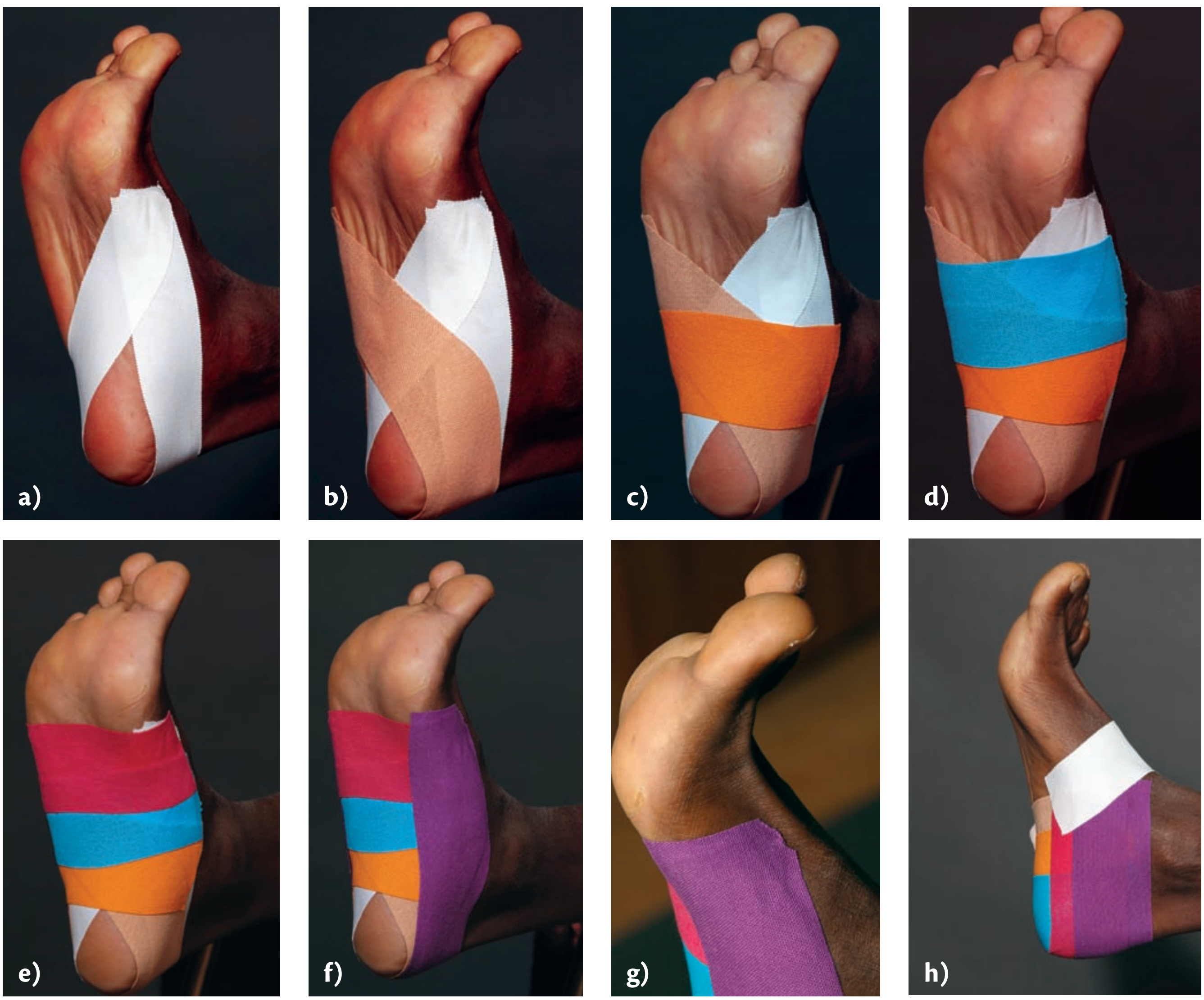


Figure 5.15 a–h) Taping of plantar fasciitis (see Chapter 22). (Courtesy of Tommy Eriksson, Swedish Athletics Association.)

draw the tape back over the heel bone (calcaneus) and around the heel. Pull up the arch by diagonally stretching the tape and attaching it where the support started on the inside of the foot.

B: Start the second support (tan colored tape) on the outside (lateral side) of the foot just behind the 5th metatarsal head, go back over the heel bone (calcaneus) and around the heel, then pull up diagonally into the arch and attaching it where the support started on the outside of the foot.

C: Start the third support (orange colored tape) on the outside (lateral side) on support B and just in front of the heel bone (calcaneus), stretch the tape up in the arch and finish on the inside (medial side) on support A.

D: The fourth support in reverse direction (blue colored tape) repeats support C, overlapping half the tape width forward into the arch, but this time starting from the inside (medial side) of the arch and attaching on the outside (lateral side).

E: The fifth support (red colored tape) again overlaps half the width of support D further on towards the toes. Start on the outside and pull across the arch of the foot and finish on the inside.

F: Anchor the supports (purple colored tape) starting at the base of the 1st metatarsal on the inside (medial side) of the foot, go around the heel and along the outside (lateral side) of the foot ending just behind the 5th metatarsal head.

G: Shows the start position for the anchor (purple colored tape).

H: Secure the taping with two half anchors (white tape) on the front side (dorsal side) of the foot, ending just behind the metatarsal heads, and make sure they don't irritate the tendons underneath.

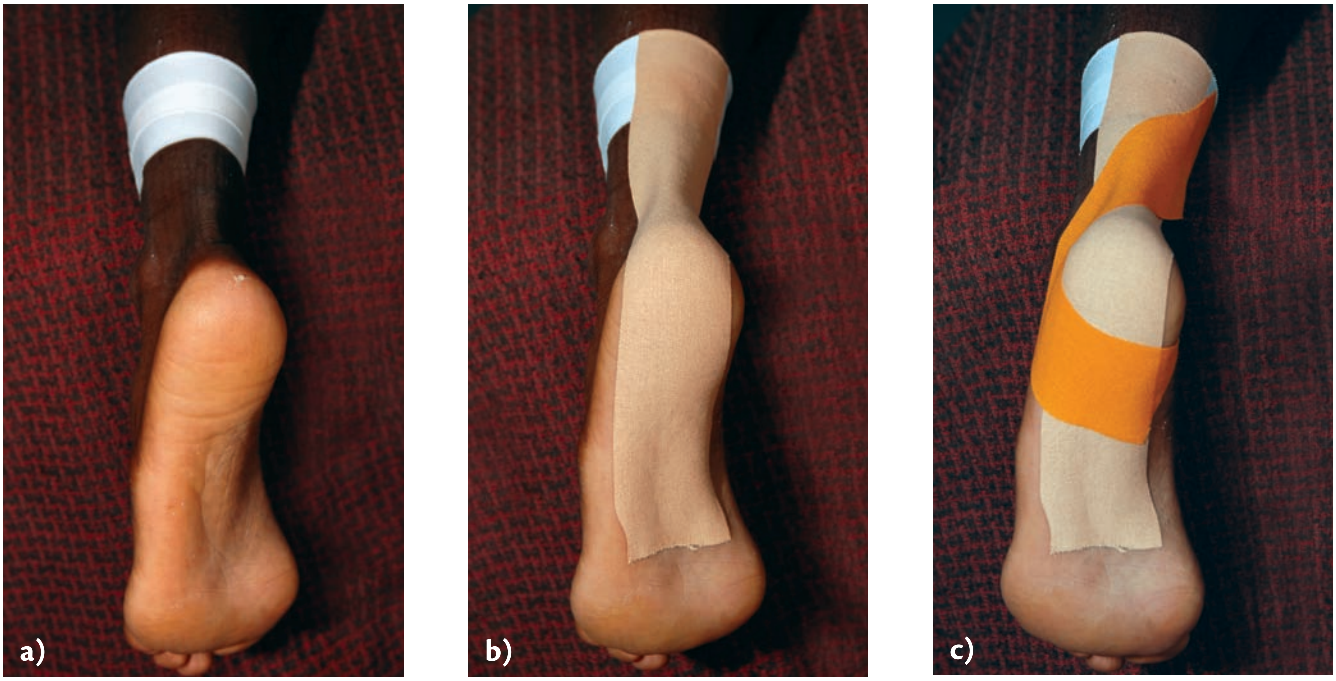
Taping of an Achilles tendon injury

Materials: Non-elastic sports tape or kinesio tape (Fig. 5.16).

Joint position: The foot should be at a 90° angle (0° anatomically).

Application steps:
A: Start with the first anchor (white tape) 2 fingers above the top of the malleoli, around the lower leg, angling the ends upward in front to get a good anatomical fit. In order to get an even wider anchor, an additional anchor at half-width above the previous tape can be applied.

B: Draw a straight piece of tape (tan colored tape) from the anchor on the upper part of the Achilles tendon and to the bottom of the arch to the forefoot at the base of the toe joints.



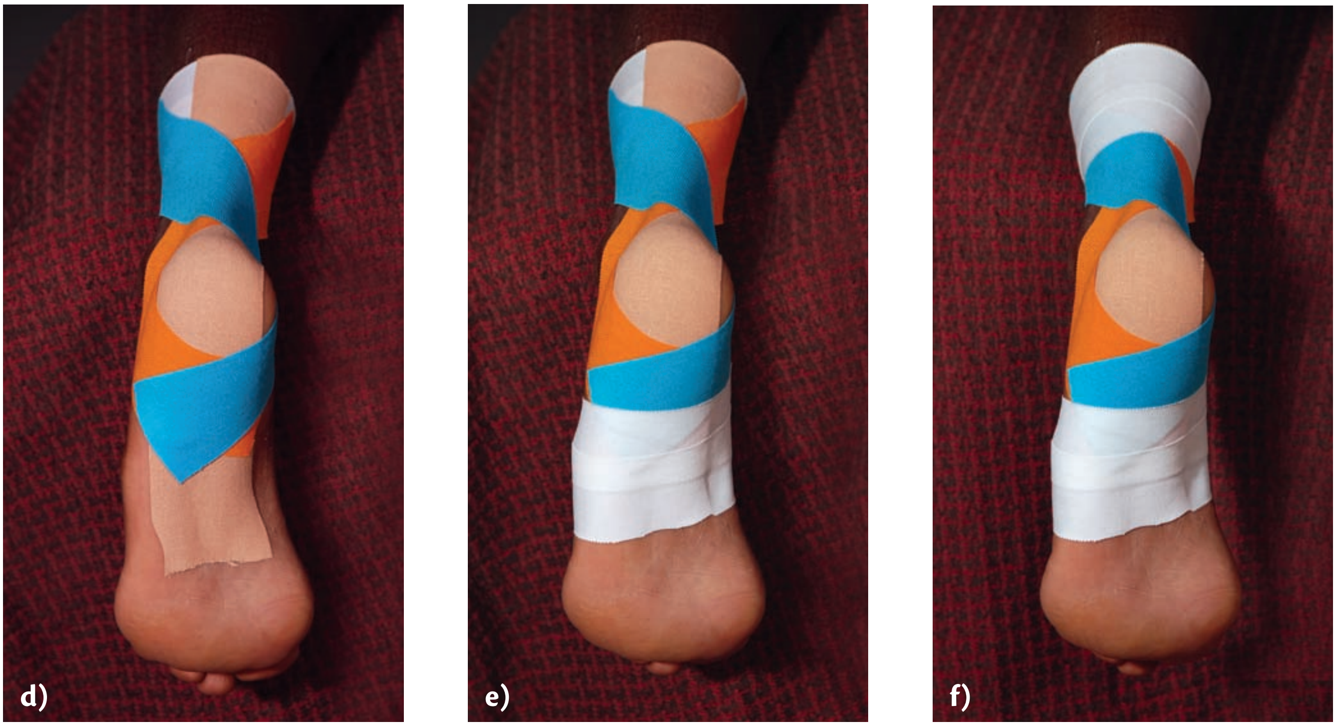


Figure 5.16 a–f) Taping of an Achilles tendon. This taping technique is intended to support and reduce stress on the Achilles tendon, calf and anterior aspect (front) of the ankle joint during activity. It can be used both as a part of the treatment and prevention of Achilles tendon and calf injuries and some ankle injuries (such as anterior ankle impingement). (Courtesy of Tommy Eriksson, Swedish Athletics Association.)

C: Starting with the next piece (orange colored tape) under the heel on the inside (medial side) then angling to the outside of the heel bone (calcaneus), go around the heel bone on the outside and diagonally across the Achilles tendon up to the lower leg anchor on the inside (medial side).

D: The next tape piece (blue colored tape) does the opposite of C under the heel on the outside (lateral side), then angling to the outside of the heel bone (calcaneus) go around the heel bone on the inside and diagonally across the Achilles tendon up to the lower leg anchor on the outside (lateral side).

E: Apply one or two circular anchors (white tape) around the midfoot.

F: Apply one or two anchors around the lower leg as described in step A.

Taping of an injury to the Achilles tendon using elastic adhesive bandage

Materials: Elastic adhesive bandage (Fig. 5.17).

Joint position: The athlete is in the prone position with the foot at a 90° angle (0° anatomically).

Application steps:
A. Stretch the elastic adhesive tape to its maximum from the base of the toes on the sole of the foot, centering the tape up over the heel bone (calcaneus) and up to the top of the Achilles tendon on the lower leg.

Anchor the support by starting 2 fingers above the top of the malleoli, around the lower leg, leaving 2.5 cm (1 in.) of the support above the anchor.

Check the amount of motion allowed; if it is necessary to decrease the dorsiflexion of the ankle even more, extend the ankle and stretch the support that goes over the Achilles tendon. Remember that the skin over the tendon may be affected, so it is important to stretch the skin with tape from top to bottom.

B: Fold down the upper support over the anchor.

C: Add an anchor to overlap the first one, half the width upward, so that adhesive side of the downturned support goes against the adhesive side of the second anchor to lock in the tension of the support.

D. Anchor the support on the forefoot again leaving 2.5 cm (1 in.) of the support below the anchor.

E. Fold back the support over the anchor.

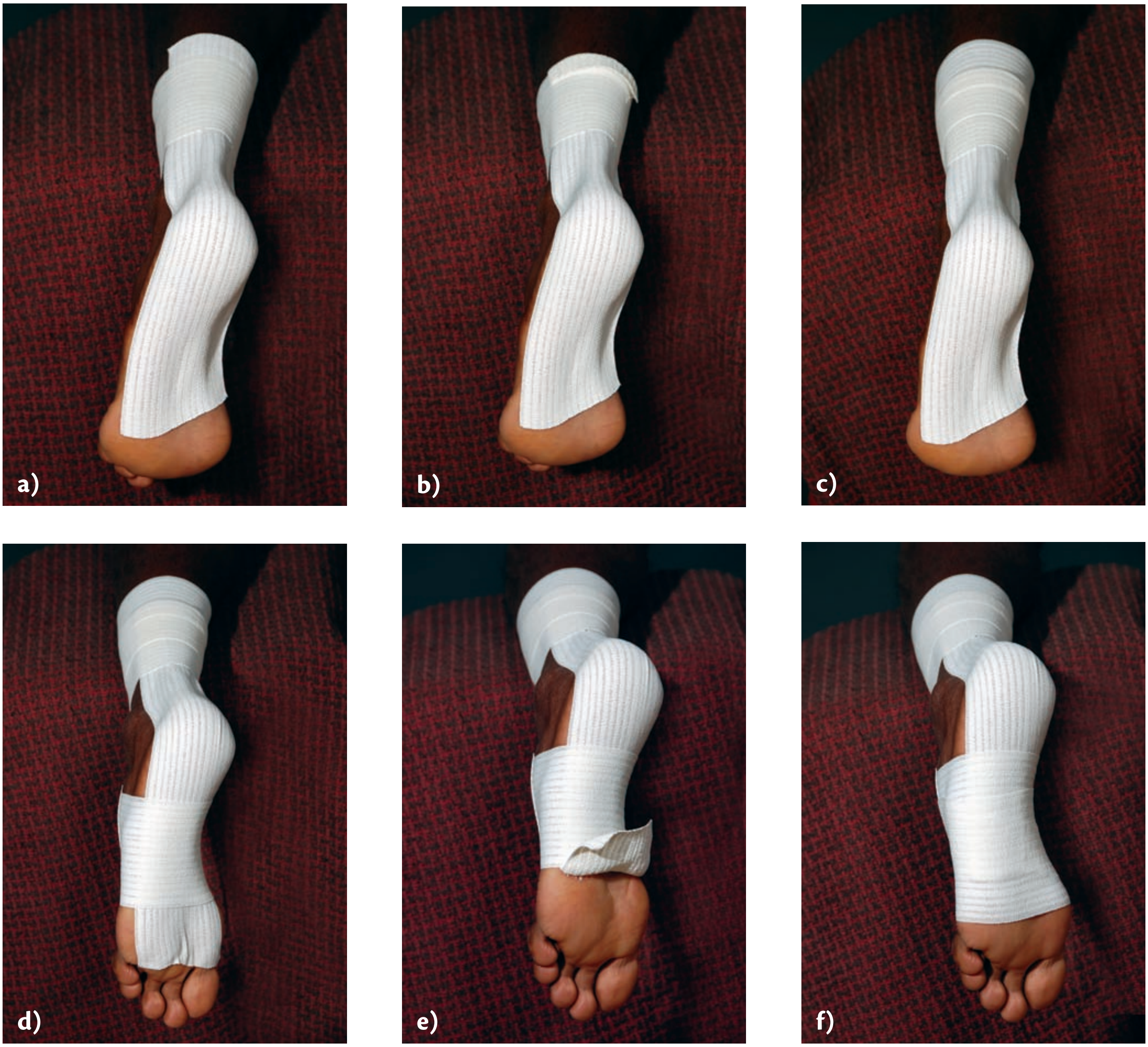


Figure 5.17 a–f) Taping method using elastic adhesive tape to treat an injury in the Achilles tendon (see Chapter 20). This taping technique is intended to support and reduce stress on the Achilles tendon, calf and anterior aspect (front) of the ankle joint during activity. It can be used both as a part of the treatment and prevention of Achilles tendon and calf injuries and some ankle injuries (such as anterior ankle impingement). (Courtesy of Tommy Eriksson, Swedish Athletics Association.)

F. Add another anchor that will cover the support. This anchor should not impede the movement of the toes, thus should be just behind the base of the toe joints.

Taping of an injury to the gastrocnemius muscle in the back of the lower leg, so called 'Tennis leg'

Materials: Elastic adhesive tape, kinesio tape, or non-elastic sports tape (Fig. 5.18).

Joint position: Standing with the ankle at 20–0° dorsiflexion depending on how hard the tape material is stretched, try first with the foot at a 70° angle (20° dorsiflexion) stretching the tape as hard as possible or at 90° (0° anatomically) and a near maximum stretch of the tape.

Application steps:
A: Start the first support (tan colored tape) under the heel, pull the tape up the back of the lower leg straight over the Achilles tendon and calf muscle (gastrocnemius) finishing at the knee.

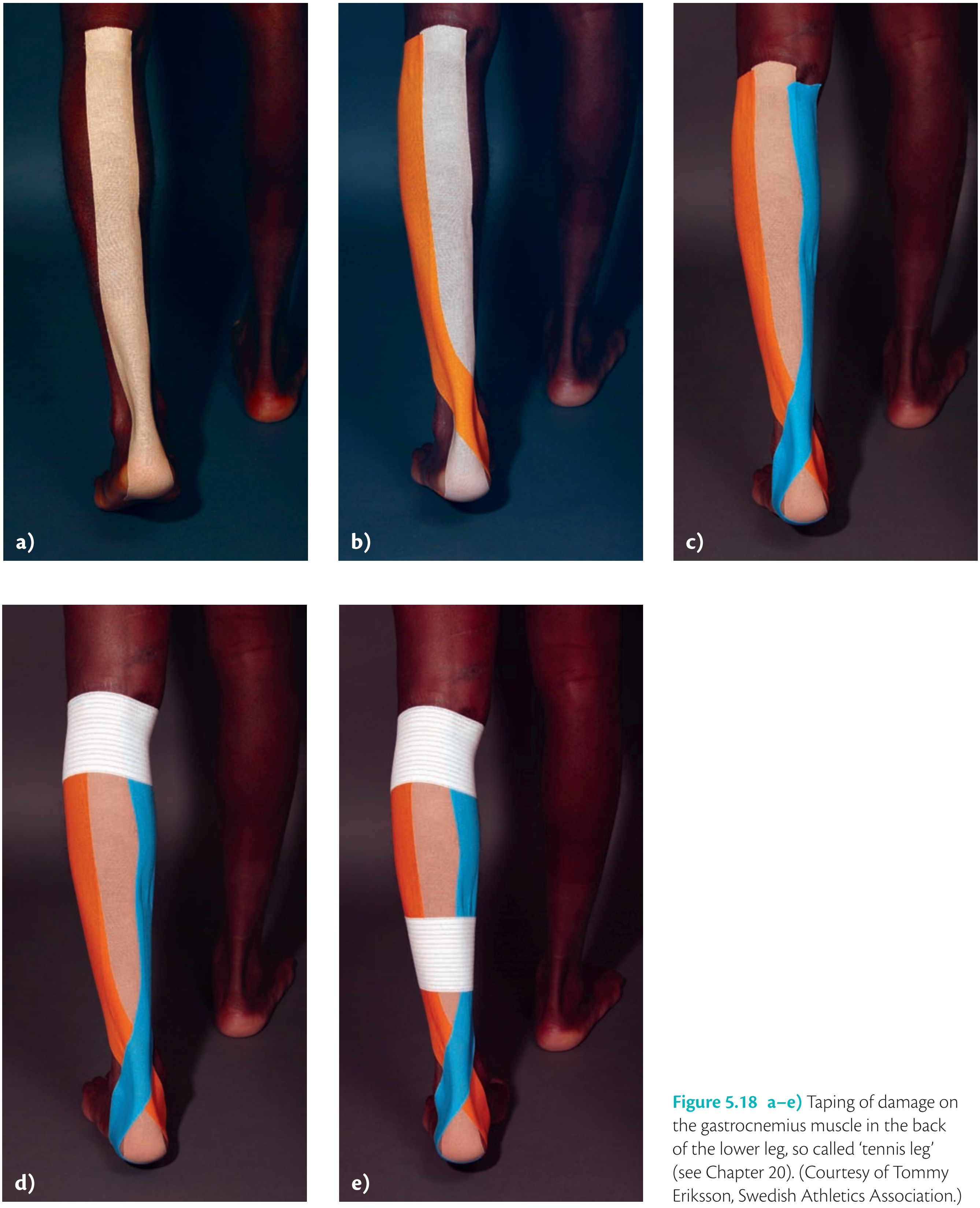


Figure 5.18 a–e) Taping of damage on the gastrocnemius muscle in the back of the lower leg, so called 'tennis leg' (see Chapter 20). (Courtesy of Tommy Eriksson, Swedish Athletics Association.)

B: The second support (orange colored tape) starts under the heel traveling upward on the inside (medial side) of the heel, stretching upward with the tape toward the outside (lateral side) of the lower leg, crossing over the Achilles tendon and continuing on the outside of the calf muscle (gastrocnemius) up to the knee.

C: The third support (blue colored tape) starts under the heel traveling upward on the outside (lateral side) of the heel, stretching upward with the tape toward the inside (medial side) of the lower leg, crossing over the Achilles tendon and continuing on the inside of the calf muscle (gastrocnemius) up to the knee.

D: Apply a circular anchor (white tape) around the lower leg just below the knee.

E: Apply another circular anchor (white tape) around the lower leg, the center point of the anchor should be at the muscle–tendon junction of the calf muscle (gastrocnemius).

Taping to stabilize the inside (medial side) of the knee joint

Materials: Elastic adhesive tape or kinesio tape (Fig. 5.19).

Joint position: Standing with the knee bent approximately 20° of flexion, relaxed with elevation under the heel.

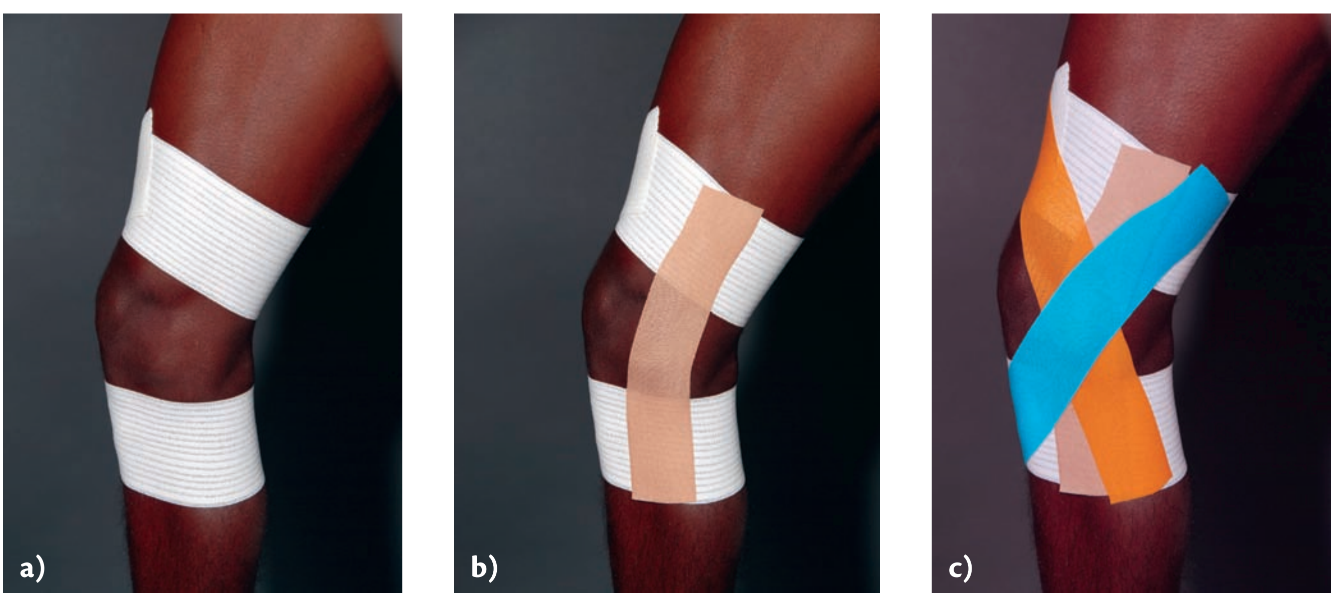
Application steps:
A: Apply an anchor (white tape) high up around the lower leg, 2 fingers width below the kneecap tip (apex of patella). Attach a second anchor (white tape) around the thigh 4 fingers above the kneecap's (patella) upper edge.

B: Stretch the first support (tan colored tape) maximum between anchors, covering the MCL.

C: The second and third support produces a cross over the MCL. Start the first part of the cross (orange colored tape) from the lower leg anchor, slightly behind the first support stretching the tape crossing over the MCL and continuing above the kneecap towards the outside (lateral side) of the leg on the upper anchor. Complete the cross (blue colored tape) from the lower leg anchor, starting on the outside (lateral side) of the lower leg anchor crossing over the kneecap (patella) tendon and continuing upwards crossing the MCL and ending on the inside (medial side) of the leg on the upper back part of the anchor.

D: To create added support to the patella and thus provide a collateral stability effect on the knee joint a piece of elastic adhesive tape (red colored tape) is applied as shown. Start with splitting one end and applying half the tape above and below the kneecap (patella) from the outside (lateral side) of the patella inward (Note: the end of the split should be on the inside [medial] edge of the patella).

E: Continue around the back of the knee and finish by splitting the other end and applying above and below the kneecap (patella).



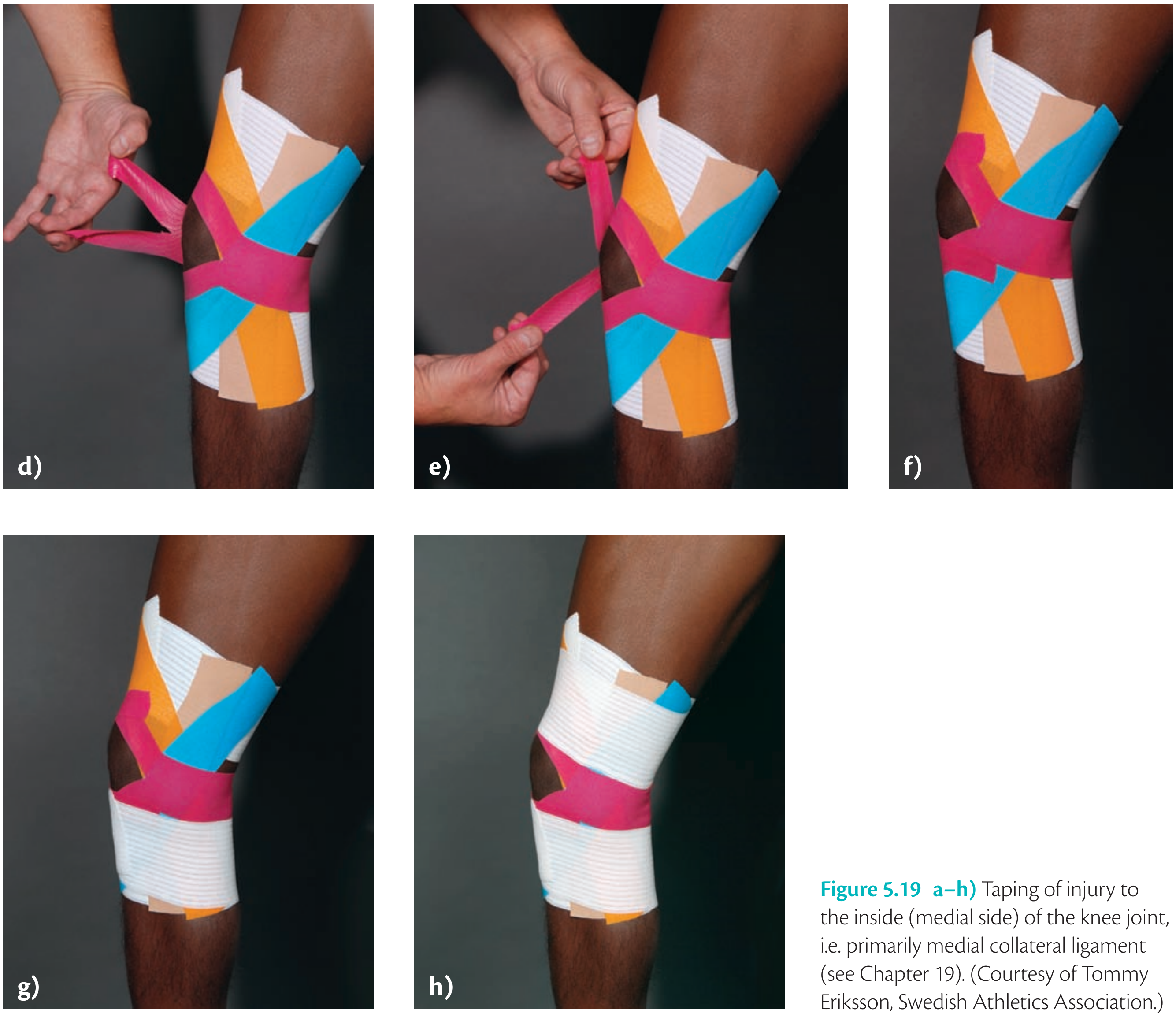


Figure 5.19 a–h) Taping of injury to the inside (medial side) of the knee joint, i.e. primarily medial collateral ligament (see Chapter 19). (Courtesy of Tommy Eriksson, Swedish Athletics Association.)

F: Finish the support (red colored tape) so that no gaps occur.

G: Anchor (white tie) with one or two turns around the lower leg covering the supports.

H: Apply one or two anchors (white tie) on the covering the supports.

Tip

If desired the same pattern of supports (straight and a cross, see steps C–E) can be applied on the outside (lateral side), before step F to give stability to the entire knee joint.

Taping for stabilizing and unloading of the patellar tendon

Materials: Kinesio tape and non-elastic sports tape (Fig. 5.20).

Joint position: Standing with the knee slightly bent.

Application steps:
A: Start the first tape piece, the width of the patella tendon (white tape) just below the apex of the patella. Stretch the tape maximum in both directions so that the tendon is 'pressed' inwards. End the tape on both sides on the level of the respective medial and lateral collateral ligaments.

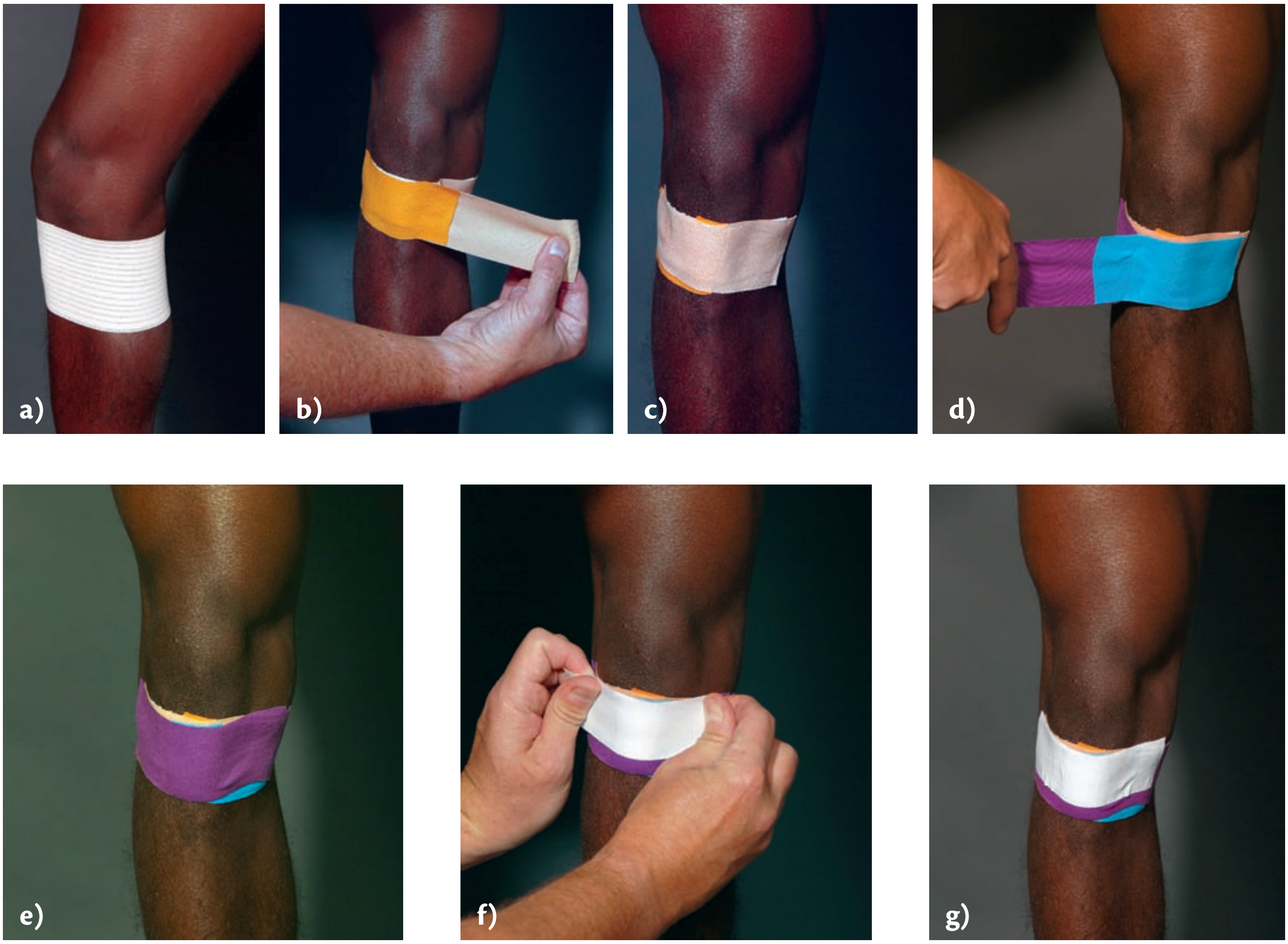


Figure 5.20 a–g) Taping for stabilizing and unloading of the patellar tendon (see Chapter 19). (Courtesy of Tommy Eriksson, Swedish Athletics Association.)

B: Attach a tape piece (tan colored tape) on the inside of the knee. Then draw another tape piece (orange colored tape) from the outside that goes over the patella tendon and attaches to the tan colored tape, adhesive to adhesive, from the inside (medial side).

C: Pull the tan colored tape to the outside (lateral side) of the knee. Doing this the 'patellar tendon' is then pulled outwards and can affect the movement of the patella somewhat, and eventually imbalances can be alleviated.

D: The opposite of Step B is done by attaching a tape piece (purple colored tape) on the outside of the knee. Then draw another tape piece (blue colored tape) from the inside that goes over the patella tendon and attaches to the purple colored tape, adhesive to adhesive, from the outside (lateral side).

E: Tighten the purple colored tape to the inside – this allows it to counteract the earlier direction of pull of the patellar tendon, thus giving a press inwards to the patellar tendon.

F: Apply now a tape piece, the width of the patella tendon (white tape) just below the apex of the patella. Stretch the tape maximum in both directions so that the tendon is 'pressed' inwards. End the tape on both sides on the level of the respective medial and lateral collateral ligaments.

G: The finished taping.

Taping to stabilize the knee

Materials: Kinesio tape or elastic adhesive tape (Fig. 5.21).

Joint position: Hold the knee flexed to 90–100°.

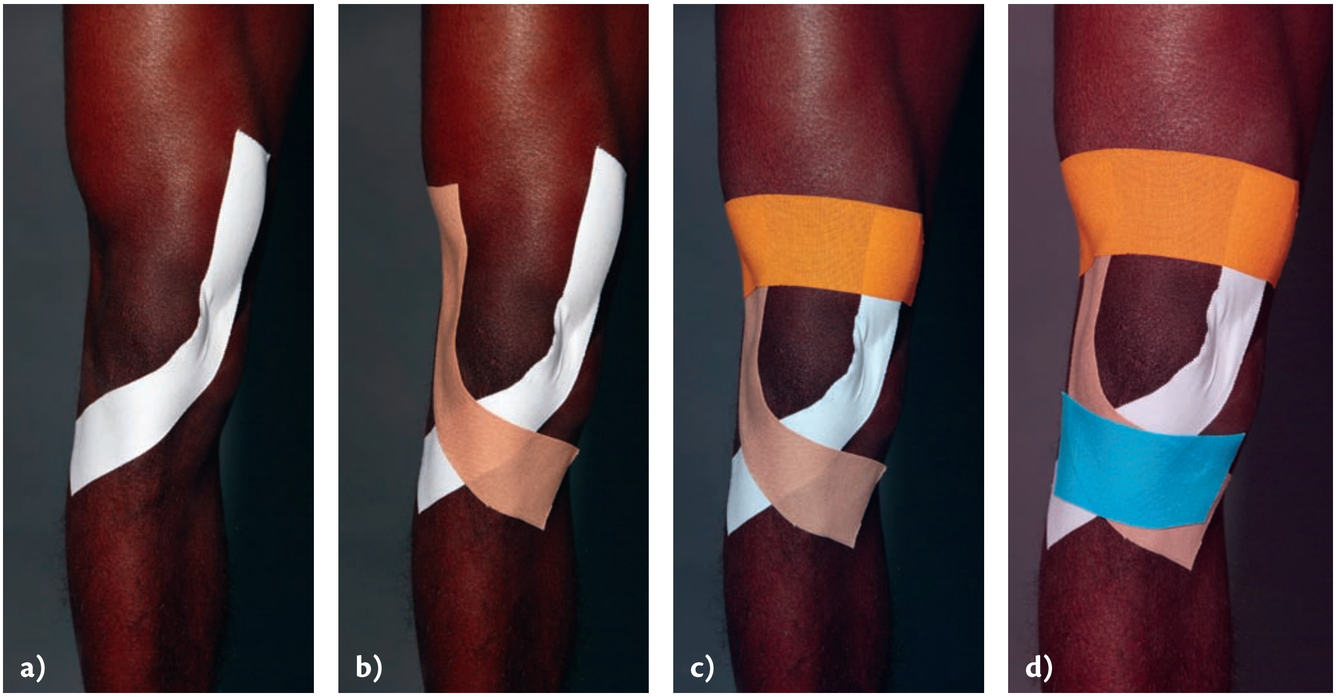


Figure 5.21 a–d) Taping to stabilize the knee joint (see Chapter 20). (Courtesy of Tommy Eriksson, Swedish Athletics Association.)

Application steps:
A: When applying the tape is not stretched at either end but is stretched to 70% in the middle. Start with the first support (white tape) from the outside (lateral side) of the lower leg, going diagonally up toward the inside (medial side), across the patellar tendon and up the inside of the femur over the vastus medialis muscle of the quadriceps.

Add a stirrup (white tape) starting on bony prominence on the femur inner bottom (medial femoral condyle). Let the tape go down over the front of the knee below the kneecap and attach to the outer upper part of the lower leg.

B: Apply a second support (tan colored tape) opposite to the first, from the inside (medial side) of the lower leg, going diagonally up toward the outside (lateral side), across the patellar tendon and up the outside of the femur over the vastus lateralis muscle of the quadriceps.

C: Stretch a tape piece (orange colored tape) from mid thigh 2 fingers above the kneecap's (patella) upper edge and to the sides. The tape should be stretched to either side to 70% leaving the attachments about 2 fingers width with no tension.

D: Apply the last piece (blue colored tape) just below the kneecap tip (apex of patella) and across the patella tendon, stretching as described above (step C).

Stabilization of the thumb´s basal joint for a skiing injury known as 'Stener's lesion' with taping

Materials: Non-elastic sports tape or kinesio tape (Fig. 5.22).

Joint position: Outstretched finger, thumb close to the index finger.

Application steps:
A: Place an anchor (white tape) on the outside of the base of the thumb. Start in the middle of the hand, cross over the saddle joint with tape and finish on the back of the hand.

B: Add a second anchor (tan colored tape) overlapping halfway behind the first anchor, further back over the base of the thumb.

C: Fixate the earlier pieces of tape with a piece (orange colored tape) from the center of the palm of the hand between the thumb and index finger to the middle of the back of the hand.

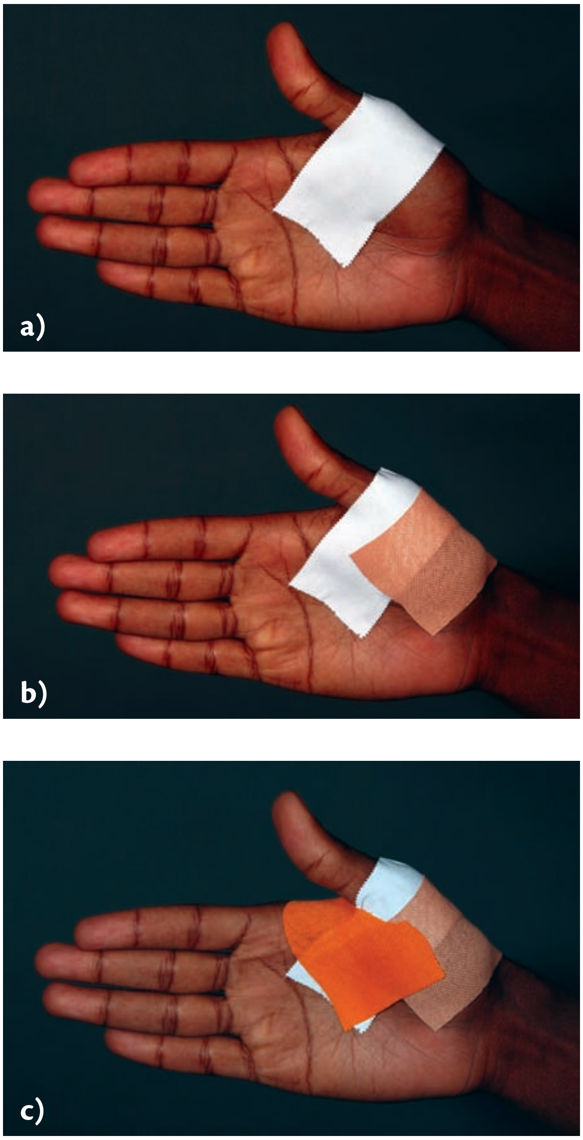


Figure 5.22 a–c) Taping of the base of the thumb for a skiing injury, a 'Stener's lesion'(see Chapter 13). (Courtesy of Tommy Eriksson, Swedish Athletics Association.)

General risks with taping

- In certain situations, e.g. in acute injuries, taping may restrict circulation.
- The long-term effect of taping is limited. It can never provide a permanent solution, and there are few justifications for using it continuously for as long as a week.
- Skin irritations may occur if tape is in contact with the skin for a long period. Tapes can sometimes lie on the skin for up to a week without seeing any skin irritation in the area, depending on the material and adhesive. As a rule tape should not be used directly on the skin for more than a few hours at a time. If it is necessary to exceed this limit, a protective material should be worn under the tape.
- Tape may cause irritation by mechanical or chemical means or because of allergy, and the effects may be exaggerated by sweating, itching and bacterial infection. In order to reduce the risk of skin irritation some tapes are backed with zinc oxide.

Practical advice

Knowledge of taping is achieved by first being taught and then through personal experience. Only through training and re-training, can you learn to tape quickly and safely. The technique shown in the Figs 5.12–5.22, with the following tips are important:

- The hair in the area to be taped should be shaved. If the skin is injured or infected one should wait until it has healed prior to applying tape.
- The skin of the area to be taped must be cleaned. If it is oily or sweaty the tape will not attach as well. Adhesive spray can be used to enhance the adhesion of the tape.
- Protective material of thin foam (prewrap) or low sensitivity adhesive tape can be added under the tape next to the skin. It should be used if the tape is planned to be *in situ* for a long time or if the skin is sensitive.
- An adhesive bandage should never be put on around a swollen joint, as circulatory problems may arise.
- In principle, taping should start below – distal to – the injured part, bridge over this and attach the tape above – proximal.
- Tape usually attaches better to tape than on the skin. Therefore, it is recommended to begin with an 'anchor' of tape on either side of the injured joint. The injured ligament should be unloaded and 'relaxed'. If, for example, the ligament on the outside of the foot is injured, the outside of the foot should be tilted up and the tape stretched on the lateral – outer – side of the ankle.
- Folds and wrinkles in the tape must be smoothed out, because of the risk for chafing and skin irritation that can otherwise be caused by the tape. The tape's effect will also be reduced if the tape looks like it has 'accordion folds'.
- The tape should be removed with caution. One should rather try to 'push' the skin down from the tape than to tear or pull the tape off. Tape edges are often difficult to dislodge, but can sometimes be withdrawn by placing tension on the skin and then drawn from the tape. Tape can also be removed with tape cutter or tape scissors and there are adhesive solvents available.

- The taped athlete should be asked about how the tape feels. If chafing or discomfort is present it should be adjusted.

Tip

Remember:
Taping after an ankle injury should be made individually, i.e. the athlete's individual anatomical and physiological requirements should form the basis for the taping.
The goal should be to consider both the biomechanical and the proprioceptive effects of tape.

The future of taping and development

Among the most interesting innovations that are being re-discovered/developed are anti-pronation taping and kinesio taping.

Anti-pronation taping

Professional athletes in sprint running, hurdling and jumping increasingly have problems from the foot's and ankle joint's medial sides. These are often characterized by overuse symptoms of the recurrent kind, with pain during activity. These problems can now be treated with anti-pronation taping. This taping is done individually for the athlete and protective material under the tape is not needed because of the new type of adhesive tape that is available. The elite athlete's experience (albeit purely subjectively) is that this type of treatment usually has a good effect. Positive clinical experience is a good start, but biomechanical and neurophysiological scientific studies are needed in the long term.

Anti-pronation taping has been used widely since its introduction in 1939 by Dye. The physiological background to anti-pronation taping according to the literature is that it has shown biomechanical effects because it evidently:

- Increases the height of the navicular and the height of the medial (inner) longitudinal foot arch.
- Reduces the internal rotation of the lower leg (tibia) and position of the heel bone (calcaneus) in stance position.
- Provides shorter contact time of the foot under load.

The research also provides some evidence that anti-pronation taping also has a neurophysiological effect because it has been shown that:

- The tape reduces the activity of several of the leg muscles during dynamic activities, e.g. walking, jumping, cutting exercises and jumping from a height.
- There is a small study that suggests that the reduction is in the order of 45% for the posterior tibial muscle.

What is also well known is that:

- Even this type of taping can lose its biomechanical effect after 10 minutes of activity, but the supportive effect experienced persists much longer.
- Protective material under the tape weakens the biomechanical effects further.
- Braces and orthotics have often replaced taping, but the fact is:
  - ✓ in sports such as sprint and hurdles the arches are not loaded.
  - ✓ this support, however, can be valuable during training, but not during competition at the elite level.
  - ✓ many of today's elite athletes feel that the previously used taping technique is clumsy, especially during competition.

Current developments

Taping material has been further improved. The modern tape has new types of adhesives that can be used for taping in different ways, which can have positive effects during competition. A tape should support the modern kinetic chain in situations such as running in a curve, high jump, etc.

The new so-called 'Tommy' taping technique can help many athletes with these problems (Fig. 5.23).

Tommy's anti-pronation taping

Materials: Non-elastic sports tape, kinesio tape, elastic adhesive tape.

Joint position: The foot should be at a 90° angle (0° anatomically).

Application steps:
A: For consideration before starting:

When using elastic adhesive tape/kinesio tape during application, besides having the foot in 90° angle (0° anatomically) it should be turned inward and twisted upward.

Steps D–F: Pull out the maximum elasticity to mimic the non-elastic sports tape.

Using non-elastic tape, tauten the tape, find the angle and apply. A common error is the desire to pull up the joint with the tape, which easily causes a painful constriction.

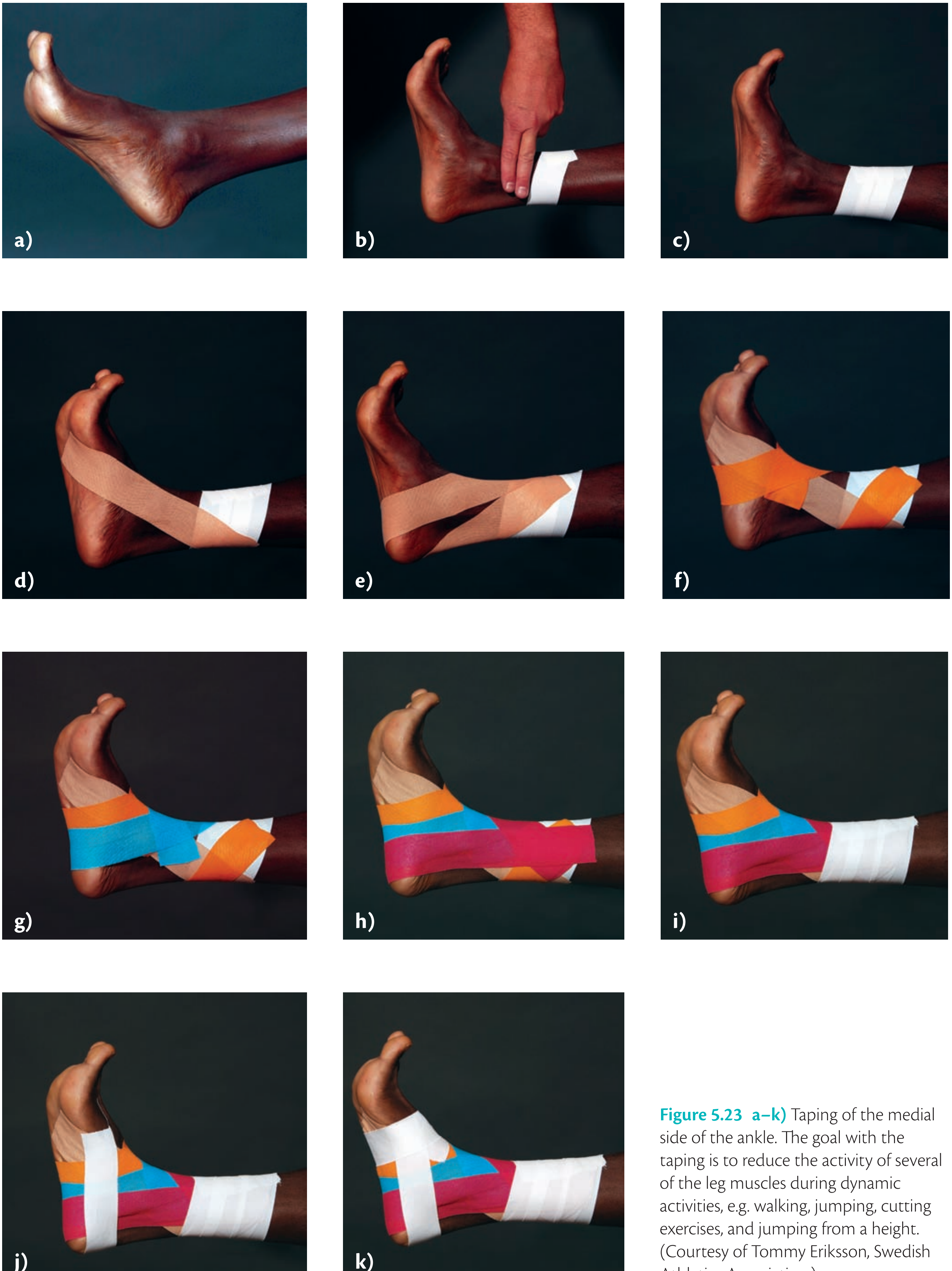


Figure 5.23 a–k) Taping of the medial side of the ankle. The goal with the taping is to reduce the activity of several of the leg muscles during dynamic activities, e.g. walking, jumping, cutting exercises, and jumping from a height. (Courtesy of Tommy Eriksson, Swedish Athletics Association.)

B: Start with 1 or 2 anchors (white tape); the first anchor starts 2 fingers above the top of the malleoli, around the lower leg, angling the ends upward in front to get a good anatomical fit.

C: Apply a second anchor above this overlapping 50% upward to achieve an even wider base if a 4 cm (1.5 in.) width tape is used.

D: Stretch one or more straight pieces of tape (tan colored tape) from the sole of the foot into the arch over the inside (medial) malleolus towards the Achilles tendon to the anchor.

E: If the athlete has a significant pronation, provide additional support to 'tilt in' the heel.

Start a piece of tan colored tape from the inside (medial side) of the anchor, lay over the Achilles tendon around the heel bone (calcaneus) on the outside (lateral side) and come up through the arch and stretch the tape to lift the back part of the arch and finish on the lower leg anchor on the outside (lateral side).

F: The next support (orange colored tape) starts at the forward part of inside ankle bone (medial malleolus) and is directed over the foot and down into the arch from the outside (lateral) of the foot to be pulled up in the middle of the arch, and finishes on the lower leg anchor on the outside (lateral side).

G: Following the same direction as the last support F, apply a new support (blue colored tape). Start a little higher up about 1 cm (0.5 in.) and overlap as described making it go further back on the heel before stretching.

H: Continue with one or two more supports (red colored tape) constantly moving the start position of the tape higher 1 cm (0.5 in.) and further back on the heel until the piece is stretched naturally over the inside ankle bone (medial malleolus).

I: Complete with an anchor or two (white tape) around the lower leg as in Step B, covering the ends of the supports on the lower leg.

J: In the case of a significant pronation, add a stirrup (white tape) from the inside to the outside around the heel, starting from the front of the arch to right behind the base of the 5th metatarsal.

K: A couple of 'figure of 8s' can be used. Make sure they start from the inside to the outside in order to support the arch.

Kinesio taping (kinesiology taping)

This form of tape methodology has become very popular in recent years and was developed by the Japanese chiropractor Dr. Kenzo Kase in collaboration with the Japanese company Nitto Denko in the 1970s. His aim was to strengthen the body's own healing processes. The tape is flexible and as thin as the skin, and tries to mimic the skin's characteristics, thus can transmit 'sensory information' to the body. This taping also enables full mobility of the joint. The injured person can shower and swim without having to change the tape.

Shoulder kinesio taping

Application steps: see Fig. 5.24.
Materials: Kinesio tape, elastic adhesive bandage, non-elastic sports tape (Figs 5.24, 5.25).

Joint position: The starting position of the athlete is important. The athlete is standing with the arm in 70° backward and outward rotation.

Application steps:
A: Apply the tape without tension (4 finger widths) below the biceps groove at the front of the shoulder.

B: Then stretch the tape about 50–70% (depending on how much correction is desired) back over the same line where the trapezius muscle attaches over the lower tip (inferior angle) of the shoulder blade (scapula).

C: Continue with the stretch about 2–4 finger widths below the shoulder blade tip, as is customary for kinesio taping. Finish with approximately 2 finger widths of tape without tension.

Joint position: Start position is sitting or standing with the arm relaxed next to the body.

Alternative kinesotape of the shoulder (see Fig. 5.25)

Application steps:
A: 'Fascia' taping technique. To decide in which direction to start the taping, lay a hand over the middle portion of the deltoideus and push the skin slightly upward so that the athlete can more easily raise their arm (abduction movement) as the tape is pulled in that direction. If the opposite applies the tape is drawn in the opposite direction. Always start the first 4 cm (1.5 in.) completely unstretched.

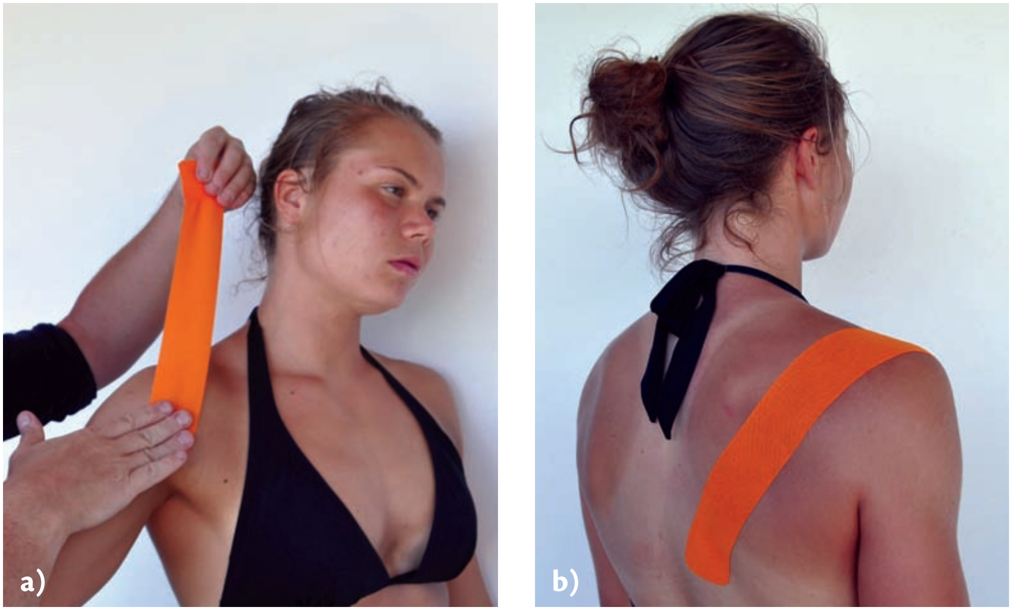


Figure 5.24 a, b) Kinesio taping of a shoulder. (Courtesy of Tommy Eriksson, Swedish Athletics Association.)

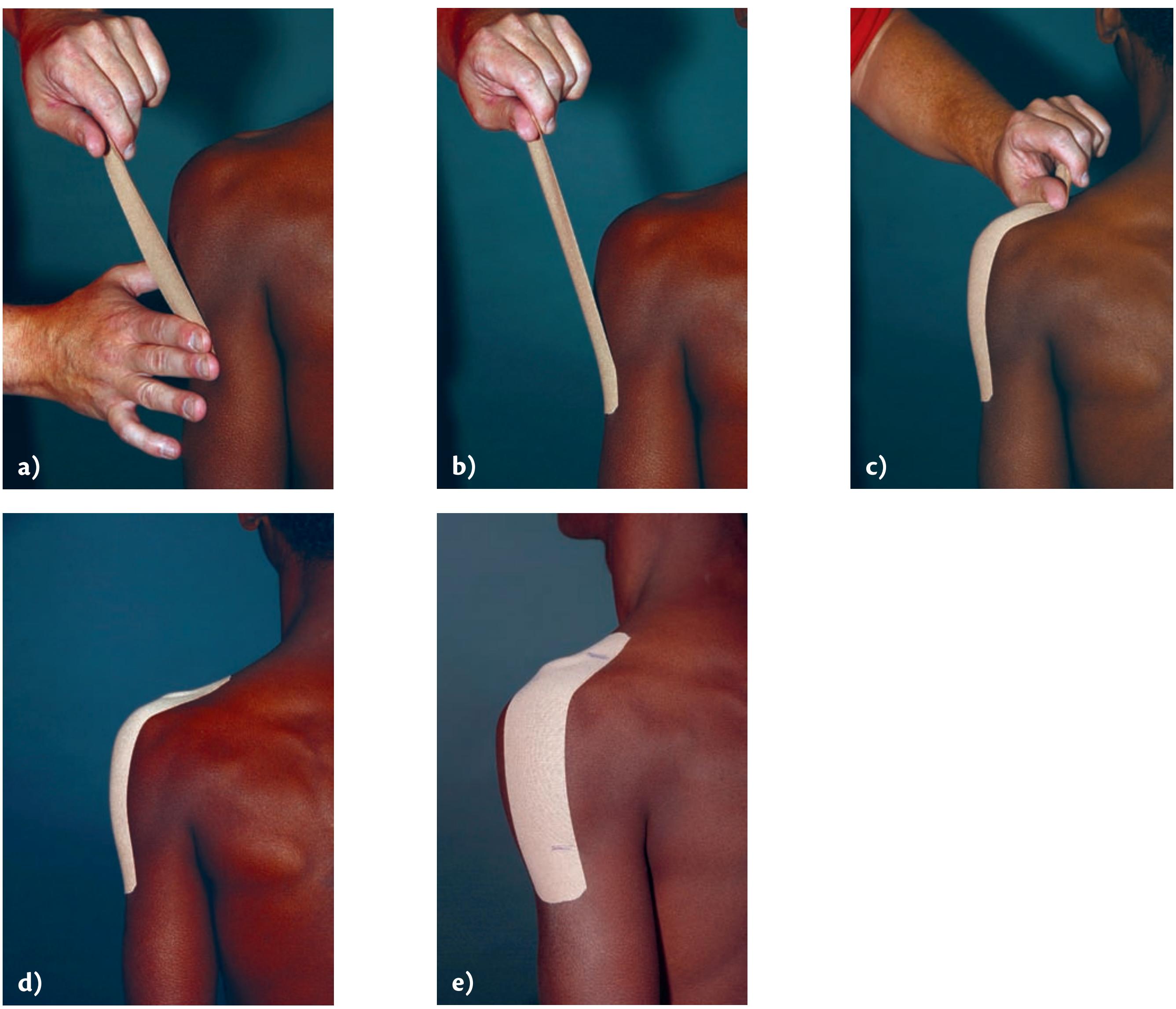


Figure 5.25 a–e) Alternative kinesio taping of the shoulder. (Courtesy of Tommy Eriksson, Swedish Athletics Association.)

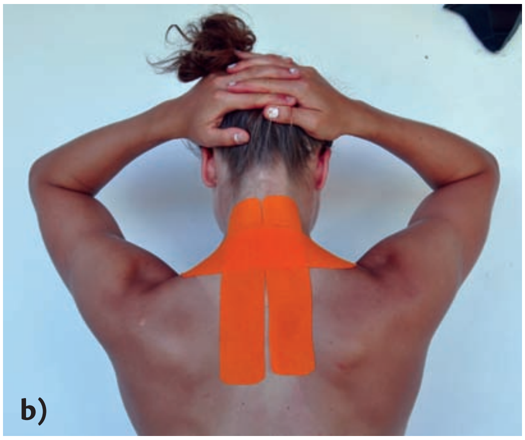


Figure 5.26 a, b) Kinesio taping of the neck. (Courtesy of Tommy Eriksson, Swedish Athletics Association.)

B: Stretch the tape 50–70% of its maximum elasticity.

C: Pull the tape over the middle deltoideus muscle along the midline of the shoulder. End at the acromioclavicular joint and let the last 4 inches of the tape be completely unstretched as at the beginning.

D: Rub the pad securely to make the adhesive stick properly to the skin.

E: Use the tape unstretched for 2 fingers wide at the start and end.

Kinesio taping of a neck

Joint position: Start position is with the neck bent forward.

Application steps (Fig. 5.26):
A: Attach the 2 pieces of tape in position just below the occipital bone on each side of the neck spinous processes with the first 4 cm (1.5 in.) unstretched.

B: Stretch the tape to 50–70%, and finish the last 4 cm (1.5 in.) with unstretched tape. The end should be between the shoulder blades.

Kinesio taping of the lumbar spine

Joint position: Start position is slightly bent forward in a pain-free position.

Application steps (Fig. 5.27):
A: Tear off the tape backing paper in the middle. Stretch the tape longitudinally about 50–70%, make sure the midpoint is along the spine where the injury is located, with a 4 finger width on either side of this. Finish applying the tape with a 2 finger width without stretching on either side.

B: Tear off the tape backing paper in half and split apart the tape around 50–70%. The tape's center point should be across the spine where the injury is located, with a 4 finger width on either side of this. Finish applying the tape with a 2 finger width without stretching on either side.

C: Tear off the tape backing paper in half and split apart the tape around 50–70%. The tape's center point should be over the injury as the first part of a diagonal cross, 4 fingers wide on either side of this. Finish with 2 finger width without stretching on either side.

D: Tear off the tape backing paper in half and split apart the tape around 50–70%. The tape's center point should be over the injury as the second part of a diagonal cross, 4 fingers wide on either side of this. Finish with 2 fingers without stretching on either side.

There is insufficient scientific evidence on the effects of kinesio taping. Those who use this tape technology believe that it is based on a philosophy that aims to give full freedom of movement, thus allowing 'the body's system to heal itself biomechanically'. Scientific studies show instead, that there is a clear increased muscle activity of taped ankles with non-elastic tape versus no tape at all. Kinesio taping has no demonstrable significant effect on either medium or maximum muscle activity compared with non-taped ankles.

If the kinesio tape is used as an elastic tape, it may have some value if it can be combined with a non-elastic sport tape. When the skin is moved with the hand and/or

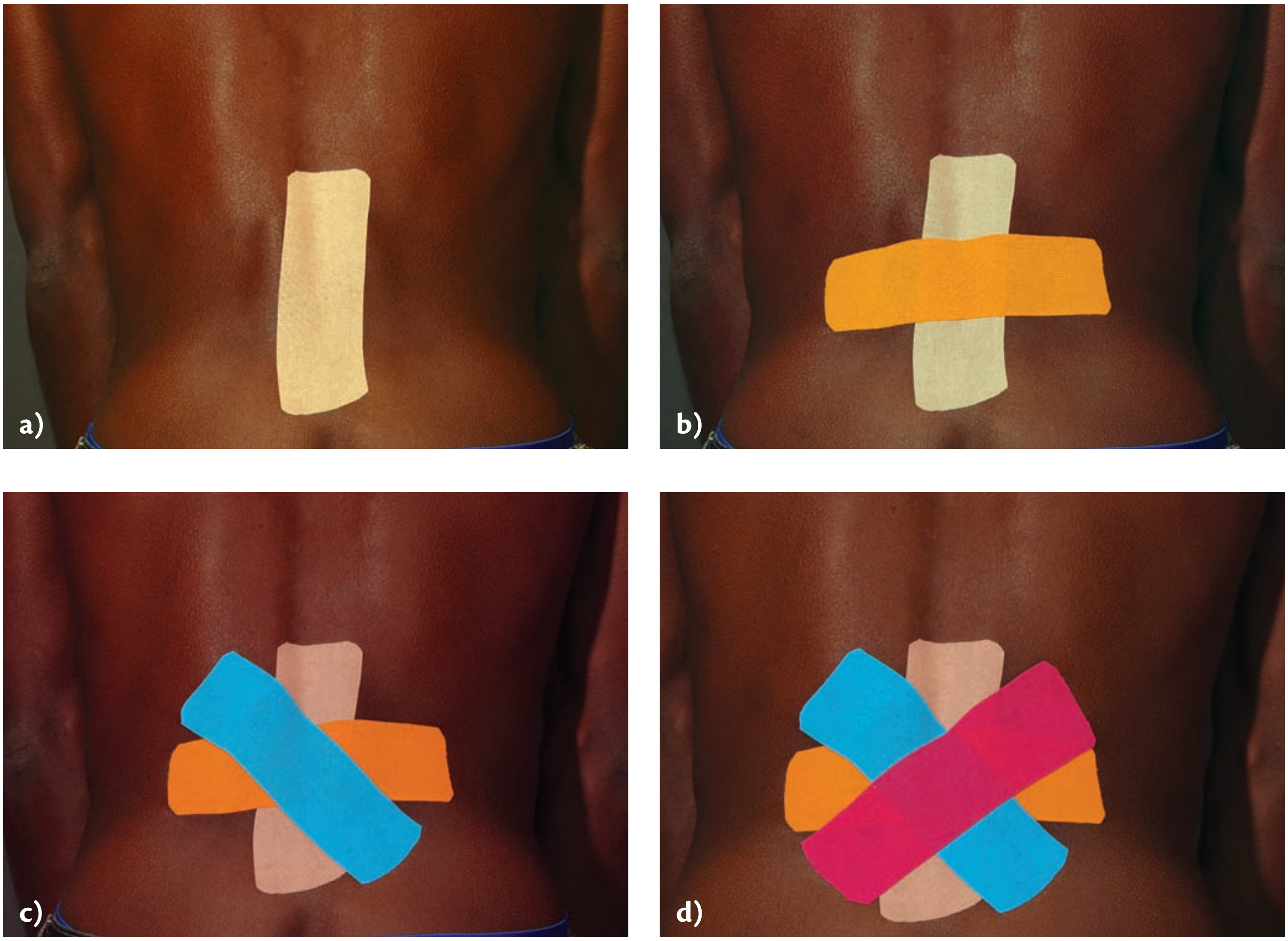


Figure 5.27 a–d) Kinesio taping of the lumbar spine. (Courtesy of Tommy Eriksson, Swedish Athletics Association.)

tape in painful conditions, kinesio taping method has an effect. The colors have no effect on power development.

However, there are possibilities with this new material, as it can withstand wet conditions well and it is possible to vary the tension directly from no stretch of the tape to the maximum stretching during the application of the taping.

Unfortunately, it is not unusual that the tape is applied uncritically and some seem to believe that tape has a curative effect in itself. There is 'big money to make' currently in this area, but once everything has settled the kinesio taping will certainly take its well-deserved and rightful place in the therapeutic arsenal.

Recent research has shown that kinesio taping (kinesiology tape application) did not reduce specific pain measures related to musculoskeletal injury above and beyond other modalities.[3] The authors suggest that kinesiology tape may be used in conjunction with or in place of more traditional therapies. There is quite a lot of ongoing research on the effectiveness of this taping technique, but there is yet no real evidence-based support of the effectiveness of kinesio taping on movement disorders. More research is clearly needed.

Tip

The use of the so-called kinesio taping technique can, with the right application, possibly have some clinical benefit.

In conclusion, this innovative tape technique has attained great popularity, especially since mobility is not affected and it can be used on all sorts of injuries to various body parts. The injured athletes experience of the treatment is positive and this is essential. However, a lot of research is still needed before it is clear exactly what effect this technology has.

Tip

- Taping of primarily hand and ankle joints is efficient in terms of prevention and treatment of injured ligaments.
- Tape can provide limited mechanical support of, e.g. the ankle, but probably also has proprioceptive effects, i.e. improves nerve–muscle function.
- Tape can also act as a psychological reminder that the athlete must deliberately moderate the movements of the lower extremities.
- The person who is taping should be experienced and be aware of the advantages, limits and deficiencies of the tape.

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6 Injury Prevention in Some Major Sports

In sports with lots of media attention, participant's injuries and the treatment of injuries could be crucial for the athlete's success. Such sports generally also have good medical expertise and as such can offer a wealth of experience. Thus we have chosen to present some experiences of the following sports (not least because we have our own experience of these): athletics with running and throwing, tennis, alpine skiing, soccer and ice hockey.

Running/jumping

Athletics includes running and jumping and is one of the major sports in the world and it forms the basis of almost all sports (Fig. 6.1). It is a sport that is very demanding and varied and requires extremely tough and extensive training before an athlete reaches world class level. However, unfortunately these athletes are exposed to a lot of injuries. There are few epidemiological injury studies of quality available, but in general, the annual injury incidence is reported to be between 61 and 76%, depending on the type of athletic event; 80–90% of these injuries are located in the lower extremities, and most are overuse injuries, such as chronic tendon injuries (tendinopathy) and stress fractures.

Scientifically reliable results have recently been presented from a large prospective study in Sweden including the country's top ten athletes in each athletic event (Fig. 6.2). In this study an athletics injury is defined as 'an injury where the athlete is forced to completely or partially refrain from participation in training and/

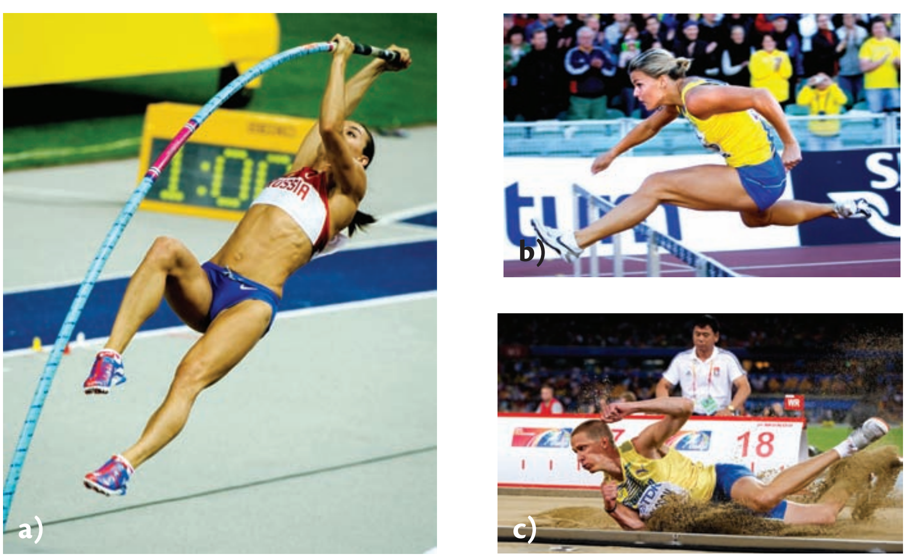


Figure 6.1 a–c) The technical developments in materials and jumping and running technique have resulted in improved outcomes in different events in athletics. (With permission, by Bildbyrån, Sweden.)

or competition in athletics' for a period of at least 3 weeks in the past year (one-year prevalence), and at the time of measurement (point prevalence). Prevalence is an epidemiological term that indicates the percentage of individuals in a population with a given injury at a given time.

The results from this study covering the entire season showed a 35% point prevalence[1] and that 68% of athletes (adults 73% and youth 61%) sustain at least one injury event per season.[2] The cumulative injury incidence observed in the latter study was 3.57 injuries per 1000 hours of exposure to athletics, and the large majority (96%) of the recorded injuries were non-traumatic with gradual onset, indicating an association with overuse. At international outdoor athletics championships, about 100 injuries per 1000 athletes have been recorded, whereof every second event resulted in absence from sports, and about 50–70 illnesses per 1000 athletes.[3]

Throwers had a tendency for more low back injury while sprinters often had injuries in the thigh muscles. Both medium/long-distance runners and jumpers had a tendency for more foot/toe and knee injuries. Adult athletes showed significantly more injuries in the feet/toes in both the 3-week prevalence and the point prevalence. Girls showed significantly more injuries to the lower legs in both the 3-week prevalence and the point prevalence. 50% of adult athletes and four out of 10 young athletes reported a long-term injury. In 74–78% of cases these were localized in the lower extremities, and consisted mainly of overuse injuries.

There is currently limited scientific knowledge of the incidence, risk factors and prevention of injuries in athletics. In order to support reliable scientific studies in this area an article has recently been published on how to define and study injuries and diseases in athletics.[4]

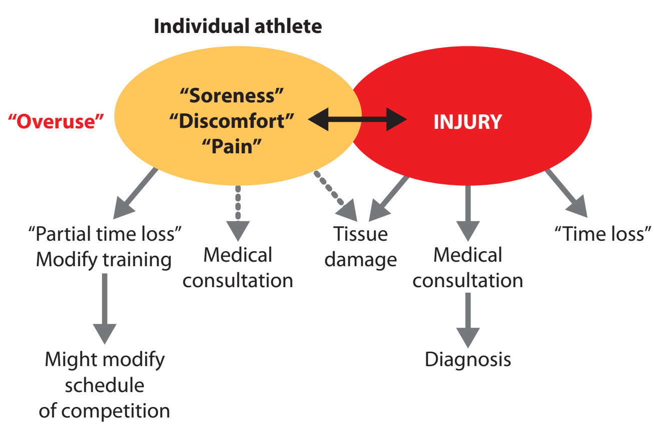


Figure 6.2 Schematic presentation of the definition used in the large study on injuries in athletics.[1]

Athletics injuries comprise injuries in running and in throwing. Since these often differ markedly they are described separately below.

Running

Running is an effective way to exercise large muscle groups and has been proven efficient in maintaining health and preventing cardiovascular problems. However, it is also a potentially harmful activity and running injuries are common, although they are 2–2.5 times less frequent compared with injury in contact sports. The average 1-year prevalence (see above) of running injuries is 37–56%. The incidence of all running injuries is between 3.6 and 5.5 injuries per 1000 running hours. For competing athletes the incidence varies from 2.5 to 5.8 injuries per 1000 running hours, depending on the type and length of running.

The examining physician must keep in mind that most runners are dedicated athletes. Runners complain of discomfort usually associated with running, but can often participate in other sporting activities such as cycling, swimming and cross-country skiing, where the level of load on the body is lower and thus the sum of the constantly repeated loads may be lower.

Running may have different characteristics. Sprinting is characterized by factors such as increased speed with greater explosiveness, decreased shock absorption early in the stride and the initial ground contact with the toes. In distance running about 75–80% of all runners have heel–toe strikes and the other 20–25% has a midfoot–toe strike (Fig. 6.3).

Running disorders commonly occur due to the repeated loads that the lower extremities are exposed to when running. The counteracting force from the ground at foot strike midphase corresponds to a vertical force of 1.5–5 times the weight. A man running with a stride length of 1.6 meters takes about 730 steps per kilometer. With a force of 250% of body weight (68 kg) at the ground contact, the runner will absorb a total of 136 tons, or 68 tons per foot and kilometer. At a rate of 4.35 minutes per kilometer the foot's striking time is approximately 0.2 seconds, which is about 5100 contacts during an hour of running. Given these enormous loads on tissues, it is obvious that even minor biomechanical abnormalities can result in a significant concentration of pressure and loads.

There are many factors that can cause a running injury. Background factors can both be external and internal.

Figure 6.3 Different types of running have different characteristics. a) Sprinter; b) long/middle distance runner; c) marathon runners. (With permission, by Bildbyrån, Sweden.)

External (extrinsic, environmental) factors

External factors are the cause of 60–80% of all reported running injuries. Most of these are due to improper training.

Improper training

The most common errors are sudden changes in the training program, such as extended running distance or changes in intensity. Examples of this can be a beginner starting to run regularly, or an injured runner who resumes running and who wants to run too much too soon, resulting in an overuse reaction. Specific examples of training errors are:

- Prolonged high-intensity exercise, with no training days with lower intensity in between or limited time for recovery.
- Extended running distances or increased intensity without the needed time for recovery and rest.
- Occasional strenuous exercise or competition activities such as marathon or other long distance events.
- Repeated hill running workouts.

The injury rate is proportional to both the absolute level of training as well as the relative exercise intensity and training volume. The total running distance per week has a significant correlation with the incidence of injuries. The relationship between running speed and the risk of injury is still unclear. Running experience has not yet been seen to have a significant correlation with running injuries.

Running in hills and different terrain

Too much running downhill can cause problems in the knee joints, as the body weight is mainly located behind the knee's vertical axis, which requires large loads on the quadriceps muscle to protect the knee. During downhill running the knee flexion and extension increase as well as patella–femoral loads, the knee extensors' force absorption and their contractions during the eccentric and decelerating muscle work. Running up and down hills is reported to be a major risk factor for running injuries. However, there is no correlation between the number of running injuries and terrain. Downhill running can cause painful syndromes, such as anterior knee pain or 'runners knee' (iliotibial band syndrome). Intensive running training uphill can cause problems such as overuse problems of the Achilles tendon (tendinopathy) and plantar fasciitis (overuse syndrome and partial rupture of the plantar fascia) (Fig. 6.4).

Figure 6.4 a, b) Running training on hills often causes injury problems. (**a)** with permission, by Bildbyrån, Sweden; **b)** photo, Kerstin Samuelsson.)

Running surface

Running surface may be of importance (Fig. 6.5). Some surfaces may triple or quadruple the frequency of injuries in certain types of sport. Running on hard surfaces, like asphalt or concrete, may cause mechanical shocks and thereby overloading of the joints and tendons and can be linked to a higher occurrence of running injuries. Running on too soft surfaces may allow excessive movement of the joints, fatiguing muscles and can cause overuse injuries. Running on wood chips on the other hand mostly offers an excellent surface (see Fig. 2.12).

Running on uneven or artificial surfaces or on slippery roads can also cause injuries. Running on slopes or on canted roads in the same direction can cause abnormal stress on one side of the body. The result is a functional leg length discrepancy, which may result in 'runners knee' (iliotibial band syndrome) or bursitis on the upper and outer part of the thigh (trochanteric bursitis).

Running shoes

A bad choice of sports shoes can cause sports injuries, because shoes can change the forces in certain anatomical structures by more than 100%. Running shoes can also affect localization, type and frequency of sports injuries. A study of three popular and well-designed running shoe brands did not reveal any differences in injury occurrence.

Inappropriate or worn out shoes can cause increased stress and strain. It is not recommended to use tennis or basketball shoes during regular running. Such shoes do not have the characteristics necessary to protect the runner from injury. Improved footwear has resulted in fewer injuries to the foot and the lower part of the leg as a whole. A recent study showed that running in minimalist footwear appears to increase the likelihood of experiencing an injury, with full minimalist designs specifically increasing pain at the shin and calf.[5] Some advise runners to run barefoot as a treatment mode for injuries, strength and conditioning, but it should be pointed out that the scientific support for this is still very limited (Fig. 6.6).

The shock absorption of running shoes is considered vital to prevent injury. Shoes that fit well have increased shock absorption. Shock absorption qualities are reduced when shoes are wet, but also through wear. After 400 km

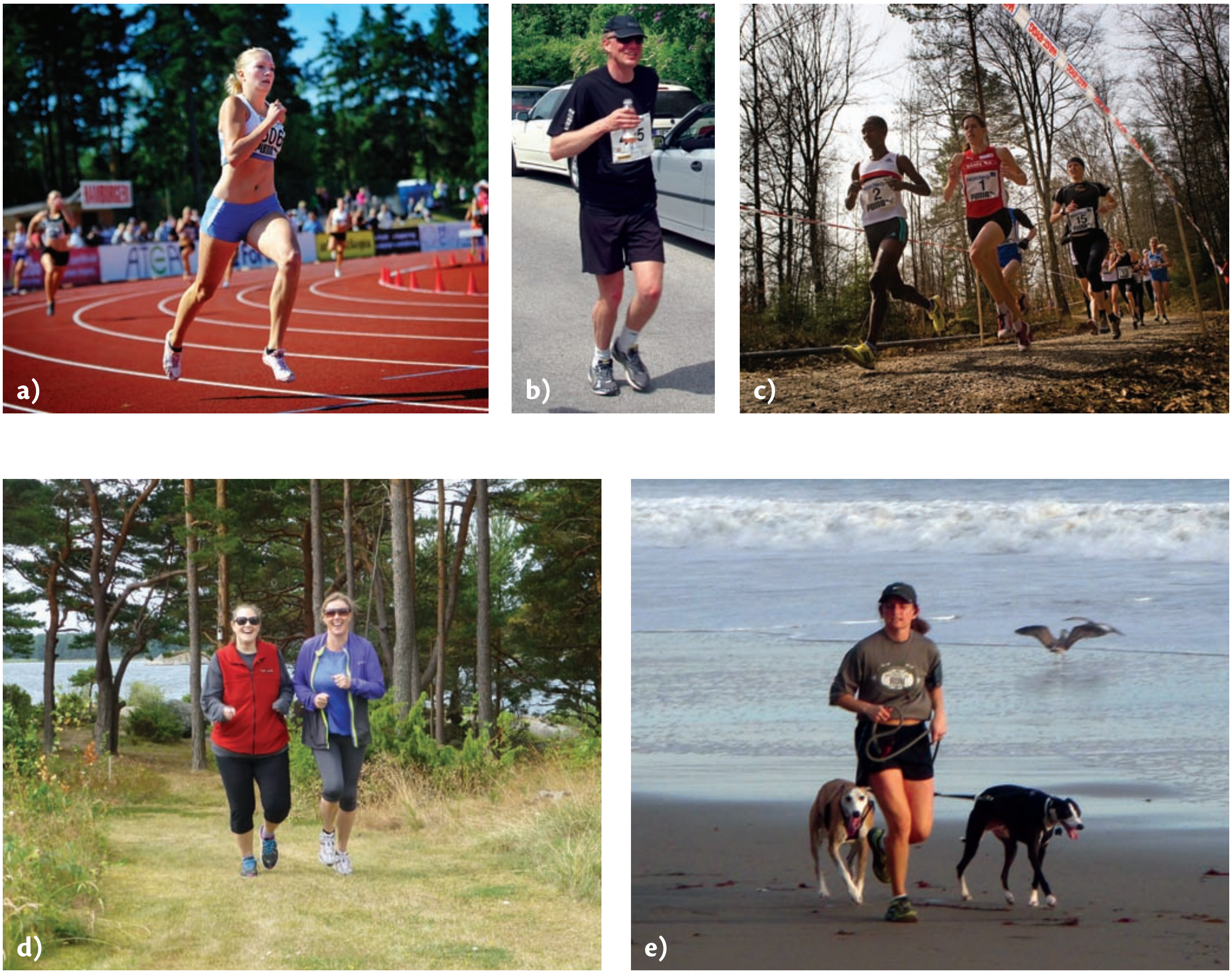


Figure 6.5 The running turf or surface can be of significance in the prevention of running injuries. **a)** Track and field athletes most often run on well-developed and prepared but hard surfaces (courtesy of the Swedish Athletic Association); **b)** running on hard surfaces such as concrete or asphalt can cause problems; **c)** running on tracks or in woods on wood chips makes the load on the body more gentle (with permission, by Bildbyrån, Sweden); **d)** running on a soft surface like grass in a nice terrain is beneficial, especially when recovering from an injury; **e)** running on sand can be nice. There are lower impact forces on sand, which may limit muscle damage, muscle soreness etc. However, the foot can sink down and give poor grip, which may cause some discomfort in Achilles ankle tendons.

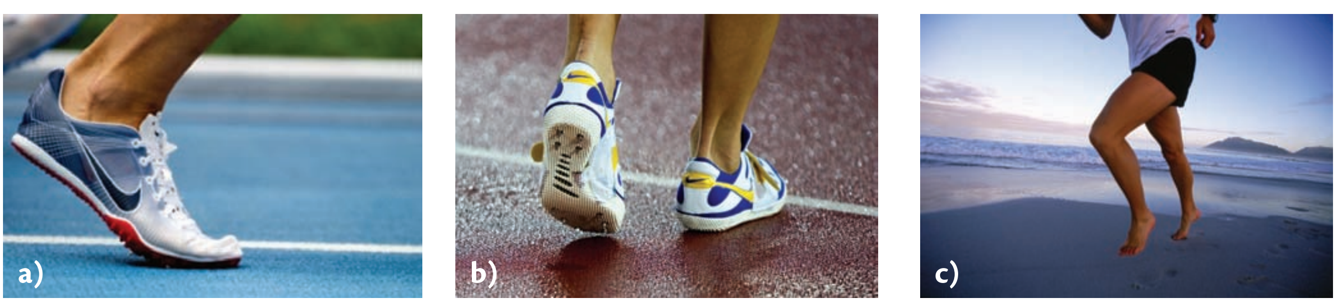


Figure 6.6 Shoes are important in most sport events in athletics. **a)** Example of shoes that are effective in sprint; **b)** shoes used successfully in the high jump; **c)** running barefoot can be efficient especially on beaches and similar. Running on sand requires 1.6 times more energy than running on a hard surface. (With permission, by Bildbyrån, Sweden.)

of running there is a reduction of 30–50 percent. Running shoes with a shock absorbing heel lift and pronation control tailored to the runner's foot type has no scientifically proven effect on the number of injuries, the risk of osteoarthritis or for health as a whole, i.e. prescribing such shoes has no evidence base.

Running technique

The movement patterns vary from one sport to the other. Long distance runners usually strike with the heel first and then roll off with their toes, while short distance runners tend to either strike with the midfoot or only run on their toes. The most common technical error is to heel strike too hard, or when overpronating the feet, which may result in overuse injuries. Repeated poor running or jumping techniques almost always lead to overuse injuries.

Internal (intrinsic, body-related) factors

The internal factors can be divided into basic, primary and secondary (acquired). The basic internal factors include sex, age, body growth, weight and length. Important primary factors are internal malalignments, leg length, muscle imbalances and insufficient strength, as well as reduced flexibility and neuromuscular function (coordination). Secondary acquired factors, such as impaired function in the kinetic chain and previous injuries, are also of importance (Fig. 6.7).

Basic fundamental factors

Gender: gender and age are not particularly significant in terms of predicting the risks for running injuries in general. The musculoskeletal system is dimensioned differently in women, who have 25% less muscle mass per kilogram body weight, lower bone density, wider pelvis and more mobile joints compared with men. It has also been found that female runners exhibit greater hip adduction, hip internal rotation, and knee abduction than men. These factors may make women more susceptible to female-specific injuries such as stress fractures in the pelvis, medial tibial stress syndrome and patellofemoral pain syndrome. It is also known that menstrual disorder is a risk factor for certain overuse injuries, such as stress fractures.

Studies indicate that women have around 50–60% of injuries, while men have 40–50%. Overall the risks of running injuries are not significantly greater for women than for men. However, women are at significantly higher risk for some specific injuries as mentioned above. Girls have a higher injury prevalence (number of injuries at a given time) than young male distance runners.

Age: the changes in the musculoskeletal system that have to do with age consist of decreasing bone density, muscle strength, fluid content, metabolism and collagen in the tendons and other tissues. Older people have a greater degree of degenerative changes in the tissues, resulting in decreased shock absorption and thereby increased risk of injury. People with over 30–40 years of extensive experience in running show no increased incidence of hip osteoarthritis. There is no evidence of any increased incidence of running injuries with age as a primary factor. This may be because older people run for pleasure, at a slower pace and over shorter distances and that they are more cautious in general (Fig. 6.8).

Body growth: young people aged 12–15 years often have an imbalance in the muscles leverage, tightness, joint mobility and coordination. The muscle–tendon complex is relatively shorter at this age. Some diagnoses are age- and growth-related, such as Osgood–Schlatter's disease, apophysitis injuries and some avulsion fractures. After the growth spurt teens usually need an exercise program that also includes stretching.

Weight and length: although obesity is often regarded as a potential problem for distance runners, a correlation between body weight and running injuries has not been found. Developing knee and hip symptoms, e.g. by osteoarthritis, are somewhat related to being overweight, because running can contribute to accelerated joint deterioration. Body length is not related to the frequency of running injuries.

Basic fundamental factors:
gender
age
body growth
weight
length
Primary internal factors:
leg position foot, shin, knee, hip, pelvis; leg length
structural variations
muscles strength, flexibility, neuromuscular coordination, ligament laxity
Secondary or acquired factors:
mechanical foot, ankle, knee, hip, spine, sacroiliac joint
muscle asymmetry imbalance, local weakness, local decreased range of movement
past and recurrent injuries

Figure 6.7 Important etiological factors in running injuries.

Primary internal factors

Malalignments of the foot can be divided into pes planus (flat feet) and pes cavus (cavus foot, high arch), each of which occurs in about 20% of the population. Pes planus leads to an excessive pronation during the stance phase.

Figure 6.8 Running can be enjoyed at any age. **a)** Young people often love to run (photo, Kerstin Samuelsson); **b)** many people enjoy running long distances even on asphalt; **c)** older elite runners can keep running, especially on forgiving trails (with permission by Bildbyrån).

Pronation is discussed on p. 540. Excessive pronation can be physiologically induced but can also be a secondary consequence of a varus position of the tibia (the lower leg is deviated inward) of more than 10°, functional equinus (the foot is pointing down), club foot (congenital talipes equinovarus) and/or forefoot supination (toes pointing inward with the medial arch elevated).

Many good runners have a slightly bow-leggedness (genu varum). The probability of injury seems to be low if the total varus position is less than 8°, while the incidence of running-related injury increases if the varus position exceeds 18°.

Various malalignments can be combined. The 'miserable malalignment' syndrome, which occurs in some runners combine forward tilt (anteversion) of the femoral neck with hip internal rotation and knees angled outwards with or without overstretching – hyperextension of the knee joint, different patella angles, extensive Q-angle, varus position of the tibia, functional equinus and compensatory foot pronation (see Fig. 19.77). A 'miserable malalignment' syndrome can cause so many problems associated with regular running that one can justifiably say that some individuals with such a malalignment simply should not run long distances.

Cavus foot (see p. 541) can also be linked to sports injuries. High arches have been found in approximately 20% of a group of injured runners. Athletes with cavus feet have reduced mobility in the subtalar (below the talus) joints, which results in a three points load, i.e. on the heel, big toe's- and the little toe's footpad, as well as reduced flexibility of the midfoot and excessive rear foot varus. In the midstance phase the heel remains in varus, the longitudinal arch is maintained and the foot does not disengage. The tibia remains in external rotation, and the end result is increased stress because the arch remains tense during the running stance phase. At reduced tibial internal rotation the stress is mediated through the lateral part of the foot and up along the outside of the leg, increasing the risk for injuries such as iliotibial band syndrome, trochanteric bursitis, stress fractures, Achilles tendinopathy, strains to the peroneus muscle, plantar fasciitis and pain in the midfoot, which are common in runners with cavus feet. The previously mentioned three point load often leads to troublesome calluses on the sole of the foot.

A functional leg length discrepancy may occur by running on canted roads, which thereby is an external risk factor (Fig. 6.9).

Figure 6.9 a, b) Canted running, if the curve is not graduated, causes running with relative leg length difference. Good running technique in the curves is important. (With permission, by the Swedish Athletic Association.)

Functional shortening can also be a result of impaired function of the sacroiliac joint, unilateral excessive pronation, muscle pain in the lower back, contractures or imbalance of the muscles. The leg length discrepancy can cause a pelvic tilt to the short side, functional lumbar scoliosis, increased hip abduction, excessive pronation, increased genu valgum and external rotation of the leg. Both legs are not on the ground at the same time while running and an absolute leg length should not be a problem. A change in the soft tissue biomechanics caused by a functional difference can lead to overload.

Leg length can be linked to injuries such as iliotibial band syndrome, trochanteric bursitis, acute lumbago and stress fractures. A leg length discrepancy that is not accompanied by other orthopedic disorders usually need not to be compensated for. A leg length discrepancy greater than 22 mm usually needs to be compensated for when it is associated with orthopedic disorders. Runners, who are subjected to repeated stress and strain, usually need compensation if the leg length discrepancy is greater than 5–10 mm.

Structural variations may contribute to the susceptibility to injury. A posterior protruding calcaneus as seen in combination with a cavus foot may cause Achilles tendon and /or bursae problems. A large os trigonum (an extra bone posterior to the talus) or a protruding posterior process can cause postero-lateral (rear, outer) ankle pain. Tarsal coalition (abnormal bridge of tissue connecting two normally separated tarsal bones) of various types can cause abnormal pain associated with loading. An extra navicular bone can cause medial midfoot pain (see Chapter 22).

Good flexibility is emphasized by many as an important factor in preventing running injuries. Running results in the hamstrings and calf muscles becoming less flexible, which can contribute to injuries. There seems to be no correlation between stretching habits and incidence of injury.

Muscle strength: the muscles stabilize the lower extremity and absorb forces to the joints and bone during running. Because of muscles' important role in terms of both stability and shock absorption, muscle weakness can increase susceptibility to stress fractures.

Neuromuscular coordination: this is the ability of the nervous system to recruit a muscle or group of muscles to perform a specific task. Disruptions in terms of balance and motor control can make a runner more susceptible to injury. Any kind of lack of proprioceptive ability (movement control without the aid of sight) can lead to functional instability, which in turn makes the athlete more prone to injury.

Ligament laxity: hypermobility often with generalized laxity of ligaments and capsules, e.g. excessive pronation, may increase the risk of injury.

Secondary or acquired factors

In the kinetic chain the lower extremity is considered as a series of movable segments and links that enables the forward drive during gait. The kinetic chain is closed when the foot is in contact with the ground during the stance phase and is open when the foot is lifted and moves forward. Anything that disturbs the normal pattern and the mechanics of the force transmission can lead to changes in gait and compensatory movement patterns at other segments in the chain. In athletes with recurrent or previous injuries, it is particularly important to draw attention to the disrupted function in the kinetic chain. Since the kinetic chain function is very complex in nature it is often overlooked as a primary cause for running injuries.

The role of secondary or acquired function disturbance as a cause of injury is still controversial. Such impairments are usually a result of increased or decreased flexibility of a segment in the kinetic chain after an injury. All impaired functions of the kinetic chain can lead to compensatory changes in posture and gait/running, which in turn may cause micro-trauma, tissue damage and visible damage.

Mechanical dysfunction: changes in position and movements of the sacroiliac joints are quite common. Although the sacroiliac joint is mostly stable, with limited movements, it has been argued that movements can occur with anterior subluxation and rotation, which can lead to asymmetry of the pelvic ring structure. This dysfunction is characterized by locking or reduced mobility in the sacroiliac joint. The main symptom, pain, is usually localized to the sacroiliac joint, but may also radiate to the buttocks and the groin region. In order to identify dysfunction in the sacroiliac joint, physicians need to be aware that it exists as a problem and to have knowledge of the biomechanics of the joint. A thorough assessment is required when treating patients with recurrent injuries.

Previous injuries: most injuries will heal sooner or later, but they may leave a scar in the tissue. Such scars may have a different elasticity than normal tissues and can cause weakness in the area with increased risk of recurrent injuries.

Tip

Previous injuries are the most common risk factor for acquiring a new injury. An injury must therefore be treated until it is healed. Return to sports should be undertaken with caution when the athlete is adequately rehabilitated.

Diagnostics of running injuries

To diagnose running injuries accurately is often a challenge. It is important to have an understanding of the injury mechanism and the various diagnostic options. Physicians often concentrate on the site of the injury when dealing with injuries due to excessive running. Any injury should be regarded as an expression of an impairment in the kinetic chain, and the whole chain must be studied in order to be able to exclude all asymptomatic underlying injuries or dysfunctions. Such an approach is especially important for persons with previous or recurrent injuries.

Injury history – anamnesis

The running injury's history is important because it forms the basis of the diagnosis. Physicians must be aware of the demands and biomechanics of running. It is important to analyze the entire running program, including changed distances and training conditions. The shoes that the runner has worn and if orthotics have been used is also something that should be discussed. A knowledgeable and experienced physician can mostly (over 90% of the time) make a preliminary diagnosis by listening to a good medical history.

Medical examination

An evaluation of the lower extremity in its entirety can be made with the runner standing, sitting, lying prone and supine. The whole of the lower extremity in relation to the pelvis and trunk should be examined closely for asymmetries in both static joint stability as well as dynamic leg position and function. Every biomechanical imbalance in the foot or lower extremity should be noted. The dynamic examination can be direct and should include gait, functional foot movement, knee cap function, assessment of leg length and testing of the sacroiliac joint function. The dynamic evaluation can also be indirect, e.g. it is possible to study the wear pattern on the runner's shoes. A complete functional examination, which includes testing of the various links in the kinetic chain, and allowing the runner to run on a treadmill for direct analysis by the examiner or videotaping, can be rewarding.

Radiographs may sometimes be of value. These can be done if there is a suspicion of joint injury, such as osteoarthritis or stress fractures. Bone scan (scintigraphy) may be of value 2–8 days after symptoms of stress fracture have arisen, but are used less frequently today. Magnetic resonance imaging (MRI) is now a common alternative without exposing the person to ionizing radiation. It can give a detailed view of changes in both soft tissues such as muscles and tendons as in the bone. Ultrasound has proved valuable in diagnosing tendon injuries, such as ‘jumper´s knee’, meniscal injury and Achilles tendon injuries. The development of arthroscopy has also been of great importance for the diagnosis and treatment of virtually all joint injuries but mainly knee, ankle, hip and shoulder injuries.

Overuse injuries due to running represents a diagnostic problem because the symptoms of this kind of injury are often diffuse and uncharacteristic. The diagnosis of a running injury is to identify not only the affected tissues, but also the underlying causal mechanisms.

Tip

A proper diagnosis is the foundation of a successful treatment, based on a thorough medical history and examination.

Injury prevention

Training routines must be checked and training errors discovered. An efficient biomechanical approach to reduce the load on the musculoskeletal system may be to:

- Change movement (change running technique).
- Change the surface (running on a soft surface instead of hard).
- Change shoes.
- Change the running distances and frequency (run shorter and longer distances with changing intervals).
- Allow time for recovery.

Shoe inserts – orthotics, orthosis

The normal position of the legs and the symmetry of the kinetic chain must be restored. Shoe inserts (orthotics), rigid, semi-flexible or soft, may be the right kind of treatment to cure malalignments or asymmetries. Shoe inserts provide support for the foot by redistributing ground reaction forces as well as realigning foot joints while standing, walking or running (Fig. 6.10).

An orthosis can be an orthopedic bandage, which can have significant impact on maximum pronation, time to maximum pronation, the maximum pronation velocity, pronation period and angle of the rear foot motion during the first 10° of the foot strike. Insufficient correction is common and orthotics have rarely the exact hind- and forefoot placement that is required to achieve a neutral position of the subtalar joint. The usual approach is to determine and set the subtalar position of 4° varus. In spite of the popularity of orthopedic orthotics and braces their use is still controversial, and this type of treatment does fail. The failure could be due to failure to adjust or replace orthotics and braces as needed.

There are no extensive scientific studies available that can demonstrate the effect of these devices. In general, over 80% of the runners are happy with their corrective treatment and they have experienced an improvement after using the orthotic devices regularly for a year. Most runners adapt to their orthotics after only 2–3 weeks, which is a much shorter time than expected.

It is important to use correct running shoes designed to offer cushioning support and the right friction. Running provides a maximum pronation point, which presents itself much later than when running barefoot. Shock absorption can be enhanced by well-fitting shoes. A running shoe should be a stable shoe with optimal shock absorption in the sole and insole and a well-fitting heel cup that is stiff around the heel footpad.

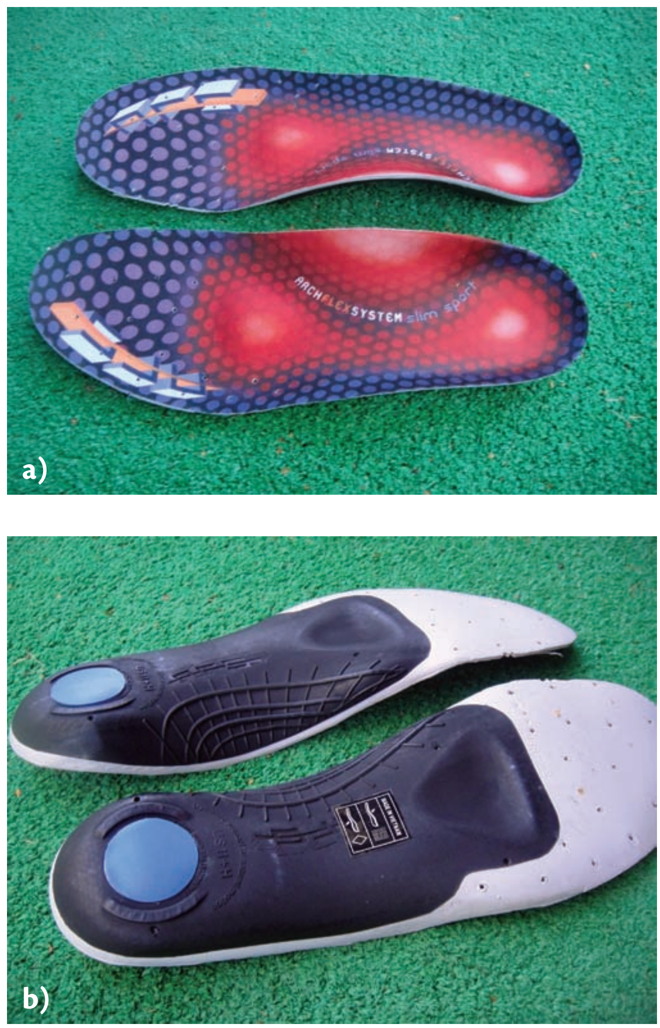


Figure 6.10 a, b) Shoe inserts, ‘orthotics’, for the support of the foot arches are used by many people. They should be well made with a correct anatomic support and with good shock absorbing ability. An anterior build up (metatarsal pad) supporting the anterior foot can be flexible. This dynamic support contributes to securing that the anterior arches are not overloaded.

Stretching exercises can be used by runners, but it should be noted that stretching can impair running economy, which may include many physiological and biomechanical factors that contribute to running performance, with the result that many today have limited their stretching activities significantly. If the athlete is very flexible, strength training could be appropriate. Good muscle strength, balance, agility and coordination are very important, as well as normal leg position, flexibility and symmetry in the kinetic chain.

Principles of treatment

When treating running injuries it is important to have an accurate diagnosis for a specific treatment. The healing phase should determine which treatment should be initiated. Treatment should start as soon as possible.

Pain, swelling and inflammation are treated with rest, reduction of load, elevation, cold therapy, compression, fixation and protective bandages. Crutches are often indicated. Anti-inflammatory medication (non-steroidal anti-inflammatory drugs, NSAIDs) may be helpful. Heat, which increases collagen extensibility of the connective tissue, reduces joint stiffness and pain, should be initiated after 24–48 hours. Local heating may be generated by heat therapy wraps.

Exercises should begin as soon as possible. The initial program should be prescribed according to the principle of slow progress, with gradually increasing load within the limits of pain and status of healing. Since strength training alone has a negative effect on the flexibility of the joints this should be combined with flexibility training, including stretching. Cross-country skiing, swimming and cycling are valuable options when it comes to maintaining a good fitness level if running is not possible. A wet vest for water jogging can also be effective.

Surgery should be avoided until traditional conservative treatment has been found not to provide further enhancement. Surgical removal of scar tissue or degenerative tissue as a result of delayed tendon healing after a chronic partial rupture of the Achilles tendon can sometimes be useful, when conservative treatment fails. Although the postoperative rehabilitation period can be long the final results are often good.

Types of running injuries and their localization

Running injuries can affect most tissues of the musculoskeletal system, including muscles, tendons, muscle membranes, bones, menisci, bursae, nerves and cartilage. The structures usually found to be involved in overuse injuries are muscle and muscle fascias (27.2%), tendon and muscle attachments (21.6%), joint surfaces (15.9%), tendons and tendon sheaths (15.1%), bursae, bones and nerves (21.4%). The knee joint, which is the most common site of injury, was involved in 48% of all running injuries, followed by the lower leg (20.4%), the foot (17.2%), hips (6.0%), the leg/thigh (4.2%) and lumbar spine (4.1%). The most common running injuries are listed in Table 6.1.[6]

Modified with permission from MacIntyre, JG, Taunton JE, Clement DB, *et al.* Running injuries: a clinical survey of 4173 cases. *Clin J Sports Med* 1991;1:81–7.

Tip

- A successful treatment is based upon a well-defined diagnosis.
- The single biggest factor for determining whether the treatment outcome is successful or unsuccessful is the patient's compliance.
- The physician must take note of every runner's special requirements before and during treatment.

Table 6.1 The most common running injuries

	Men (%)	Women (%)
Patellofemoral pain syndrome	24.3	29.6
Overuse injury in the lower leg	7.2	11.4
Iliotibial band syndrome	7.2	7.9
Plantar fasciitis ('heel spur')	5.2	4.0
Patella tendon pain	5.1	3.1
Achilles tendon problem	4.7	2.7
Pain in the midfoot	3.1	3.8
	n = 2 359	n = 1 814

Throwing sports

The importance of throwing injuries is increasing in both professional and amateur sport. They affect both adults and children. Sports that are especially prone to throwing injuries are tennis and other racquet sports, javelin, discus and hammer throw, shot put, basketball and handball and sports with other movements of the arm above the head, such as swimming, baseball and volleyball (Fig. 6.11).

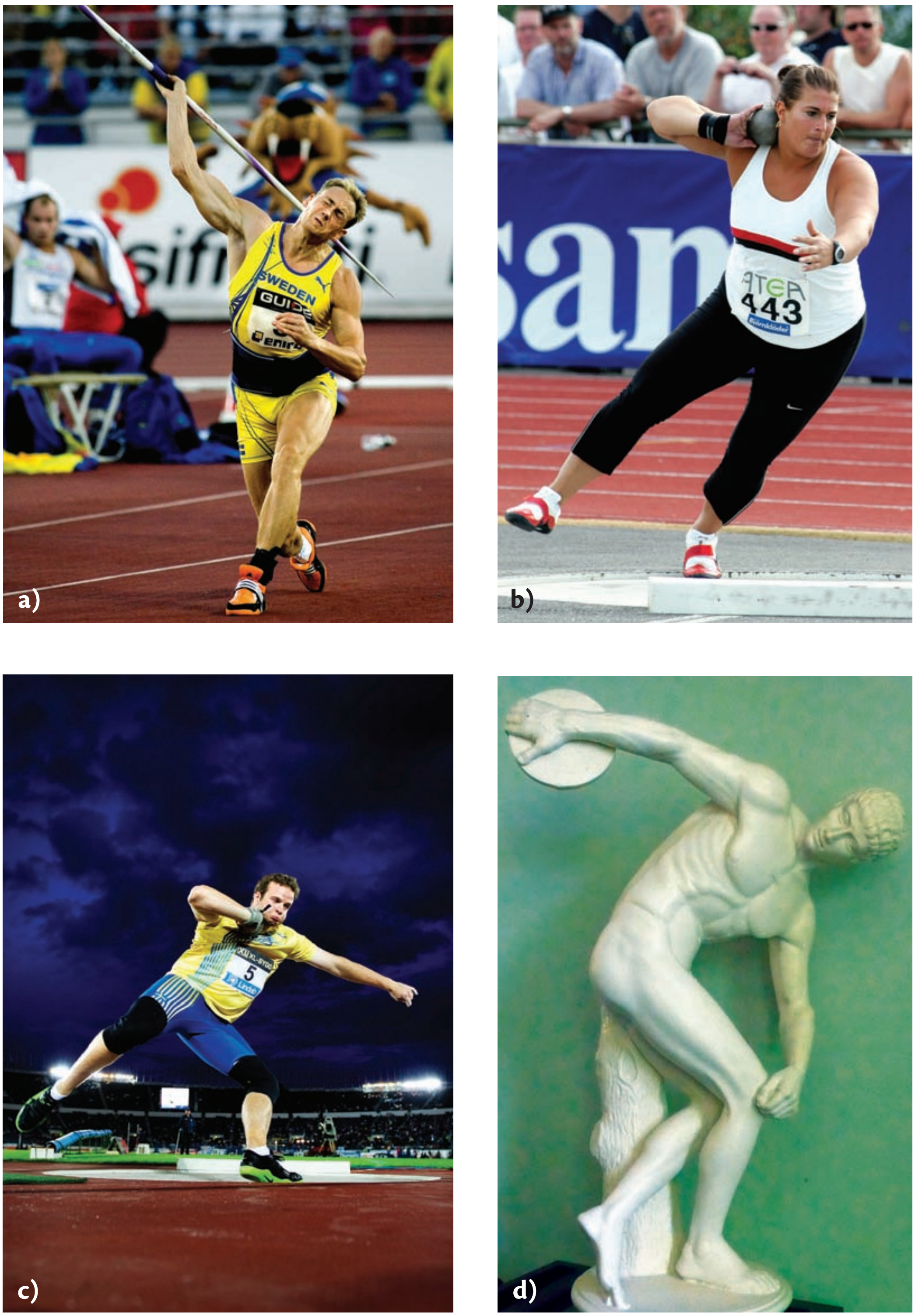


Figure 6.11 Throwing sports such as javelin, shot put and discus results in great demands on strength, technique and speed/acceleration, which may increase the risk of injury. **a)** Javelin; **b)** and **c)** shot put. (With permission by Bildbyrån); **d)** discus thrower – a classic sculpture from ancient times. The statue expresses harmony and balance.

Throwing mechanism

The main principle of throwing is a movement chain that is used to generate and transmit energy from the larger parts of the body (legs and trunk) to a smaller (more injury prone) upper extremity. Throwing is divided into the following chain of movement sequences: step, pelvic rotation, thoracic rotation, elbow extension, internal shoulder rotation and wrist flexion. This biomechanical motion is a combination of real rotation of the shoulder joint, i.e. glenohumeral joint, hyperextension of the trunk and scapular movement towards the thorax. When a ball is thrown, as an example, a significant amount of energy and power is transferred to the throwing arm and the ball. After the ball has been released, the kinetic chain needs to slow down the arm and the body that is in motion.

Throwing mechanism (here illustrated with a pitcher throwing the baseball, which is the most studied throwing mechanism) can be divided into four phases: wind-up, acceleration, deceleration and follow-through (Fig. 6.12).

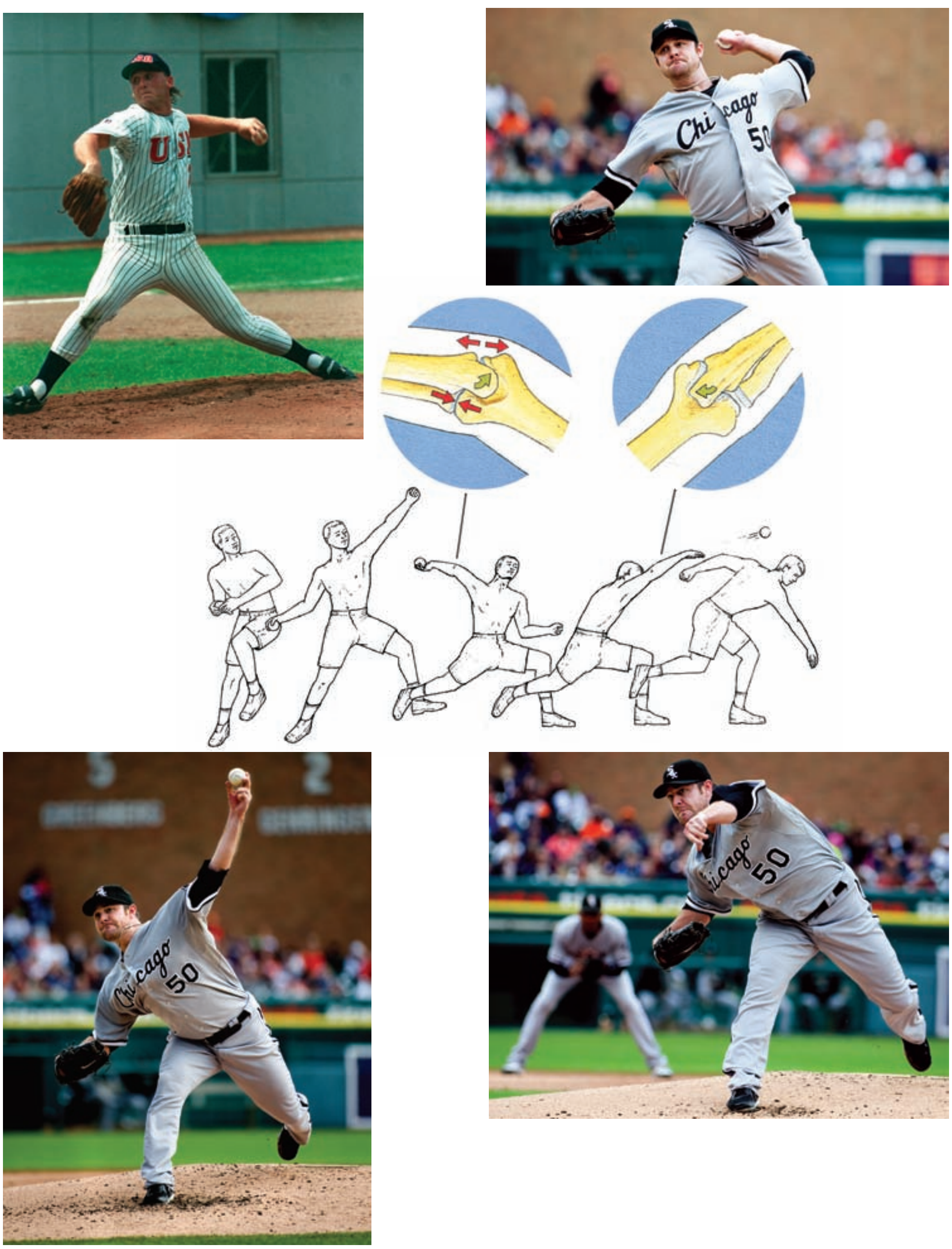


Figure 6.12 Throwing mechanism in baseball. (With permission, by Bildbyrån, Sweden.)

The main principle of throwing is a kinetic chain – the movement chain that is used to generate and transmit energy from the larger parts of the body (legs and trunk) to a smaller (more injury prone) upper extremity. The phases of a throw/tennis serve comprise:

1. **Preparation phase (wind-up)**
   This phase begins with the player taking a serve position which is abduction, extension and early external rotation. During the wind-up the shoulder is stretched, externally rotated and abducted, and the elbow is bent at an angle of approximately 45°. At this stage, the shoulder's anterior structure is at moderate tension. The purpose of this phase is to get the player/thrower in a good starting position.
2. **Pulling the arm backward (cocking phase)**
   The phase starts after the ball has been thrown up and ends with a maximum external rotation of the shoulder with the racquet.
   During this phase, the player/thrower turns forward to the target. The stance foot is placed, the arm is pulled out and the player extends the body. Forward movement is initiated by abducting the hip on the stance leg, followed by knee and hip extension. The shoulder's muscles stabilize the scapula and sets the scapular socket in position. The rotator cuff and other shoulder muscles are also working to stabilize the shoulder joint. The shoulder remains abducted at approximately 90° throughout this phase. At the end of the backward movement the shoulder is externally rotated 150–180°. (See Chapter 6 individual sports.)
   Risk of injury is present:

- At increasing rotation of the shoulder blade (scapula).
- At tension in the anterior shoulder capsule. During competitive conditions, the shoulder capsule can get over-stretched and shoulder flexibility increased. A competitive thrower often has 10–15° more external rotation in the throwing shoulder than in the non-throwing shoulder.
- When the elbow is in maximum valgus (see p. 272, Fig. 12.13) there is a risk of lateral compression and tension and possible stretching on the medial side.

3. **Arm acceleration (acceleration phase)**
   This starts at maximum external rotation of the shoulder joint and ends when the ball is struck by the racquet. Arm acceleration is the explosive phase, when the body is bent forward to a neutral position and the ball is released. The throwing shoulder remains abducted at approximately 90° during this phase. The shoulder's internal rotators are contracted to achieve maximal internal rotation speed. The rotator cuff muscles are particularly active for stabilizing the shoulder joint.
   Risk of injury is present:

- At quick powerful internal rotation and adduction of the shoulder.
- At flexion of the trunk and extension of the elbow.

4. **Braking of the arm (deceleration phase)**
   The braking of the arm is a short phase that begins when the player has struck the ball or the pitcher releases the ball. During this phase, the shoulder has a maximum internal rotation to about 0°. A posterior shoulder force is produced to counteract translation (shift) forward of the upper arm. The teres minor muscle is the most active of all shoulder muscles during this phase.
   Risk of injury is present:

- Acceleration and deceleration phases can cause damage to the shoulder's internal rotators.

5. **Follow through** This phase begins after the racquet and/or arm is moved forward and a deceleration starts. The follow through starts at maximum internal rotation of the shoulder and ends when the arm has followed through its movement across the body and the player/thrower is in a balanced position. The kinetic chain during this movement helps to reduce stress on the serve and throwing arm as body weight and energy is transferred to the front leg. The posterior shoulder muscles remain active throughout the follow through. The serratus/anterior muscle is the most active shoulder blade stabilizer during this phase. In addition, the forearm is rotated into pronation during the follow through.
   Risk of injury is present:

- The shoulder and arm have to work eccentrically to decelerate movement, with great load on the back's muscles.
- Forearm pronation can cause rotational and shear forces on the lateral side of the elbow and compression on the back of the elbow.

The wrist is forced forward in serve with the risk of overload.

Equipment in throwing

An example of effective equipment design change has occurred in javelin, in order to alter their performance and make them more difficult to throw. In men's javelin the world record reached potentially dangerous levels (104.80 m by Uwe Hohn, DDR) during the 1980s. With increasing distances there were also more frequent flat landings (‘no throws’). The men’s javelin was therefore redesigned by IAAF in 1986, whereby the centre of mass was moved 40 mm forward from its previous position at the centre of pressure on the javelin. The tip of the javelin was also redesigned to be of a blunter and less aerodynamic shape (Fig. 6.11A). The flight distance thereafter decreased by around 10% and the world record is now 98.48 m, by Jan Zelezny, CZE, set in 1996.

Treatment

Overuse injuries due to too much throwing are common. An athlete who starts to show signs of strain after repeated overhead movements must limit the activities to avoid pain and possible further injury. Most problems of this nature are usually solved by rest and gradual return to sport: for details see Chapter 8, Treatment principles and Chapter 10, Shoulder injuries.

Tennis

Tennis is an international sport that appeals to millions of people, both as a competitive and recreational sport. Tennis can be played at any age and it is considered an ideal activity in older age (Fig. 6.13).

Figure 6.13 a–c) Tennis is a game that can be played and appreciated by all ages. (**a**) photo, Mårten Renström.)

Tennis is a physically, mentally and emotionally demanding sport (Fig. 6.14). The tennis game is characterized by short explosive movements involving most of the muscles of the body. These movements are often repeated over a hundred times a match or training session. Since there are no time constraints, a match can last a long time: a 5 set match occasionally up to 4–6 hours. This variability requires that the player is physically well trained both anaerobically to perform optimally and aerobically optimized to recover during and after the match.

We know a lot about the inherent requirements needed for tennis in terms of strength, range of motion and the amount of training and competition. We also know the potential problems that arise in muscles, tendons and bones over time. These are often secondary to the tissue's extensive adaptation, which in turn is related to anatomical, biological and biomechanical factors. This adaptation can lead to problems of the upper extremities, back, hips, etc. and should especially be considered in children and growing young adults.

Figure 6.14 a, b) Tennis players are true athletes. To become number 1 or in the top 10 in the world is a major achievement and requires an outstanding physical capacity but also a strong psyche and a will to win. (**a)** with permission, by Bildbyrån, Sweden.)

Tip

It is important for all active in tennis to understand how tennis forces are generated and distributed, and how these large loads affect the body, so that players are given the opportunity to reach their highest potential while secondary problems can be avoided and injuries prevented.

Tennis as an elite sport

The tennis world is guided by the ITF (International Tennis Federation), in charge of youth tennis, Davis cup, rules, drug misuse, etc., by the ATP (Association of Tennis Professionals), in charge of men's tournaments and World Tour, and the WTA (Women's Tennis Association) in charge of women's tournaments. One of the problems with elite tennis is the long competition season, which currently covers 10–11 months for both men and women. Those who are low-ranked or those who have not been able to perform as well as they had hoped often feel compelled to continue to compete, increasing their competition rate even more. The men's end year ranking is based on the total points from 19 competitions including the Grand Slams, the eight ATP World Tour Masters 1000, etc. WTA has a similar system for women's tennis. The basic training period (since 2011 increased to around 6 weeks) is too short compared with the competition period, and causes stress and not enough time for proper recovery and then effective conditioning. This also increases the risk of injury and often creates difficulties in the long-term planning as well as peaking in performance before important tournaments. The ATP and WTA have therefore shortened the competition season, but it is still too long for the players to be able to have a satisfactory recovery and then be able to undergo a good basic training period with well-planned timing.

Other risk factors are the physical demands that are increasing in tennis with time, not least due to increased competition, increased speed, longer matches and technological development. The game has not only evolved technically but also the material of the racquets, balls, stringing, etc. has been modernized and improved (see below) (Fig. 6.15). External factors include the large demands placed on the upper body, core and back when it comes to speed, movements and loads. The game of

Figure 6.15 a, b) Well-designed equipment is important to prevent injury. Here clay shoes are used when serving on clay.

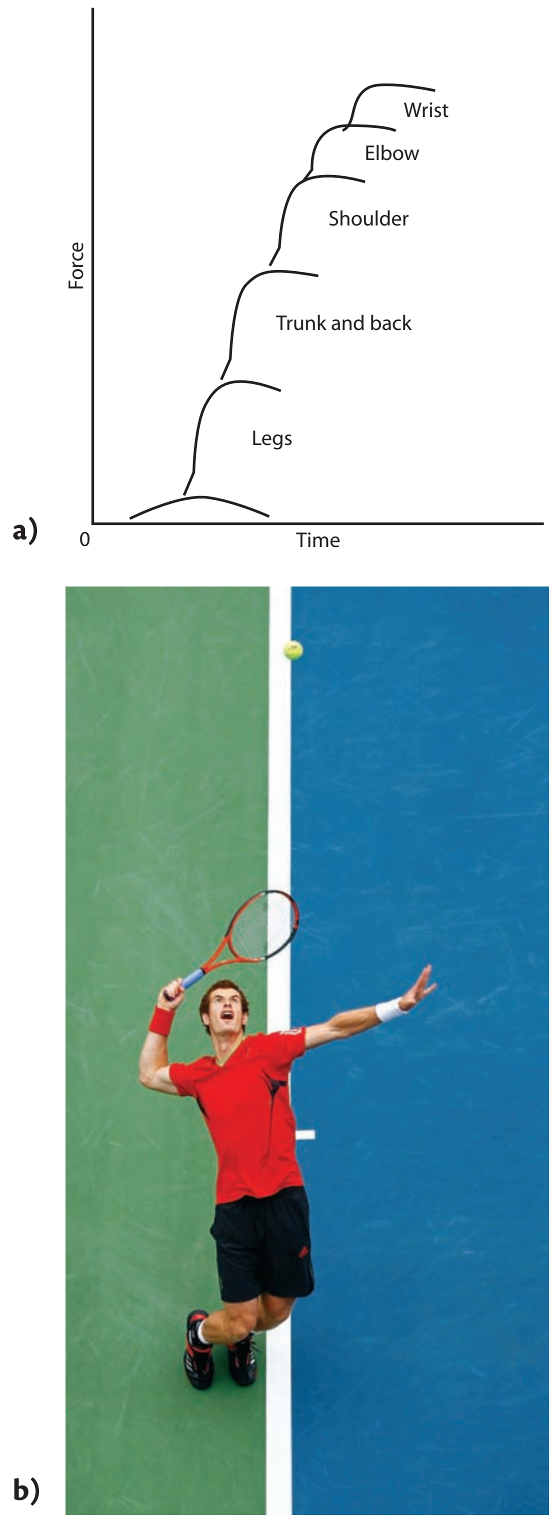


Figure 6.16 The kinetic chain. A tennis player should use the whole kinetic chain by using the power from the lower extremities and transfer it upwards. a) The concept of the kinetic chain includes linking muscle groups to perform rigid movements in order to create a greater force (courtesy of Dr Ben Kibler, Lexington, Kentucky, USA); b) elite tennis players utilizing the whole kinetic chain (with permission, by Bildbyrån, Sweden).

elite players is characterized by repetitive, asymmetric and difficult technical movements.

These are executed by high-intensity acceleration, deceleration and change of direction, that require lateral movement, good balance and the production of explosive strokes. An elite player must generate 4000 watts (746 watts = 1 horsepower) of energy in each serve. The whole body is involved. The thoracic rotation is about 350°/s and the shoulder rotation speed is 7000°/s. The elbow extension occurs at a rate of 1100°/s. These movements give the ball very, very fast speeds. With the help of two specially designed radar sensors positioned behind the baseline at either end of the court, ball speeds up to 209 km/h (130 miles/h) for women and up to 250 km/h (156 miles/h) for men have been registered.

The world elite trains today around 1000–1200 hours per year with 1–3 workouts a day, 6–7 days a week for almost the entire year. The well functioning kinetic chain is the key to develop and transfer the force produced by the legs through the push-off from the ground through the trunk and the shoulder to the arm that takes a grip of a tennis racquet during a stroke.[7] The shoulder, elbow and wrist functions are the power transmitters in this chain. If any part of this link is not functioning optimally, it can lead to a high risk of injury (Fig. 6.16).

Tennis equipment

Tennis equipment can be a risk factor.

Racquet development

Tennis equipment such as the racquet can be a risk factor. Until 1965, all professional tennis racquets were made of wood, giving a 'good feel' for the game. A steel tennis racquet was patented in 1965 by Rene Lacoste. In 1968 Spalding marketed the first aluminum racquet. The greater strength of metal frames could accommodate greater string tension. In 1970 an oversized aluminum racquet 'Prince' was developed by Howard Head. The prime hitting area, or so called 'sweet spot' was doubled in size. The modern composite material racquets have facilitated a change in playing style from one of technique to one characterised by power and spin. The combination of the increased stiffness of modern racquets and harder tennis balls has led to an increased shock transmission from the racquet to the player.[8] Players felt uncomfortable with these stiff racquets because they sacrifice control. Potential impact on the game dynamics or the risk of injury will be discussed below.

There are many recent innovations in racquet technology. The average racquet is now about 71 cm (28 in) long, and weighs from 284 to 397 g. There are racquets with extra wide bodies and with a new material – graphite fiber-reinforced thermoplastic viscoelastic. The most common racquets are now made of aluminum or of a composite of graphite, fiberglass and boron or kevlar. While some racquets can help reduce arm and shoulder problems, other can contribute to them; the bottom line is that good vs. bad technique on every stroke can always be a major contributor to arm and shoulder problems.

Open stance

Today's racquets are more powerful, stronger, and lighter with improved handling. They allow a changing technique as the players can hit the ball harder and do so also with open stance. This means that they can hit winners with an open stance. During the open stance the feet are aligned parallel to the net, which facilitates a full follow through (Fig. 6.18). However, the open stance position also puts more stress on the body and requires improved core strength and balance. The risk for injury is increased not the least for the core, the back, the shoulder and elbow. The open stance involves constant loading and unloading of the hip and thereby it increases the risk of injury to the hip joint and its stabilizing structures, i.e. the joint capsule, the labrum, and the muscles and ligaments. Strength imbalances and poor flexibility in the core and around the hip can increase this risk.

Grip

In non-professional tennis players who get wrist injuries, the different racquet grips can be related to the injury localization: an Eastern-grip causes injuries to the radial side, such as flexor carpi radialis tendinopathy and DeQuervain's tendinopathy, and a Western or semi-Western grip to the ulnar side, such as extensor carpi ulnaris tendinopaty and triangular fibrocartilage pathology (Fig. 6.17).[9]

Strings

Other injuries include a common injury such as the tennis elbow. Concerning racquet and tennis elbow it can be said that lighter racquets are better and healthier than heavier racquets. Strings can be a risk factor for tennis elbow problems. Materials found in tennis racquets are nylon, gut, or synthetic gut for the strings. Gut gives better control, higher speed velocity and less vibration to the wrist. Many top professional players use poly-based strings, which delivers the added spin and control that these top players really want. However, these top players restring their racquets just a few hours before every match and in many instances they may be used only for 8–10 games, otherwise playing with a stiff, dead string can be a prominent cause of tennis elbow. The looser the racquet string the higher the speed for the ball. A harder string will give improved control of the ball, but seems to increase the risk for tennis elbow.

Turf

Tennis has different surfaces to play on and they put different stresses on the body. Grass, as played in Wimbledon, makes running smooth. The points are shorter, resulting in less running. The racquet mostly meets the ball lower on grass, with less strain on the arm. Sliced groundstrokes are rewarded on grass. Grass can, however, be tough on the arm, as there are more unpredictable hits and because the ball hits the racquet with more speed, generating more shock and torsion.

Shoulder injuries

The shoulder is exposed in elite tennis players, especially due to the increasing role of the serve, which is now the dominant type of stroke. 45% of the strokes at the French Open and 60% in Wimbledon is the serve. 50% of the total energy and the power of the serve are developed in the legs, hips and torso. The common biomechanical motions involve proper foot placement, knee flexion

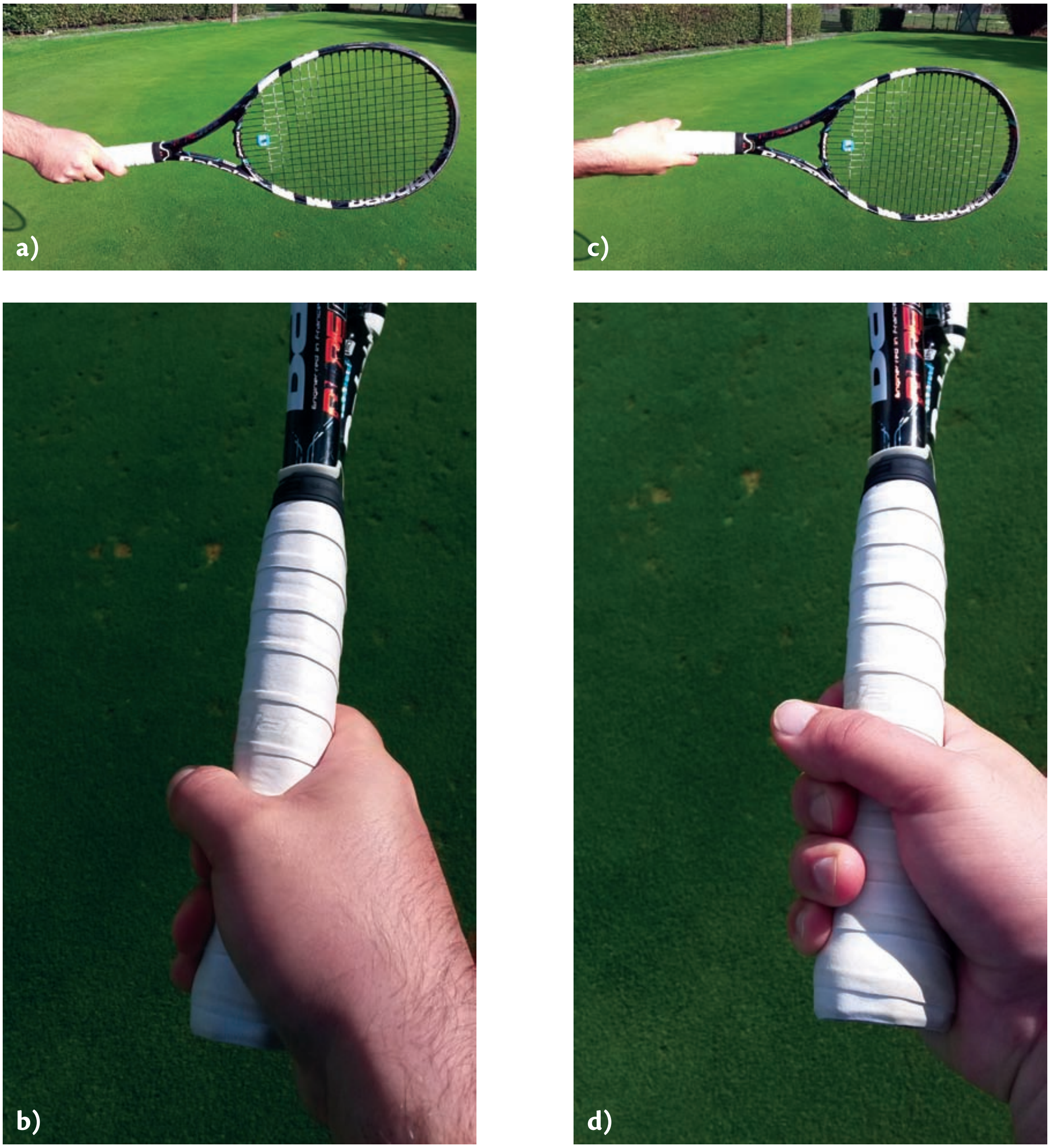


Figure 6.17 Tennis players hold the grip on the racquet in different positions. This may affect the stroke biomechanics and the biomechanical loads on the tissues, e.g. in the shoulder and the arm. There are several different grips. The players mostly use four different grips to hit a forehand: Continental, Eastern, semi-Western and full Western. **a)** Continental grip: the racquet is held like an axe. It is preferred when hitting a serve. This allows more top spin; **b)** Eastern grip: 'shakes hand with the racquet'; very common among beginners. Note that the hand in both the Eastern and Western grip is in the same position with only the tilt of the racquet changed; **c)** semi-Western grip; **d)** full Western grip, which has the second knuckle positioned on the lower part of the grip. The racquet is rotated 135° compared with a Continental grip. This grip gives more top spin and the player must hit the ball earlier. The effects of the different grips on injuries to the forearm are presented in Chapter 13, p. 293. (Photos, Mårten Renström, Eastbourne, UK.)

to extension, hip/trunk counter rotation – away from the court, back hip tilting backwards, hip/trunk angle cocking 30°, arm cocking in scapular plane/scapula retraction, so-called shoulder over shoulder and long axis rotation. The shoulder contributes 13% of the total energy and 21% of the total force.

The body works and fails as a unit

There is a risk of a negative adaptation (maladaptation) of the structures. This maladaptation of the shoulder tissue is found in 60–86% of tennis players. Decreased internal rotation of the shoulder starts a series of biomechanical changes that lead to injury to the shoulder and elbow. This reduction of internal rotation of the dominant shoulder of the tennis player is combined with an increase of the external rotation on the same side. Limited and reduced internal rotation in the dominant shoulder results in a tight posterior capsule, which causes a compulsory displacement of the arm anteriorly in the shoulder joint. Excessive external rotation can cause stretching of the anterior and lower capsule structures, causing anterior instability and internal impingement. Increased shoulder tightness may be a factor for other injuries of the musculoskeletal system.

Management of serve-related injuries

Is it possible to modify the biomechanical and physiological demands? Biomechanical problems can be addressed by a detailed analysis of technique and training by the tennis coach. Stroke and movement patterns should be studied. In general, it should be said that it is essential to use all of the kinetic chain by including the force of the lower extremities and up to generate optimal development of force and an effective rotation of the arm before there is a hit of the ball.

Injury preventive measures may include specific change in mechanics in faulty motions, e.g. incomplete flexion of the knee joints in the cocking phase (see Throwing mechanism p. 97) or incomplete cocking of the shoulder in the serve, as they can create increased loads on the shoulder and elbow. These mechanical problems can be corrected after a detailed analysis through changing the training by the tennis coach. Targeted strength training can improve the serve. It is also possible to modify the number of tournaments played, and shorten the competitive season.

The measures against the undesirable adaptation (maladaptation) of the shoulder tissue due to the great physical demands on the shoulder in tennis are getting better and better through continued active and thoughtful research. Increased resources for research would be extremely valuable for tennis as a sport, especially considering that the requirements and thus loads on the tissue are continuously increasing. Unfavorable adaptation of the tissue resulting in loss of flexibility and strength can cause injury. A regular assessment of the players is necessary to consider the adaptation effects.

Figure 6.18 Top level players nowadays hit the ball with an open stance, i.e. the body is twisted so they have the body parallel with the net when they hit the shot. **a)** Right-handed forehand; **b)** two-handed backhand; **c)** left-handed forehand. (With permission, by Bildbyrån, Sweden.)

Trunk/core stability essential

The trunk/core is the main body segment that links the forces of the movements that are produced by the arms and legs together. During a tennis serve, only a small part of the power comes from the serving arm and the greater part comes from the legs and trunk/core muscles.[10] Core stability is considered to be the ability to control the position and movement of the trunk over the pelvis and the lower extremities. This type of control is necessary in order to achieve optimal development, movement and control of forces and movements to the external parts of the kinetic chain, such as the shoulder, elbow and wrist in a tennis serve. Many believe that the pelvis and its surrounding structures are the basis of core stability and stress the importance of the gluteus maximus muscle as a stabilizer. Even the gluteus medius muscle is important as a stabilizer for the trunk. Reduced hip external rotation has a positive relationship with various types of knee injuries such as anterior knee pain. A mathematical analysis of the tennis serve has shown that a reduced force from the hip by 20% means that it requires 34% greater speed for the arm, or 80% more shoulder mass to transfer the same force to the ball. It is very important to maintain the core stability to protect the spine and its surrounding muscles when different types of forces act on these structures (Fig. 6.19).

Tip

Good core stability reduces the risk of injury. There is also a more efficient use of muscle strength, better balance, stability and posture in tennis players as well as improvement of performance.

Injuries in tennis

The frequency of injuries in the general tennis population as a whole is generally low: injury incidence varied from 0.05 to 2.9 injuries per player per year. There are few reliable figures available. Pluim and colleagues argue that there is great variation in the incidence of reported injuries in tennis literature.[11] Overall for the general population the majority of the injuries were located in the lower extremities (31–67%), followed by the upper extremities (20–49%) and trunk (3–21%).[12] Acute injuries commonly occur in the lower extremity whereas chronic injuries occur in the upper extremity and trunk. Injuries to the trunk comprised 5–25% of all injuries. Back pain in tennis is not going away! Low back pain is common and 50% of elite players had a history of low back pain of at least 1 week duration.

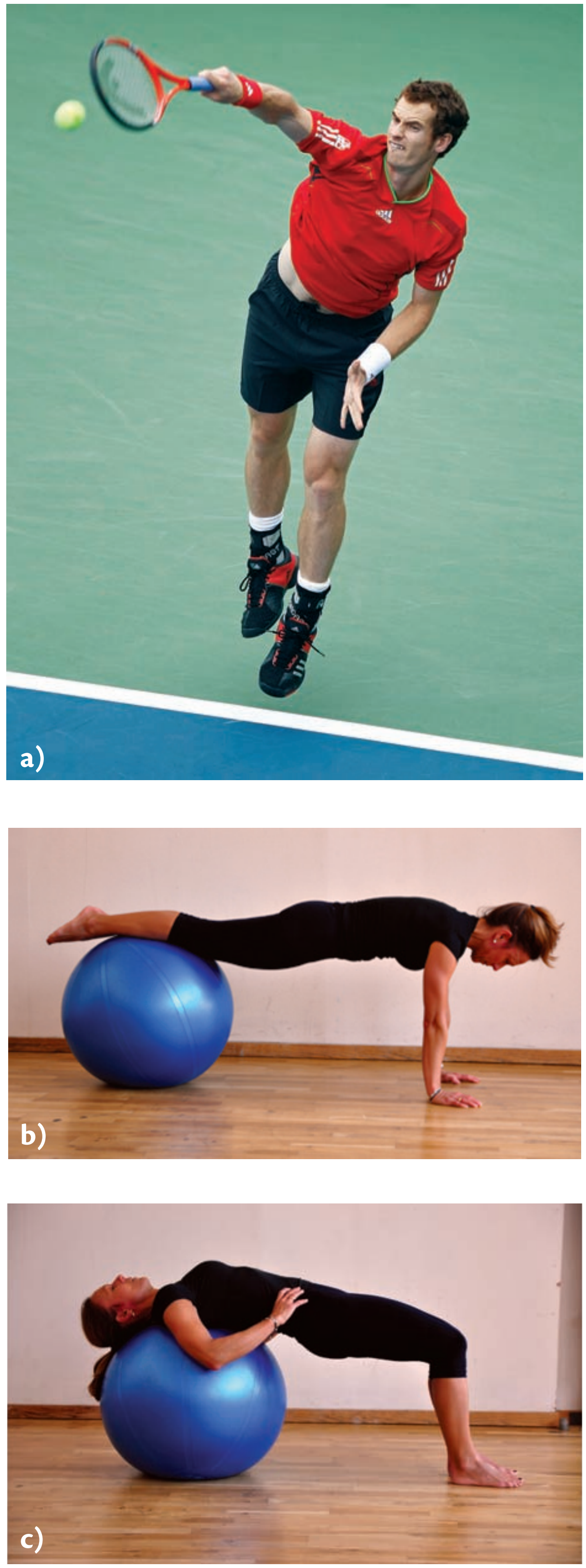


Figure 6.19 a) The tennis serve depends on good core stability and strength (with permission, by Bildbyrån, Sweden); **b, c)** core training can be performed efficiently with an excercise ball (photo, Frohm/Heijne).

46.7% of retired players with back pain had abnormal radiographs of the lumbar spine.[13] MRI findings such as facet joint arthritis and synovial cysts and pars injuries are common in asymptomatic young tennis players.[14]

The most common injuries in tennis are muscle ruptures (35%) such as hamstring tears, which are the most common, ankle sprains (26%) followed by ligament and tendon injuries. There is a higher proportion of ankle sprains in female tennis players compared with male players (9.7% vs. 4.5%.)

Injuries in elite – top level players

For top level players the injury trend analysis from the US Open Tennis Championships between 1994 and 2009 shows a total of 76 injuries per tournament, of which 44 were acute injuries seeking medical assistance (Fig. 6.20). In this tournament the ankle, followed by the wrist, knee, foot/toe and shoulder/clavicle were the most common injury locations.[15]

In a case series of 148 professional tennis players 38% reported missing a tournament because of back pain and 29% suffered from chronic back pain. A cohort of 139 elite tennis players studied over 2 years found an overall incidence of almost 13%, with injury in tarsal navicular in the foot (27%), pars interarticularis in the spine (16%), the metatarsals in the foot (16%) and the tibia (11%).

Injuries in junior players

The injury profile in junior players has been studied in a local tennis club in Stockholm, Sweden in a prospective 2 year study. The injury incidence for boys was found to be 1.7 injuries/1000 hours of tennis playing time and for girls 0.6. Ankle sprains, low back pain and rotator cuff problems were most common. In summary it can be said that the injury incidence in junior tennis is low. However, almost 50% of the injuries required absence from tennis for more than 4 weeks.[16] Metacarpal stress fractures in high-level junior players (n=7) are located in the second metacarpal and are related to playing intensity.

There have been a number of investigations that have reported the incidence and/or prevalence of shoulder pain within a larger group of study participants sustaining an injury from playing tennis. The percentage of tennis players at all levels with shoulder injuries in these studies ranged from 4% to 17%.[12]

The shoulder is the most exposed part of the upper extremity of elite tennis players, from 25 to 45.7%.[7]

Figure 6.20 **a)** Elite player in pain; **b)** medical personnel are quickly on site; **c)** immediate examination and diagnosis is often important for correct treatment of an acute injury; here, a serious knee injury. (With permission, by Bildbyrån, Sweden.)

Many elite junior tennis players receive an acute or chronic overuse injury of the rotator cuff due, primarily, to the tennis serve, which is the most demanding of all the tennis strokes. The tennis serve often has a maximum acceleration, deceleration and control, at the same time being repetitively performed with the arms above shoulder level. This is the major factor predisposing to impaired internal rotation, increased external rotation causing capsular impingement, as well as hypermobility in the dominant arm. On the other hand, a strong rotator cuff increases the stability of the shoulder and has a protective effect.

Shoulder injury in players at all levels ranges from 4% to 17%. They are commonly due to repetitive use and related to scapular dyskinesis, rotator cuff pathology or glenohumeral internal rotation deficit, which results in internal impingement and/or labral pathology. Significantly higher forces in the back for the kick ('topspin') serve vs. the flat or sliced serves, potentially leading to greater injury risk potential.

Medical service and physiological support in tennis

The ATP World Tour and WTA have built up an extremely efficient medical service at their competitions around the world. ATP World Tour has 15 full-time staff, who are very knowledgeable and experienced physiotherapists on the tour (Fig. 6.21). They spend 25 weeks each working at the various tournaments and get to know the top players well. Similarly generous, medical services are not available in many other sports. At some tournaments the players are offered additional consultations in, for example, dermatology, nutrition, podiatry and orthotics and off-season consultations for high performance training.

Several countries' National Tennis Associations have built up medical teams so that their top and upcoming young players can get access to physicians, massage therapists and physiotherapists throughout the year when needed. Some teams also include naprapaths, osteopaths and chiropractors. Many also use the screening systems developed by the US Tennis Association, WTA and ATP World Tour and many also use the USTA Tennis High Performance Profile. These tests are supplemented by functional movement tests (MAQ). The objective of MAQ training is to develop systematically the players' functional strength, flexibility and neuromuscular control. Major focus is put on shoulder stability, knee control and core stability during the screening period. The testing sessions during the ATP World Tour tournaments have made it possible to construct injury prevention and performance enhancement programs. Individualized exercise programs based on the areas of deficiency are given to the elite players at these tournaments.

Tip

The sport of tennis needs to develop strategies to minimise injuries, i.e. prevention. To reach this goal meticulous injury and disease registration is vital to establish the epidemiology as well as the risk factors and injury mechanisms.

Figure 6.21 **a)** Experienced ATP physiotherapist in action in the medical room at a major tennis tournament; **b)** experienced ATP physiotherapist in action on the court at a major tennis tournament (photo, Todd Ellenbecker, ATP, Phoenix, Arizona, USA).

Alpine skiing

Alpine skiing is a sport where the skier slides down a snow-covered hill on skis with fixed-heel bindings, while skiing using free-heel bindings includes cross-country, ski jumping and Telemark. Competitive alpine skiing includes the four disciplines: slalom, giant slalom, super giant slalom and downhill (Fig. 6.22). The first competition in slalom was held in 1922 in Wengen, Switzerland. The Alpine Ski World Cup has a television audience of 250 million viewers. An addition to this event has been made in recent years, so-called freestyle skiing, that includes several events such as mogul skiing, aerials, half pipe and ski cross.

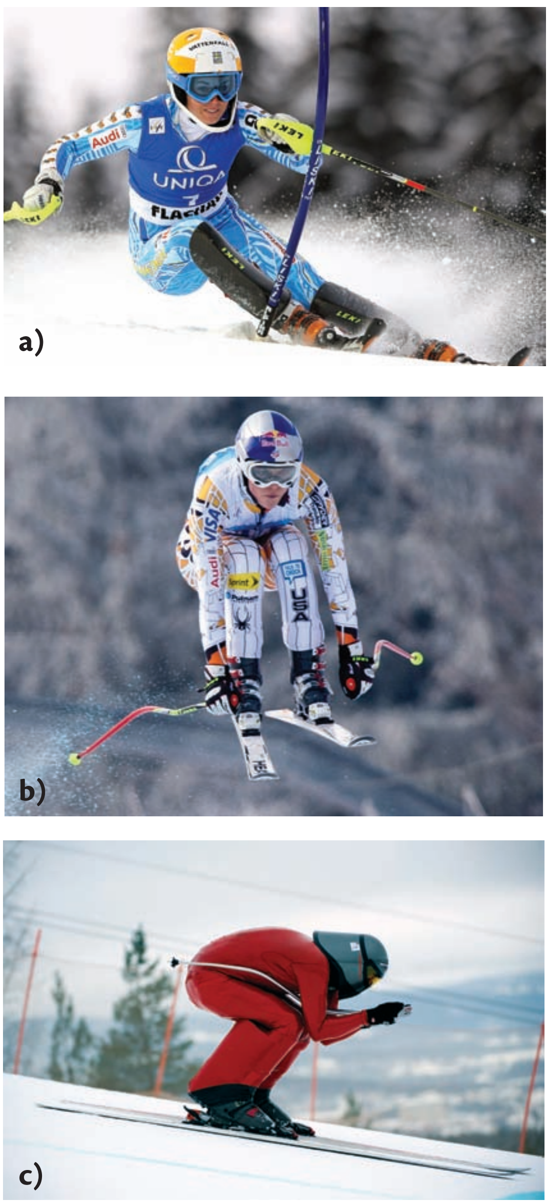


Figure 6.22 Types of alpine skiing. **a)** Slalom; **b)** downhill; **c)** speed skiing at over 200 km/h. (With permission, by Bildbyrån, Sweden.)

Since the 1960s, the number of skiers has increased substantially – more than 40 times in the USA to around 15 million today (Fig. 6.23).

Alpine skiing exposes its participants to a real risk of injury. There is an injury rate of 2.5 per 1000 person ski days. The number of skiing injuries is probably more than 1 million a year, worldwide. Approximately 600,000 ski- and snowboarding-related injuries occur in North America each year, with head injuries accounting for up to 20% of all injuries.

Figure 6.23 **a)** Alpine skiing is popular among the general public in countries with snow. (photo, Kerstin Samuelsson); **b)** the elderly should be physically active and skiing is an ideal recreational sport, although there are some risks.

In the FIS World Cup in freestyle, downhill skiing and snowboarding, according to a major study conducted by Norwegian researchers, there are 27.6, 29.8 and 37.8 injuries causing loss of time and 14.4, 11.3 and 13.8 serious injuries per 100 athletes per season, respectively.[17] About 1/3 of the riders in the World Cup alpine, freestyle and snowboarding incurs an injury that results in time loss every season (Fig. 6.24).

A total of 17% of all injuries in Norwegian hospitals are injuries from skiing and snowboarding. Many of these can cause prolonged absence from the sport. Injuries can also cause effects in the long term, and cause altered joint biomechanics and early onset of osteoarthritis and severe head and neck injuries. Alpine skiing is usually a pleasure, but all must be aware of the risks that this sport entails. One can get far with good equipment and common sense.

The etiology of ski injuries

Skier-related factors

In relation to the exposed population, men seem to be more affected by collisions than women. Avoiding reckless skiing habits and exercising caution while skiing near solid objects are probably important factors when it comes to avoiding injuries (Fig. 6.25).

Figure 6.24 Examples of modern variants of alpine skiing. **a)** Ski-cross; **b)** snowboard. (With permission, by Bildbyrån, Sweden.)

Figure 6.25 A hill or slope for alpine skiing and snowboarding must be well groomed and perfectly prepared. **a)** Careful piste grooming and preparation with machines is important; **b)** a snowboard slope has to be perfect; **c)** an amputee competes well in alpine skiing. (With permission, by Bildbyrån, Sweden.)

Equipment

From a skiing safety standpoint, there is no doubt that ski bindings are the most important factor. The number of injuries caused by the ski as a lever to bend or twist the leg has decreased significantly, especially since the 1980s. After the so-called carving skis were introduced, injury rates in general have declined by 9%. Female skiers who have not adjusted and tested their bindings recently have a higher risk of injury compared with those who have more recently checked their bindings. Bindings require repeated cleaning, lubrication and re-setting and should furthermore be serviced at least once a season. Bindings should be looked after and do not borrow someone else's skis unless it is possible to re-adjust the bindings to a correct setting!

Tip

It is very important to adjust the bindings regularly since the injury risk thereby decreases.

The perfect binding has still not been invented. The ski boots should be comfortable and fit well. They will distribute the load on the leg in both forward and backward tilt. In the transition to the binding the boot must meet internationally recognized standards.

Tip

Despite progress, there is currently no binding design, setting or function that can protect the knee and lower extremities from serious injury.

Recent research shows that traumatic brain injury is the leading cause of death for skiers and snowboarders. The majority of head/face injuries involved nervous system injuries/concussions and many were serious. Across all disciplines, the injury incidence was higher in women than in men. Safety helmets clearly decrease the risk and severity of head injuries in skiing and snowboarding and do not seem to increase the risk of neck injury, cervical spine injury or risk compensation behavior. Helmets are strongly recommended during recreational skiing and snowboarding.[18] Helmet use is almost 100% in 10–15-year-old skiers for whom helmets are mandatory. Helmet use decreases slightly during adolescence.[19]

Type of injuries

The most common injury associated with skiing is distorsion (sprain) of the knee joint, which accounts for 23% of all alpine ski injuries. Anterior cruciate ligament (ACL) injuries are the most common diagnosis in both downhill and freestyle, and represent 38% of all knee injuries. In downhill at the World Cup level, there is an incidence of knee injuries of 3.2 per 1000 rides. Other common injuries include: ligament injuries of the thumb (10%), abrasion and cuts (8%), shoulder contusions (5%) and crushing and clamping injuries caused by the edge of the ski boot (4%). Tibial fractures represent about 3–4% of all injuries, which is a dramatic decrease compared with the 1970s.

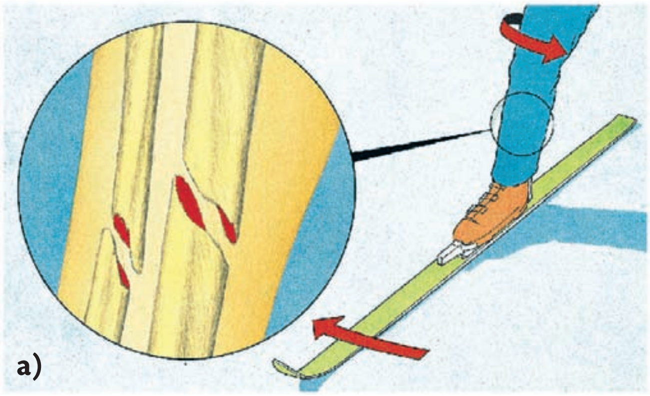
Since 1980 there has been a dramatic increase in the number of ACL injuries, which in the early 1970s accounted for less than 1% of all ski injuries. There are significant differences between the skiers with predominantly severe injuries to the medial (inner) collateral ligament (MCL) and skiers with isolated ACL injuries. Several of the injuries to the ACL were caused by backward falls. The people who suffered an ACL injury were more skillful and more often male. Those who suffered an injury to the MCL were more often women. Those with torn ACL had a higher and stiffer ski boot than a control group of riders in a particular study.

Recent research verifies that the risk of ACL injury is greater in female athletes. The findings suggest that core strength is a predominant critical factor for ACL injuries in young ski racers. Interestingly, good alpine skiers have an increased risk of ACL injury if they have a parent who has had an ACL injury, compared with those without any ACL injury.

Injury mechanisms

In the 1970s, the most important factor in ski injuries was a major load on the lower limb with excessive external rotation. Other mechanisms have also been described, such as internal rotation of the tibia relative to the femur (Figs 6.26). In the 1990s, new injury mechanisms have been responsible for serious injuries, especially to the ACL.

A common injury mechanism is that the skier falls backward, so that the ski boot's shaft causes an anterior drawer of the upper part of the tibia (Fig. 6.27A). Female skiers have a threefold higher risk of injuring their ACL than men. The mechanism seen in total ruptures of the ACL has shown that the ski boot caused the injury. After a jump the skier lands on one ski while slightly off balance, with the upper body leaning backward. The rear end of the ski hits the snow first, the ski cuts into the snow and the ski boot forces the tibia shaft forward. When the skier lands the knee is fully extended, and the opposite arm is thrown back in an attempt to regain



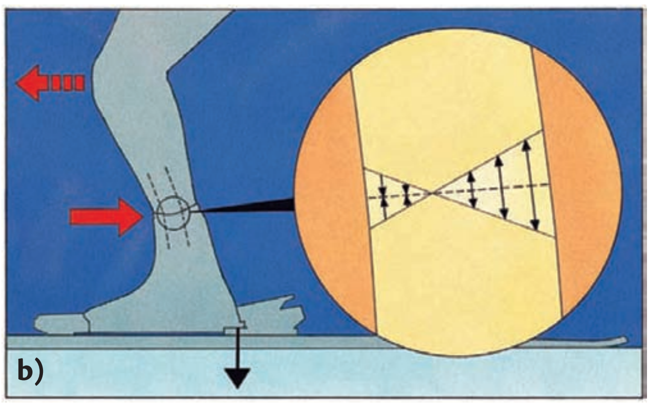


Figure 6.26 Injury mechanism in skiing. **a)** Fracture of the tibia caused by a rotational trauma; **b)** fracture of the tibia caused by a flexion trauma.

balance. The actual ACL injury occurs at the moment when the foot is pressed flat against the snow. The fixed forward tilt built into modern ski boots contributes to this type of injuries.

Another mechanism in the case of injuries to the ACL is when the skier falls uncontrollably (Fig. 6.27B). The only way to prevent that injury would be if the anterior ski boot could release or allow the ankle to bend down. This injury mechanism is unique to ski trauma and is called 'phantom foot'.

When the skier falls backward the ski is lifted so that only the inner edge of the ski behind the skier's foot is in contact with the snow. This inevitably leads to the ski turning and causes an internal rotation of the tibia relative to the femur. This occurs when the knee is bent more than 90°. This mechanism can cause isolated injury to the ACL or injury to the lateral or posterior/lateral parts of the knee. This mechanism is probably more common than the anterior drawer caused by the ski boot.

So-called carving skis have become increasingly popular over the past 15 years. New research has shown that when using these, a fall forward with rotation was the most frequently reported cause of ACL injuries (51%) compared with backward falls (29%).

Figure 6.27 There are two major classifications of knee injury mechanism in alpine skiing. **a)** Landing on the tail of a ski from a jump, mogul or change in terrain may leave the skier's body and knee in extension. The high boot back hits the back of the tibia, forcing it forward and tearing the anterior cruciate ligament; **b)** the injury mechanism called the 'phantom foot'. The skier is falling backwards, usually sitting back at an angle on the uphill ski. Only the inner edge of the posterior part of the ski is in contact with the snow. The ski turns and causes an internal rotation of the tibia relative to the femur and knee ligaments are damaged. There are six specific criteria: uphill arm back, skier off balance to the rear, hips below the knees, uphill ski unweighted, weight on inside edge of downhill ski tail and upper body generally facing downhill; if they are all present, then a serious knee injury is imminent. (Courtesy of Profs. Robert J. Johnson and Carl Ettlinger, University of Vermont, Burlington, Vermont, USA.)

A new mechanism of ACL injury has been reported in World Cup skiers, i.e. the very best. This starts with a valgus load, which tightens the MCL, and compression of the lateral joint chamber arises. This compression and/or an anterior drawer or forward sliding of the upper portion of the tibia due to a powerful quadriceps muscle contraction causes an ACL rupture through a simultaneous internal rotation of the tibia.

The combination of high, stiff ski boots and bindings that cannot release upward at the toe is at least partly responsible for the unfortunate increase in ACL injuries. It is obvious that modern ski equipment is not very efficient when it comes to protecting the ACL. A large number of serious injuries are caused by skiing, from the large forces that the unprotected human body is exposed to, because of the unnatural extension of the foot through the system: ski–binding–boot. As much as 30% of all ski injuries are probably a consequence of ski bindings which have not worked properly.

Return to skiing after serious knee injury from skiing

Nordahl *et al*. reviewed skier's return to skiing after injury.[20] Male skiers in the study reported confidence in their own ability, active strategies and support on all levels, as well as enhanced physical ability. The female skiers did not return to their pre-injury level of competitive alpine skiing. They stated a lack of support on all levels, deterioration in their physical ability and two out of three reported passive strategies and no or ambivalent confidence in their own ability. The most important factors were family support, support on all levels, access to a physiotherapist and time given.

Tip

For the risks of skiing injuries to be reduced, it is required that the ski bindings are well designed, are adjusted properly to the ski boot and are regularly checked. All skiers must also prepare well through regular good strength training.

Football/Soccer

Football/soccer is the most popular sport worldwide and is practiced at a competitive level by over 265 million licensed players, in addition to many children and recreational athletes (Fig. 6.28). About 30 million of the licensed players are girls/women and the number active is growing rapidly around the world. Football/soccer is organized globally by FIFA (Federation Internationale de Football Association), founded in 1904 – a federation of all the world's national football associations, today with over 200 members. The national associations are organized geographically into six confederations, South America, North America/The Caribbean, Africa, Asia/Oceania and Europe.

Figure 6.28 a, b) Football/soccer is so much fun and it is the most popular sport in the world! (**a**) with courtesy of the Swedish Football Association; **b)** courtesy of Tommy Holl, GAIS, Göteburg, Sweden); **c)** football/soccer is the world's largest youth sport with millions of active players (photo, Lars Peterson jr).

FIFA and its six regional confederations are responsible for the players' health in the short and long term. The medical service and the responsibility for the players' health lies with FIFA's medical committee, composed of physicians with various specialties from different confederations. The goal is that each national association will have its own medical committee and each confederation a common medical committee. To assist in this effort FIFA Medical Assessment and Research Centre (F-MARC) was formed in 1994, to be responsible for the prevention of injuries and diseases related to football/soccer. It is also their mission to improve and spread the knowledge about diagnostics, treatment, rehabilitation and prevention globally in the world of football/soccer.

F-MARC and its six regional confederations work for the players' health in the short and long term in three areas:

- Anti-doping in cooperation with WADA.
- Epidemiological studies of injuries and diseases relevant to football/soccer, as a basis for preventive measures.
- Research and education in order to develop and improve football/soccer medicine through educational programs such as 'teach the teacher'.

FIFA have accredited over 30 centers. It is important to cooperate with these accredited centers through universities globally, by implementing preventive programs against injury and illness. In several parts of the world evaluation of many prevention and education programs in football/soccer medicine are now underway.

Football/soccer's biggest problem is the increasing frequency and severity of injuries (Fig. 6.29). The increasing risk of permanent disability after a severe injury, such as early development of osteoarthritis of the knee and hip joints secondary to cruciate ligament, meniscus and cartilage injury. Such an injury often results in long breaks to secure proper rehabilitation and often a too early end to the athletic career. Also injuries caused by overuse increase, with risk for prolonged absence from the game.

Other problems are of an internal medical nature such as sudden cardiac death (see Chapter 7, p. 129), infectious diseases, asthma, diabetes, obesity, malnutrition, etc. These may have different significance in different geographical regions, such as infectious disease in Africa.

Injuries in football/soccer

Injuries in football/soccer occur both during competition and training. In children and youth football training injury incidence was nearly constant for players aged 13–19 years, ranging from 1 to 5 injuries per 1000 hours of training. Match injury incidence tended to increase with age through all age groups, with an average incidence of about 15–20 injuries per 1000 match hours in players older than 15 years. Between 60 and 90% of all football injuries were classified as traumatic and about 10–40 % were overuse injuries. Most injuries (60–90%) were located at the lower extremities with the ankle, knee, and thigh being most affected. Fractures were more frequent in children younger than 15 years than in older players.[21] The authors conclude that three main areas seem to be of particular relevance for future prevention research in young football players: (1) the substantial number of severe contact injuries during matches; (2) the high number of fractures in younger players; and (3) the influence of maturation status and growth spurts.

Male players sustain 17–51 injuries/1000 match hours and 2–6 injuries/1000 training hours and in general, slightly more injuries than women. In the Swedish top league, Allsvenskan, in 2005 female players had an injury incidence of 3.8 injuries/1000 training hours compared with men (4.7) and during matches 16.1 injuries/1000 match hours while men had 28.1. However, there was no difference concerning severity of injuries.

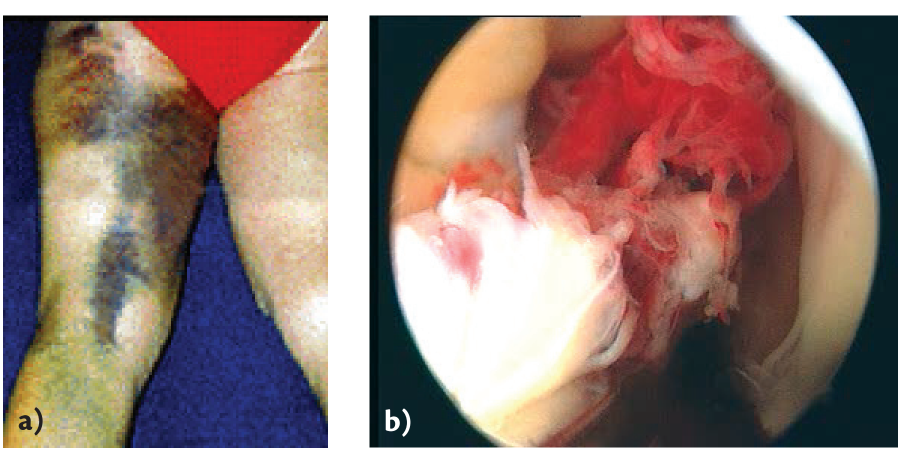


Figure 6.29 Unfortunately football/soccer players can sustain serious injuries in muscles and joints. **a)** An hematoma/bleeding of the skin indicates a severe hamstring injury; **b)** anterior cruciate ligament injury seen at arthroscopy. (Courtesy of ArtroClinic, Stockholm, Sweden.)

Between 70 and 90% of injuries are located in the lower extremity. Around 70% are traumatic, such as ankle and knee distortions, contusions and muscle rupture in the lower leg and thigh. About 30% are overuse injuries, particularly to muscles, tendons, tendon attachments and bone. Hamstring injuries are the most common injuries in both sexes. Groin/hip joint injuries are much more common in men, while knee injuries are more common in women.

Knee ligament injuries cause absence from football/soccer in 31% of men and 37% of women. New injuries in the same location, so called re-injury or recurrent, occur in 11–22%.

Risk factors for injury

Prevention requires an analysis of risk factors for injuries in soccer as well as studies of the epidemiology and injury mechanisms. These risk factors are divided into internal (intrinsic) and external (extrinsic) factors.

Internal factors are related to the player himself such as age, sex, height, weight, nutrition, strength, endurance, and anatomical abnormalities such as flat feet, increased bow-leggedness (genu varum) and knock-knees (genu valgum).

External factors are related to the environment that the individual is working out in, e.g. playing field and weather conditions, rules, protective equipment, relationship of shoe to surface, foul play, etc. Recent research shows that injuries in football/soccer may have climate or surface as risk factors.

Climate factors

Ankle sprains and ACL injuries are generally more likely in teams playing in warmer climate zones, whereas Achilles tendinopathy are more likely in teams playing in cooler zones.

Playing turf as risk factor for injury

The effect of synthetic playing surfaces on the risk of injury in athletes is frequently debated in the orthopedic literature. Biomechanical studies have identified increased frictional force at the shoe–surface interface, theoretically increasing the risk of injury relative to natural grass. This increase in frictional force is potentially relevant for the risk of ACL rupture, where non-contact mechanisms are frequent.

Football/soccer is increasingly played on artificial turf. The development has been very rapid as it offers considerable advantages, for example, independence from weather, so allows much more playing time.

The first generation artificial turf, e.g. AstroTurf, had short-pile nylon fibers, and no infill (minimal padding). This turf was installed in the 1960s in the Astrodome in the USA. The first football pitch with artificial turf in Europe was installed at Valhalla in Göteborg, Sweden in 1975. A scientific evaluation of the first 2 years was made of the risk and risk factors for injuries. They observed that football played on artificial turf in cleated boots increased the rate of injury.[22] The second generation synthetic turf systems featured sand infills. Today there is a third generation artificial turf (e.g. FieldTurf) available, with longer-pile polyethylene fibers, mixture of (silica) sand and (cryogenic) rubber infill and shock pads.

Biomechanical studies have identified increased frictional force at the shoe–surface interface, theoretically increasing the risk of injury relative to natural grass. Studies have shown that there are significantly higher peak torque and rotational stiffness on artificial turf. Studies on American football show that the ACL injury rate is higher on third generation artificial turf. The risk for injury is less studied in football/soccer. So far no difference in risk for injury and in injury severity between natural grass and artificial turf has been found. There is a difference in injury pattern as there are more ankle sprains and fewer muscle strains on artificial turf.

Injury mechanisms

Football/soccer allows, by the rules, fair body contact between players, which still can cause injuries. Unfair body contact causes about one-third of all injuries and many of these could be prevented by changes in the regulations and/or the strict application of the rules by the referee. Through registration of the injuries occurring during training and competition, combined with studies of TV recordings from matches, the mechanisms causing serious injuries have been identified. These scientific studies have resulted in rule changes not allowing, e.g. tackles from behind, from the front and from the sides, which can cause broken bones or serious knee injuries.

Elbow tackles to the head have been shown to cause concussions and other head injuries and were increasing in number. Forbidding elbow tackles in recent years has resulted in a decrease in the number of head injuries.

Injury registration

An important background to injury prevention is the registration of injuries during competition and training related to the match and exercise time, injury location, type of injury, severity, injury mechanism, un-fair play

Figure 6.30 Tackles can cause injury. a) Tackle from the side; b) tackle from behind, which can lead to an unbalanced landing; c) tackling in combination with a jump increase the risk for injury. (With permission, by Bildbyrån, Sweden.)

and referee assessment of the incident. It is important to use the accepted definitions of injuries, injury types and severity. Distinction between traumatic injuries and overuse injuries is necessary. Trauma is caused by momentary overload and may result in muscle rupture of tendons; repeated load – overload – causes tissue damage with inflammatory conditions in the muscle–tendon complex as a result.

Injury survey

About 70% of all injuries are traumatic injuries of which about 30–50% are due to un-fair play; the remaining injuries are overuse injuries. Between 70 and 90% of all injuries affect the lower extremities, and about 70% of them are traumatic injuries to the knee and ankle (Fig. 6.30).

A traumatic injury is caused by body contact by external forces, often in conflict with internal forces, and occurs during matches in about 60% of men and approximately 55% of women. 40–50% of the injuries in connection with training occur due to internal forces (intrinsic forces that are accelerated and decelerated by the individual) without body contact and only 25–35% are due to body contact. Head injuries account for between 10 and 20% of injuries, of which in both men and women 80% are caused by head-to-head contact and elbow–head contact (Fig. 6.31). By forbidding elbow tackles these injuries have been reduced by half.

Traumatic injuries and acute muscle and tendon ruptures in the lower extremities

The most common injury locations are the ankle (about 20%), knee (about 20–25%), thigh (around 25–30%), and groin (about 10%).

Figure 6.31 An elbow tackle against the head can cause concussion and will usually be given a yellow or a red card by the referee. (With permission, by Bildbyrån, Sweden.)

Ankle injury

Pivoting trauma (distortion trauma) occurs both as a result of internal forces, such as when landing after a jump or cutting, and/or by external forces, such as tackles to the lower leg, usually with the shoe cleats fixed to the ground, often associated with foul play. Most often the lateral ligaments are injured, less often the medial ligaments and syndesmosis (see p. 509). Excessive force can result in ankle fractures (see p. 519).

Tip

The risk of a re-injury or recurrent injury in the ankle is five times higher after a previous injury than in an un-injured ankle and 5–10 times greater in the first 6–12 months after the first injury.

Prevention

- Preventive training of strength, endurance and balance (neuromuscular, proprioceptive training).
- Preventative taping, especially after previous and recurrent sprains.
- Optimal healing time and rehabilitation before returning to training and competition.
- The use of shin guards that cover the lower leg well, in front, outside and the insides and ankles.
- Use of shoes with proper cleats and friction relative to the surface (Fig. 6.32).
- Improve the assessment of foul play by better training of the referees at the national level.
- Inform the young players of the risks of foul play and the importance of respect for the opponent (Fig. 6.33).

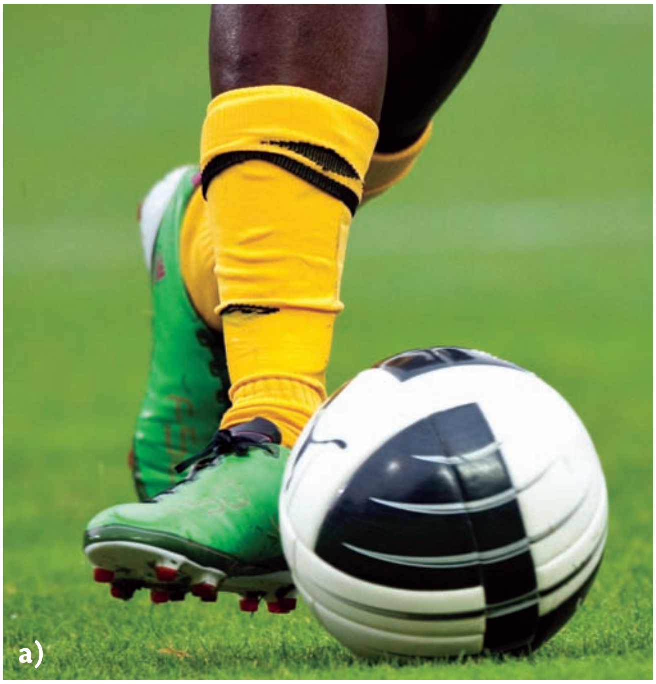


Figure 6.32 a, b) The football/soccer shoes should fit as well as a cast of the foot, so that the ball can be handled with 'feeling'. (With permission, by Bildbyrån, Sweden.)

Knee joint injury

In men most knee injuries are caused by external forces with body contact and by internal forces, while women usually sustain an injury by internal forces without body contact, through increase in speed (acceleration) and/or decrease in speed (deceleration), improper landing after a jump and pivoting and cutting. Foul play with tackles from behind, from the sides and front contributes greatly to the number of serious injuries. A knee injury can mean the end of a football career.

Prevention

- Preventive training of eccentric leg strength and endurance of primarily the quadriceps and hamstring muscles on the anterior and posterior aspects of the thigh is of great importance, in order to improve the active stability of the knee joint, balance training (neuromuscular, proprioceptive training) and core stability.
- For young women, the training of proper landing technique and muscle strength can significantly reduce injury to the ACL (see pp. 401–6).
- Taping, elastic heat protection, and orthotics may in some cases have some preventive and protective effect.
- The correct choice of shoes in regard to cleats and friction against the surface is important.
- Optimal healing time and rehabilitation, controlled with functional testing and measurement of muscle strength before returning to training and competition is essential to avoid a new injury.

Figure 6.33 Situations that may cause knee injuries are often associated with foul play and should be avoided if possible because knee injuries are often serious in football/soccer. **a)** Skillful offensive players are often well guarded by the defense; **b)** sliding tackles can be difficult to control. (With permission, by Bildbyrån, Sweden.)

Research on prevention

F-MARC Projects – general preventive programs in football/soccer

FIFA 11 is a preventive program including 10 simple exercises and education about the importance of fair-play to prevent injuries in soccer. Studies in Switzerland have shown a reduction of injuries during training by 25% and during matches by 12% if the program is completed. It can be recommended as part of warming up before every match and training for children, young people and recreational players.

FIFA 11+ is a more demanding and developed preventive program for juniors and seniors at all levels and has shown a reduction of injuries during training by 37% and during matches by 29%, including contact injuries. Both programs are recommended as warming up before competition and training.

Knee injury preventive programs

Knee injuries are common in football/soccer and teenage girls are particularly exposed. One of football/soccer's worst nightmares, the ACL injury, forces some players to give up soccer and many to suffer future knee problems. ACL injuries are 2.6 times more common in young girls compared with men/boys.

The so-called PEP project – a FIFA sponsored project on the prevention of ACL injuries in female soccer players aged 12–16 – has shown that preventive training can be effective.

'The Knee control project' was initiated in 2008 by the Swedish Football Association and Folksam Insurance Company. The purpose was to educate football/soccer coaches, managers, parents and players how to train 'knee control' with the aim to prevent knee injuries in female players aged 12 and over. Over 100 physical therapists across Sweden have been trained in 'knee control'. A CD (Knee control - Prevent injuries - Perform Better) contains simple sport-specific exercises to be used during warm-ups. The program has been adapted to football/soccer's specific movement patterns. The exercises can be individually adapted.

Tip

The goal is to learn good movement patterns with good knee control at an early age and to improve core strength, leg strength, landing technique, balance and coordination.

The project recommends that clubs do the knee control exercises regularly during practices. It takes about 10–15 minutes during warm up, preferably twice a week. The important thing is that the exercises are made carefully, with the goal of learning the movement patterns that prevent injuries (Fig. 6.34).

'The Knee control' study

The 'Knee control study' is the largest scientific study in the world with the aim of preventing injuries in sport.[23] About 500 of 700 possible teams of girls born 1992–1996 in 8 of 24 Swedish football/soccer districts agreed to participate in the study. Overall, 341 teams completed the study with more than 4500 players.

Results: the group that had trained in knee control had a significantly lower risk (two-thirds) of suffering an ACL injury compared with the control group. Players who trained in the program at least once a week during the season only suffered half as many acute knee injuries in total, including knee injuries sustained without contact with another player and severe knee injuries with more than 4 weeks of absence from play.

Tip

In summary, this large study showed that a simple exercise program of 10–15 minutes significantly reduced the risk of serious knee injuries in girl football/ soccer players.

The education of referees on injuries and injury risks associated with foul play should be improved and strengthened, as well as assessing the impact of foul-prone players on the game (Fig. 6.35).

Figure 6.34 a, b) In young football/soccer players injuries often occur on body contact but also on landing after jumping. (**a)** with permission, by Bildbyrån, Sweden; **b)** with permission by the Swedish Football Association).

Tip

Education of all players, especially the young, as well as of referees, coaches and other team members stressing the importance of fair play, preventive training and other preventive aspects would be of great value and in our opinion would have great impact on injury prevention.

Figure 6.35 Well-educated referees with civil courage are very important for the game. **a)** A good referee must be able to talk to and calm the players. The players must not gather around the referee to protest!!; **b)** a side line referee has an important role to play; **c)** a yellow card should be taken seriously and met with respect by the players; **d)** a red card should be used in situations where there is a major risk to other players. (Courtesy of Swedish Football Association.)

Thigh muscles

Injuries to the thigh mainly include muscles and sometimes the bone, the femur. Muscle injuries are dominating and have increased in number and severity over the last decade especially in the hamstring muscles at the posterior aspect of the thigh.

Hamstring injury is currently the most common injury in football/soccer. This muscle group is involved in 37% of all muscle injuries in top level elite football/soccer. 83% of these are to the biceps femoris muscle, 12% to the semimembranosus and the semitendinosus quadriceps are injured in 17%.

Common mechanisms are contusions (blunt trauma) by, for example, a knee to the outside-front part of the thigh, causing tissue damage and bleeding also in the deeper lying tissue, when the muscle is pressed firmly against the underlying femur. Bleeding may also occur at a sudden overload in explosive actions and are associated with muscle–tendon ruptures.

Foul play, poor warming up, increased intensity and speed of the game as well as insufficient time for recovery are all important background factors causing injury. There is a high risk of recurrence/re-injury at early return and incomplete rehabilitation. The risk is up to 30% of hamstring injuries.

Prevention

- Reduce extensive scarring in the area through adequate management during the acute phase.
- Routinely carry out thorough warming up of the major muscle groups.
- Use warming protection – e.g. thermal pants in cold weather.
- Use well-studied preventive programs with eccentric strength, endurance and stretching including core stability strength and balance.
- Complete water and energy upload with re-filling during competition and training.
- Secure optimal healing time related to the severity, treatment and rehabilitation.
- Deal with foul play.

Groin pain and injury

Pain is the predominant symptom in the groin region and often results in chronic pain after repeated overload (Fig. 6.36). Acute traumatic injuries are uncommon. Acute instantaneous overuse injuries occur with rupture and avulsions of the adductor's origin at the symphysis pubis (usually adductor longus), iliopsoas tendon insertion on the medial and posterior aspects of the femur and the rectus femoris' origin above the acetabulum. A rupture in the rectus abdominis insertion on the top of the symphysis occurs more rarely. Growing children and adolescents can be subjected to avulsions from the bone attachments (avulsion fractures) (see p. 567).

Figure 6.36 Groin injuries and pain are common in football. (With permission, by Bildbyrån, Sweden.)

Prevention

- Preventive eccentric strength and endurance training as well as balance, core stabilization and stretching.
- Thorough warm-up before every practice and competition.
- Thermal pants in cold weather.

Overuse injuries in the lower extremities

Repeated overload causes tissue damage, which easily turns to prolonged inflammatory pain syndromes. The higher the frequency, the higher the weight/load, the greater the risk of chronic tissue damage and pain; most dangerous is the combination of maximum frequency/maximum weight/load. Approximately 30% of all football/soccer injuries are overuse injuries in muscles, tendons, tendon sheaths, muscle–tendon transition, tendon attachment to the bone, bursae and stress fractures in the bones. Repetitive training elements are in itself a risk, e.g. technique and shooting practice. Anatomical background factors (intrinsic factors) may be a contributing cause of overload.

Prevention

- General preventive measures can be used in similar conditions.
- Adequate treatment and rehabilitation in the acute phase is the most important prevention.

- All training should progress over time and allow for recovery and tissue adaptation.
- All loads give a reinforcement and increase in tissue mass, called hypertrophy. Without load the tissue will decrease in mass and strength (hypertrophy).
- All weight training should be done by gradually increasing the frequency and weight of time for adaptation. Longer rest or immobilization reduces tissue mass and strength. After such occasions, all training should start from a low level and slowly progress.
- General endurance training and speed are the foundation of all prevention.
- Preventive training should be performed with proper technique and strength training adapted to age.
- Thorough warming up of large muscle groups, mobility, flexibility, stretching of the muscle–tendon complex and cool-down after training and matches.
- Water and energy upload and refilling during and after training and matches.
- Otherwise, see Chapter 4 on prevention.

Concussions

In football/soccer concussions make up 2–3% of all injuries, this is the same rate as for American football! The most common cause of a concussion is when one player's head strikes the head of another player. Other causes for concussions occur when a ball strikes a player's head or when an elbow or arm strikes the head. One problem is that a player does not want to leave the field and stop playing.

FIFA and UEFA have therefore decided on some rules to complement the Interpretation of the Laws of the Game and Guidelines for Referees as follows:

- In the event of a suspected concussion the referee stops the game to allow the injured player to be assessed by the team physician. In principle this should take no more than 3 minutes, unless it is a serious incident.
- Any player suffering a head injury that requires assessment for potential concussion will only be allowed to continue playing after the assessment, on specific confirmation by the team physician to the referee of the player's fitness to do so.

There is limited research on how common concussions are in football/soccer but it is an increasing problem. The following possible prevention steps have been suggested at least for young players:

- Teach proper instruction on the correct way to head the ball.
- Adjust the ball to the appropriate size for the age of the players. Smaller balls are less likely to cause injury.
- Recommend 'no heading' rules for younger players.
- Use padded goalposts.

Summary of when a team's medical team should enter the football pitch

When a player sustains a trauma and an injury is suspected, the referee is entitled to call the medical team and team physician from the sideline to provide medical assistance to the player on the pitch.

There are two situations in football/soccer where the team physician can run onto the pitch without being asked by the referee, namely when there is a suspicion of:

- Sudden cardiac arrest.
- Severe head injury, such as concussion.

This should be done at the sole discretion of the physician, according to FIFA.

Ice hockey

Ice hockey and bandy are two very popular team sports in the winter in the northern hemisphere. As the number of indoor halls in both ice hockey and bandy are increasing rapidly, the previous reliance on natural ice and climate have declined in recent years. The rapid development of games in indoor halls have led to the season thus been extended over the years with competitions from September to April–May and has meant hockey has quickly spread to the south in North America, southern Europe and eastward into Siberia–Asia. (What is written below on injuries and prevention in hockey also applies largely in bandy.)

Ice hockey is a fast and intense team sport in which players can achieve high speeds such as 50 km/h at the same time as the rules allow body contact. The playing surface is hard and unyielding and contained by the rim and Plexiglas around the board. Contacts with the board and with the goal cage can cause injury. The stick and the hard puck as well as the sharp blades on the skate further increase the risk of injury, when in contact with the player. When shooting the puck with the stick it can reach speeds up to 160 km/h.

Injuries in ice hockey can sometimes be severe, but in ice hockey the importance of preventing injuries was realized early on. Ice hockey, along with American football and bandy, adopted and used protective equipment early in the sports' development and subsequently made rule changes to reduce the number and severity of injuries (Fig. 6.37). Swedish ice hockey and Swedish companies

Figure 6.37 a–c) Injuries can happen in sports on ice such as ice hockey **a)** and bandy **b, c)** (with permission, by Bildbyrån, Sweden).

were early in the development of protective equipment. Many successful top level players contributed in the 1950–60s with their experiences and ideas for the successful development of the helmet Spaps, the WM (Jofa-) and ABC helmets. Meanwhile, the Swedish Ice Hockey Association developed standards and test methods for helmets and introduced early a new rule on the mandatory use of helmets for ice hockey games. The Swedish as well as the Canadian industry have been very instrumental and have become a world leader in the development of protective equipment.

Hockey organizations

International Ice Hockey Federation (IIHF)

Ice hockey is regulated as a game globally by the International Ice Hockey Federation (IIHF), founded in 1908. The federation has been dominated by North America (USA and Canada) and Northern and Central Europe (Russia and the Nordic countries). The sport is spreading rapidly southward, both in America and in Europe. Professional ice hockey is the most developed in North America and the elite is organized in the National Hockey League (NHL), while the Russian newly established professional league KHL, including Siberia, is of growing interest. In Europe, the trend towards full-time professional leagues is continuing primarily in Northern and Central Europe.

An important difference between North America and the rest of the ice hockey world is the size of the rink, which is smaller in the US and Canada, resulting in a tighter game with more body contact and thus increasing the risk of injury. Injury prevention requires increasingly detailed statistics of injuries with common definitions in both games and training. The national ice hockey associations have an important task in this to obtain a basis for improved prevention of injuries. Internationally, among others, multiple Olympic team sports within the IOC have been cooperating to create common definitions and injury forms, which opens the possibility of comparing the injury panorama and mechanisms and to initiate preventative measures, such as rule changes in ice hockey, football/soccer, handball, etc.

The National Hockey League (NHL)

NHL was founded in 1917 following the demise of its predecessor league, the National Hockey Association (NHA). The 'Original Six' teams are the Boston Bruins, Chicago Black Hawks, Detroit Red Wings, Montreal Canadians, New York Rangers and Toronto Maple Leafs.

The league doubled in size for the 1967–68 season. The NHL today has 30 teams across the continent.

NHL games are played on a rectangular hockey rink with rounded corners surrounded by walls and Plexiglas. It measures 60.96 m (200 feet) by 25.91 m (85 feet) in the NHL, approximately the same length but much narrower than IIHF standards.

In the NHL, fighting leads to major penalties, while IIHF rules call for the ejection of fighting players. Usually a penalized team cannot replace a player that is penalized on the ice and is thus one player short for the duration of the penalty. The NHL and IIHF differ slightly in playing rules, such as the areas of play for goaltenders, helmet rules, officiating rules, timeouts and play reviews.

Player safety has become a major issue for the NHL especially the last few years after 2010. Concussions caused by hits to the head have had significant effects as elite players were being taken out of the game. To aid with removing high speed collisions on icing, the league recently mandated hybrid no-touch icing.

Swedish Ice Hockey Association (SvIF)

SvIF organizes all competitive ice hockey in Sweden and has about 68,000 licensed players in men's ice hockey. Ice hockey for women started in Sweden in the late 1970s/beginning of the 1980s. Women's ice hockey differs in rules on one essential point and that is that body tackles are prohibited. The injury incidence is thus generally lower in women's ice hockey according to studies in American college ice hockey. Through the years, the Ice Hockey Association has shown a keen interest in injury prevention and the mandatory wearing of a helmet was introduced early for all players, and later facemasks for youth players and visors for adult players. These measures were initiated based on statistics that showed the number of head injuries such as fractures, concussions, eye and dental injuries were increasing in number and severity, but also on the active work of the Association to develop standards and test methods for helmets and face masks. Within European standards, testing and approval of personal protective equipment are handled by the Personal Protective Equipment, a consumer division of the European Union.

Female ice hockey

Ice hockey for women started to grow in the 1970s but is today one of the fastest growing women's sports in the world. The number of participants increased 350% in the last 10 years. In 2011, Canada has >85,000 women players, the US> 65,000 while Finland has >5,000, Sweden 3,000 and Switzerland >1,000. Women's ice hockey was added as a medal sport at the 1998 Nagano Winter Olympic Games and this was a big boost to the sport.

There are some differences in the women's game compared with the men's. Body checking is not allowed in women's hockey and in competitions women are required to wear protective full face masks.

Injuries and prevention

Injuries in ice hockey occur during matches (about 75%) and in training (25%). At the elite level, the injury incidence is reported to be between 50 and 78 injuries per 1000 match hours. Trauma causes injuries in about 85% and overuse in about 15%. The most common areas of injury are the head, shoulder, hip and knee. Head and face injuries comprise up to 40% of the total number of injuries and include concussion in 3–7%, and in general a lot of lacerations and dental injuries. Nearly 40% of knee injuries cause time loss, i.e. absence from the game. Groin injuries cause time loss in approximately 15%, back injuries in 10% and shoulder injuries in about 10–20%. The most serious injuries are to the head and cervical spine and can result in prolonged convalescence. These injuries have increased in incidence in recent years. Recurrent concussions tend to result in extended absence from the game and continuing problems.

Prevention requires an analysis of the external and internal risk factors in ice hockey. Particularly important are external factors such as rink size, board and Plexiglas, goal cages, ice condition, rules, protective equipment, foul play, etc. The playing position on the rink can play a role: 60% of injuries are in forwards, 36% in defenders and 4% in goalkeepers.

Injury mechanisms

Ice hockey allows fair body contacts and tackles. Collisions and intentional tackles can occur at high speeds and at the same time contact with the board or ice can cause serious injuries in about 25% of cases. Contact with the hockeystick, especially in the face, is responsible for about 25% of injuries, while the puck is the cause injury in over 10% (see Fig. 6.38).

Overuse injuries occurs in about 15%, usually affecting muscles and tendons of the extremities and back. Through analysis of video recordings it has been demonstrated that elbow tackles to the neck, head and possibly falls onto the ice or tackles against the board or Plexiglass cause head, spine, shoulder and chest injuries. Tackles against the edge of the board can cause injuries to the spleen, liver and kidney (see pp. 324–5). Foul tackles

Figure 6.38 The injury mechanism can vary in ice hockey. **a)** Game intensity increases when there is a scoring opportunity and so does the risk of injury; **b)** tackle against the board can cause serious injury (with permission, by Bildbyrån, Sweden).

from behind and knee tackles from the side can cause severe bone and joint injuries and muscle bleeding in the thigh (see Fig. 6.39).

Injury survey/prevention

Head injuries (see p. 310) can be divided into skull injuries and facial injuries. Skull injuries include lacerations of the scalp, skull fractures and concussions, that can affect the cervical spine. The injury mechanism may be direct trauma, such as an elbow or shoulder tackle to the head or contact with the board, Plexiglass or ice, or that the puck or stick hits the head.

Preventive measures

Use of an approved helmet reduces the risk of skull fractures, wounds and concussions, but does not prevent brain acceleration–deceleration (compare coup and contrecoup effects, i.e. brain injury that occurs both at the site of trauma, as well as on the opposite side of the brain, see p. 310). Coup injuries occur when a moving object impacts the stationary head and contrecoup injuries are when the moving head strikes a stationary object.

Rules should be applied and foul play dealt with.

Figure 6.39 Violations of the rule must be penalised. **a)** Head injuries can be caused in many ways; **b)** a foul tackle can give head injuries; **c)** a player carried out on a stretcher with a head injury. (With permission, by Bildbyrån, Sweden.)

Facial injuries (see p. 316) include lacerations, facial fractures (jaw, cheek and nose) and dental injuries, caused by stick strokes and hits by pucks in the face.

Preventive measures

- Use of approved visor or full-face protection has reduced significantly the number of dental and facial injuries of all kinds.
- An intraoral individually tested mouth guard reduces the number of dental injuries further. A visor reduces eye injuries.
- Apply rules and penalize foul play. Young players should be given information about the risk of injury and foul play early in their careers.

Tip

All ice hockey players should wear full face protection.

Dental injuries

Dental injuries (see p. 320) are still quite common among seniors because many do not use mouth guards or full facemasks as often as they should (Fig. 6.40). In young people 68% did always use an intraoral mouth guard, but only 32% used them appropriately during matches and 51% during training. The reasons given why tooth protection was not used were that players were uncertain of the effect (43%), that the mouth guards felt uncomfortable to wear (27%), that they caused difficulties in breathing (24%) and that they did not fit well (12%).

Preventive measures

Using individual intraoral mouth guard.

Shoulder injuries

Shoulder injuries (see p. 313) include traumatic shoulder joint dislocation, ligament injury and dislocation of the acromioclavicular joint (see p. 245), fractures and cartilage injuries in the humerus (upper arm) and scapula (shoulder blade). Injury mechanisms are mostly direct trauma towards the joint in a tackle shoulder to shoulder or trauma against the Plexiglass or falls on the ice (Fig. 6.41).

Preventive measures

- Using shoulder pads with protecting shell (see p. 48, Fig. 4.14).
- Penalize foul play.
- Strength training of the shoulder muscles (see p. 250).

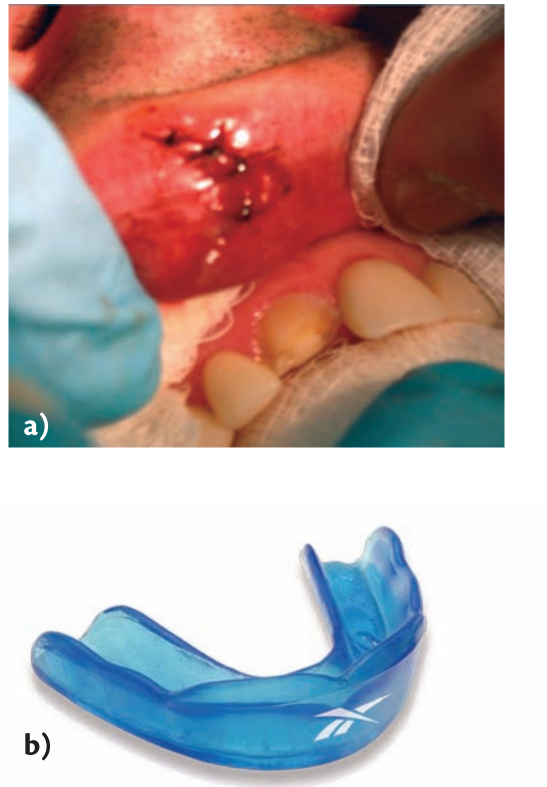


Figure 6.40 **a)** Injuries to the teeth and gums are not uncommon in ice hockey (courtesy of Dentist Paul Pincinninni, Toronto, Canada); **b)** example of mouth guard (with permission, Reebok/CCM).

Tip

It should be mandatory to wear mouth guards in combination with a full face mask in youth ice hockey. However, there are many young players reporting that they routinely do not wear their mouth guards in a proper way.

Groin injuries

Groin injuries are fairly common in ice hockey. Skating makes ice hockey a very fast team sport in an area limited by a board. This places great demands on the skating technique, with quick turns, stops and quick starts forward or backward. Thereby leg, groin, back and abdominal muscles are exposed to large and fast loads in these explosive moments of skating. In addition, the loads generated in the shooting moments, especially at slap shots, during which the whole body is involved, can be a risk factor. Examples of injuries in the groin include acute muscle ruptures and overuse injuries such as tendinopathy, groin hernia, femoroacetabular impingement in the hip joint, stress fractures, etc. (see Chapter 17, p. 356).

Figure 6.41 Shoulder injury may occur **a)** when falling on the ice or **b)** from tackles against the boards (with permission, by Bildbyrån, Sweden).

Preventive measures

- An important part of the preventive training is different moments of the start-stop-start to strengthen, especially the groin and core muscles.
- For other preventive measures see p. 116 (soccer injuries).

Knee injuries

Common injuries in and around the knee joint (see p. 401) involve the inner (medial) collateral ligament (MCL), ACL and medial meniscus. Injuries to the surface of the joint articular cartilage are not uncommon on the femur and tibia, patella and femur. During falls on to a hard surface such as ice, bleeding in the bursa in front of the knee may occur.

Common injury mechanisms

- Tackling causing a trauma towards the outside of the knee joint.
- Hyperextension of the knee joint from a tackle made from the front.
- Falls on the patella towards the ice.

Preventive measures

- Using shin guards as well as knee guards, that unload the patella and resists hyperextension. There are no protective knee guards that prevent ligament (cruciate ligaments) injuries, but a combination with a knee brace can help.
- Penalize foul tackles.
- Strengthening the quadriceps and hamstring muscles.

Muscle injury

An example can be a muscle bleeding by a thigh muscle contusion. Injury mechanism can be a violent trauma or a collision towards the outside-front of the thigh.

Preventive measures

Using pants with unloading padding on the outside-front of the thigh.

- Penalize unfair play.
- Adequate acute treatment reduces and prevents risks of complication.

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7 Injury Management Options and Possibilities

Illnesses and injuries often occur within sports. A basic rule is that the earlier an injury or illness is treated, the fewer the symptoms that develop and consequently the healing and rehabilitation time becomes shorter. In this chapter proper management in different situations is described, as well as the tools that can be used in this management (Fig. 7.1).

Figure 7.1 a–c) Proper acute management on the field can be very helpful and facilitate proper healing of the injury, thereby limiting the consequences and shortening the rehabilitation time. Emergency acute management may sometimes be necessary especially concerning high-energy trauma in cycling, speedway, etc. (With permission, by Bildbyrån, Sweden.)

Arena safety and contingency plan

A prerequisite for a proper treatment to be initiated at an early stage is that good medical equipment is available in the facility where the training and competition are conducted.

Sudden death

Sudden death in a sport arena is a rare event associated with major trauma and media attention. Most deaths are caused by sudden cardiac arrest; usually a spectator is affected. The risk is estimated to be about 1/500,000 per year, equivalent to 0–2 cases per year at a large football stadium.

In acute heart failure, usually due to ventricular fibrillation or absence of cardiac activity (cardiac arrest – asystole), urgent measures are required to increase the chances of survival.

Tip

Cardiopulmonary resuscitation with regular cardiac compressions should be started immediately especially if a defibrillator is not immediately available.

Cardiopulmonary resuscitation (CPR) is performed at a rate of about 50 compressions on the chest and underlying heart of the unconscious victim for 30 seconds, followed by 2–3 breaths into the mouth/nose and followed by 50–60 new compressions. This treatment is continued until medical personnel arrives. (According to the International Liaison Committee on Resuscitation guidelines, CPR involves chest compressions at least 5 cm (2 in.) deep and at a rate of at least 100 per minute).

The arena should have defibrillators available. A defibrillator is an electrical device that is used to restore normal heart rhythm in acute cardiac fibrillation and in acute cardiac arrest (asystole). This is called defibrillation or electrical conversion. Defibrillation should be able to be implemented in as short a time as possible, preferably within 0–3 minutes (taking into account the time it takes to reach a maximum distance with packed arena).

Defibrillation is a method where the defibrillator sends an electric shock through the chest to restore the heart's electrical conduction. The automated external defibrillator (AED) is rechargeable and instructions for using it step-by-step in emergency situations are presented below. Potential users should be trained regularly by medical personnel at the scene. Defibrillators are being increasingly used in more public places in addition to stadiums (Fig. 7.2).

The time to successfully defibrillate a possible cardiac arrest amounts to a maximum interval of 3–5 minutes. For every minute of delay the chance of survival is reduced by about 10%. When the ambulance personnel arrive they will continue with advanced CPR, including intubation and medication if necessary.

a)

b)

Figure 7.2 a, b) An automated external defibrillator (AED) should be available where sport of many kinds are being played. A heart-starter should be used by whoever comes first on the scene when there is suspicion of a heart problem. A commonly used type is HeartStart FRx, which is used by the Swedish Football Association's National teams. (Courtesy of Philips from Laerdal Medical.)

Tip

The time to the first CPR and defibrillation is most important for the survival after a cardiac arrest.

In addition there should be emergency medical equipment such as stretchers, medicines for cardiac arrest (e.g. adrenaline) and anaphylaxis, equipment for fracture fixation and spine-board available. Responsible and trained personnel should be in place. The medical team should be competent and work well together. The persons carrying out the treatment should have good knowledge of how this equipment is used.

Medical Action Plan (MAP) – contingency plan

For sports fields, schools and at large public events it is recommended that a medical action plan (MAP) is established, including who is medically responsible, communication paths, necessary medical personnel, medical equipment, transportation and planned regular practice to increase safety during major events. The MAP should clearly state what first aid is and how transportations can be arranged.

The MAP should include:

- Written documentation of the arena/sports facility's medical care and resources.
- Who is medically responsible.
- The need for specified medical personnel (physician, nurse, etc.).
- The need for medical equipment, including defibrillators, stretchers, medical examination rooms.
- Which communication system to be used and how.
- Who should be alerted to be the first person on site in acute life-threatening medical events (e.g. cardiac arrest) in the arena.
- What transport and transport routes are available from the arena to nearest emergency hospital.
- How the stadium's medical safety is linked to the existing emergency medical system, including emergency medical services at the nearest hospital.
- Who is responsible for conducting regular training and practice of the personnel and how often this should be done.

A prerequisite for proper treatment to be performed at an early stage is that appropriate medical equipment is available at the locations where training and competitions are carried out. A defibrillator should be available within 0–5 minutes.

Sports Medicine management and equipment at the arena

Arranging sporting activity at arenas also requires planning for the spectators. Serious incidents at the stadium are more common among spectators than among athletes.

The medically responsible person at big events should be an arena physician; at smaller events, if agreed, the team physician could be used in taking care of injuries or acute illnesses among spectators. Officials and other medical staff can be used as well.

The physician's medical bag and Sports Medicine management in the sports arena

This section has been written in collaboration with Professor Mats Börjesson, *et al.*[1]

Illnesses and injuries often occur in sports. A basic rule is that the earlier an injury or illness is treated, the fewer the symptoms that develop consequently and the healing and rehabilitation time becomes shorter. A prerequisite for proper treatment to be performed in the early stages is to have good medical equipment available in the places where training and competition is conducted, the medical team is competent and working well together and that the persons treating have a good knowledge of how the equipment is used.

The need for medical equipment varies depending on the scope of the activities undertaken, the athlete's age and health condition and location of the activity. Each emergency bag must be adapted to the needs that exist. This chapter offers suggestions for appropriate basic equipment. It describes the contents of a bag suitable for sports clubs, sports facilities, schools, etc, and then discusses what a team physician's bag should contain.

When hosting an arena competition or sports events, planning for the caretaking of the audience is also required. Serious incidents at the stadium are more common among spectators than among athletes. As mentioned above it is now recommended that sports fields, schools and generally at large public events, establish a MAP.

General guidelines for the medical team before a sports activity

- Be well prepared.
- Gather the medical team to join in a discussion and plan the medical services.
- The physician and the medical team are part of the whole team, i.e. coaching staff. It is important to have good and established relations with the coaches.
- Form a well-functioning medical team around the team/in the club.
- Develop good, broad qualified contacts in the adjacent disciplines including general practitioners, cardiologists, magnetic resonance imaging (MRI) services, laboratory services, etc.
- Consider that medical confidentiality must be respected, especially in contact with the media. Coaches, trainers and others can comment on various injuries without the player's consent, which is not the case for the medical team.
- Adequate information should be given to the injured player and coaches. Get together and form a joint opinion!
- Educate players and coaches in injury prevention, nutrition etc.
- Communicate with the player/athlete. The physician is the medically responsible person of the sports team and therefore also the medical team and all decisions should be based on a solid medical basis. It also applies when the player might want to use alternative therapies.
- In sports activities such as football/soccer in the top divisions, the physician and physical therapist should sit on the bench with the team.

Responsibilities

The physician has overall responsibility for the entirety of the medical work. The physician will record the player's medical background, new injuries and relevant diseases, as well as ensuring that the contents of the medical bags are updated to meet basic requirements and minimize risk of abuse (doping). The physician should be keeping in contact with the mass media when it comes to medical assessments. At elite level there are sometimes national injury reports to be completed.

When traveling, check the general standard of hygiene in hotels and restaurants, water quality, menu and if there are any restrictions on food intake. The physician is responsible for ensuring anti-doping rules are followed and should always be present at doping controls.

Tip

Advice: to work as a Sports Medicine physician demands, in addition to broad medical knowledge, also sports medical knowledge and commitment.

Education in Sports Medicine is essential and can be obtained through the national Sports Medicine associations and at various related national and international courses and congresses.

Physical therapists are responsible more for the physiological preparations prior to training. They design warming up and rehabilitation exercises for injured players and are responsible for ensuring alternative training is being implemented. Physical therapists promote active injury prevention through education in groups and on an individual level, including recovery, as well as monitor the development of equipment such as tape, braces, supports, etc. In some clubs athletic trainers, naprapaths, osteopaths and chiropractors are responsible for this area. It is essential that they are well educated and have good knowledge and good judgment.

The physician and physical therapists have a shared responsibility for the implementation of proper emergency care, overall management of injury and illness, preventive activities, record keeping and injury reporting. Physical training for a group can be operated to good effect as a team effort between physical therapists, physicians and (physiologically responsible) coaches.

The role of the physiotherapist – the 'physio'

It may be the physical therapist and/or athletic trainer, naprapath, osteopath, chiropractor and masseuse , who in reality has a key role in the medical team, as the 'spider in the web' or 'facilitator', i.e. forms the link between the coach, the player and the rest of the medical team, in addition to his/her own specific tasks.

Equipment managers, together with physical therapists are responsible for ensuring that adequate and effective materials and equipment are available prior to training/competitions. There must be sufficient fluid to drink, which is carefully composed to be taken during the competition/training for optimal recovery.

Medical bags

Minor emergency bag for the physician to take out on the field

- For examination:
  - ✓ Blood pressure cuff, stethoscope, a spatula, a flashlight, reflex hammer.
- For lacerations:
  - ✓ Antiseptics are applied to living skin or tissue to prevent infection, whereas disinfectants are applied to surfaces, equipment. Examples are chlorhexidine (solution or sponge), sodium chloride in plastic vials.
  - ✓ Scalpel.
  - ✓ Gloves, sterile drapes × 2, steristrip.
  - ✓ Stapler × 2, multiple sutures, suture set × 2.
  - ✓ Absorption bandages, elastic bandages, gauze, surgical tape, sterile dressing, topical wound care ointment.
  - ✓ Suture set × 2 and dressings × 2.
  - ✓ Elastic, multi-purpose bandages (e.g. Tubigrip), that provide lasting, effective support with freedom of movement; finger bandages.
- For injection:
  - ✓ Anesthetic cream, sodium chloride for wound irrigation, preinjection swab.
  - ✓ Syringes: 5, 10, 20 ml, tourniquet, venflon.
  - ✓ Pharmaceuticals: epinephrine injection for allergy/shock, inhaled beta-2 agonists.
  - ✓ Local anesthetics, e.g. with cutaneous spray or xylocaine–adrenaline.
  - ✓ Anticonvulsant, e.g. rectal diazepam.
  - ✓ Injection vials containing epinephrine, morphine, atropine, methylprednisolone.
- Other:
  - ✓ Cotton, scissors, blister and skin protection, oropharyngeal airway.
  - ✓ Elastic bandages, adhesive tape.

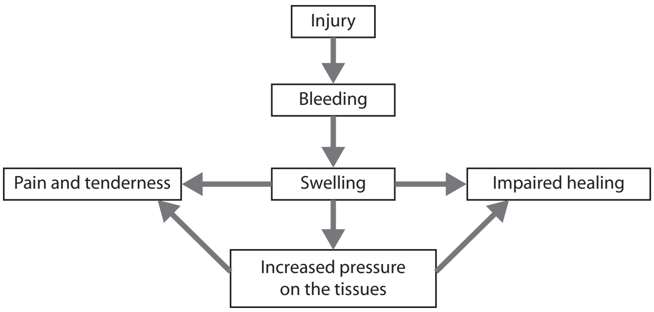

Figure 7.3 Vicious circle when there is a tissue injury.

General medical bag for a sports club

- Soap and sponges, disposable gloves.
- Wound cleaning agent, e.g. sterile saline in disposable bags, wounds and eye wash.
- First aid kit, sterile swabs, gauze, cotton.
- Elastic bandages and elastic cohesive bandages, elastic and non-elastic tape.
- Patches and surgical tape, foam.
- Scissors, tweezers and safety pins.
- Mouth thermometer, flashlight.
- Cold packs or ice.
- Disposable cups.
- Pharmaceuticals/medications
  - ✓ Painkilling drugs, e.g. acetylsalicylic acid and acetaminophen, oral.
  - ✓ Nasal spray or nasal drops in disposable pipettes.
  - ✓ Medication for sore throat and similar problems.
  - ✓ When traveling overseas: anti-diarrhea such as loperamide.
  - ✓ Creams, such as skin ointment for abrasions, cortisone ointment for treating insect bites and sunscreen to prevent sunburn.
  - ✓ Glucose.
  - ✓ Antihistamines for allergy.
  - ✓ Topical hydrocortisone.
  - ✓ Proton pump inhibitors or similar for gastritis irritation of the lining of the stomach.
  - ✓ Supplementation with certain prescription drugs can be done in consultation with involved physicians (see below).

The contents of the medical bag should be handled with discretion and common sense. If in doubt about the appropriate treatment, consult a physician.

The physician's bag

The contents of the medical bag should be coordinated with the activities that form the basis of the physician's involvement. The contents are therefore very individual. The following should be seen as a recommendation:

- Dressings as above.
- Chlorhexidine.
- Sterile gloves, sterile dressings needed.
- Disposable syringes and tips.
- Scalpel and blades, needle holders, forceps, scissors and hemostats.
- Foreign body forceps, suture material, especially disposable suture set.

- Stethoscope, blood pressure cuff (sphygmomanometer).
- Ear (otoscope) and head mirror for eyes, tongue depressors to hold the tongue aside.
- Flashlight.
- Drugs other than those listed above:
  - ✓ Medication for pain and inflammation (non-steroidal anti-inflammatory drugs [NSAIDs], acetaminophen).
  - ✓ Local anesthetics for injection, such as xylocaine.
  - ✓ Local anesthetic eye drops.
  - ✓ Ointments for hemorrhoids such as corticosteroid preparation.
  - ✓ Medication for infections – antibiotics such as penicillin.
  - ✓ Sedatives and tranquilizer.
  - ✓ Motion sickness agents, e.g. scopolamine, antihistamine.
  - ✓ Medication for allergic disorders.
  - ✓ Medication for diarrhea, e.g. loperamide.
  - ✓ Medication for gastric symptoms, e.g. omeprazole.
  - ✓ Medication for acute constipation, e.g. sodium citrate.
  - ✓ Eye anti-bacterial ointment, e.g. chloramphenicol.
  - ✓ Ear ointment and ear drops.
  - ✓ Medication for asthmatic and allergic attacks.
  - ✓ Drugs for acute coronary syndromes, such as adrenergic beta-blocker metoprolol tablets/injection, which is a selective ß1 receptor blocker.
  - ✓ Medication for exercise-induced asthma.

Special equipment for acute conditions should be available at the stadium including:

- Laryngoscope with light source.
- Endotracheal tubes of a couple of sizes.
- Small tubes for nose and mouth.
- Syringe (50 ml) and large catheter for suction.
- Peripheral venous catheter (PVC).
- Three-way stopcocks for IV medication infusion for single use.
- Ringer's solution, 500 ml.

With increasing experience of what is needed, the medical equipment increases in the two above described bags. Always check that a drug is not on the doping list!

Knowledge of the athletes' health greatly facilitates the work of the dedicated physician. Health examinations of athletes before the season begins, and periodically during the season, is of value. These examinations are now mandatory in several sports; in some sports the reports have to be registered (reported) to the respective specialized international sports federations, such as in football/soccer, prior to the season (e.g. in football/soccer for European teams – the so called UEFA license). In many situations diseases and injuries can be prevented or treatment time shortened if the physician has knowledge of the athletes' medical history including muscle and joint status, previous diseases and the possible need for medicines. Therapeutic use exemption (TUE) for essential medicines such as in diabetes may need to be sought (see Chapter 2, p. 26).

Equipment in a well-functioning sports arena

In a sports arena the medical safety of both the athletes and spectators should be optimal.

The audience should quickly have treatment if an emergency should arise, especially in the form of life-threatening complications such as cardiac arrest. Medical planning should be formalized as a so-called MAP (see p. 130). The MAP should include:

- Written documentation of the arena/sports facility's medical care.
- Who is medically responsible.
- The need for specified medical personnel (physician, nurse, etc.).
- The need for medical equipment, including defibrillators, stretchers, medical examination rooms.
- Which communication system is to be used and how.
- Who should be alerted to be the first person on site in acute life-threatening medical events (e.g. cardiac arrest) in the arena?
- What transport and transport routes are available from the arena.
- How the stadium's medical safety is linked to the existing emergency medical system, including emergency medical services, the nearest hospital.
- Who is responsible for regular training and practice of the personnel and how often this should be done.

Defibrillators

In acute heart failure, usually due to ventricular fibrillation or absence of cardiac activity (asystole), urgent action is needed to increase the chances of survival. One usually expects to have 3–5 minutes to successfully defibrillate a possible cardiac arrest. Cardiopulmonary resuscitation (mainly chest compressions + mouth to mouth) should start immediately (see p. 129).

Tip

On sites where there are regular sports activities going on there should be a defibrillator available close by. This is especially true if transport time exceeds 2–3 minutes.

Equipment that should generally be available

In addition to the above described medicine bag the following equipment should be available in the sports facilities, sports grounds, schools and the like:

Splints or similar equipment to immobilize fractures.
Crutches with adaptable length.
Stretcher with blankets.
Sand pillows as support for e.g. neck injuries, collars for neck support.
Other equipment as described earlier.

In summary, the audience should quickly get treatment if an emergency should arise, especially in the form of life-threatening complications as cardiac arrest. Medical planning should be formed as a MAP (see above).

Very acute emergency care at the sports stadium

Dealing with life-threatening conditions, see p. 129 (Fig. 7.4). Injured athletes should be hospitalized as soon as possible in the following conditions:

- Unconsciousness or permanent headache, nausea, vomiting and dizziness after a head injury.
- Breathing problems after a blow to the head, neck or chest.
- Pain in the neck, whether they radiate to the arms or not, after trauma.
- Abdominal pain.
- Blood in the urine.
- Fractures or suspected fractures.
- Very severe joint or ligament injury.
- Very severe muscle or tendon injury.
- Dislocation.
- Eye injuries.
- Very deep lacerations with bleeding.
- Injury with intense pain, numbness, muscular pain or weakness, paresis or paralysis in the lower legs after back trauma.
- Injuries with uncertain severity, diagnosis and treatment.

It is of utmost importance that the injured person has a free airway and any bleeding is stopped, so that the life may be saved.

Acute care in the arena

Soft tissue injuries involve different tissues:

- Muscle and tendon injuries such as muscle strains, muscle hematoma, tendon ruptures etc.
- Joint and ligament injuries such as sprains of the ankle and knee, dislocation etc.
- Soft tissue injuries in fractures.

Soft tissue injuries involve, however, not only muscles, tendons and ligaments, but also blood vessels that are damaged in the area. Bleeding occurs, which spreads diffusely into the tissues around the injury. Nerve tissue in the area may also be injured. The bleeding causes a swelling, which increases the pressure on the tissues in the injured area. Tissues will therefore become tense and sore. The increased pressure affects pain-sensitive tissues and affects the circulation. The hematoma with increased swelling and increased pressure causes a decline in the healing conditions (see Fig. 7.3).

Figure 7.4 Acute management at the injury site. **a)** The first examination of the injured athlete can be done by a physiotherapist or a physician on the pitch (with permission, by Bildbyrån, Sweden); **b)** emergency bag used during the Olympic Games in London, 2012.

Tip

With soft tissue injuries, it is important to restrict and limit the hematoma as quickly as possible. Treatment should be initiated immediately. Correctly performed, acute care of a soft tissue injury often determines how quickly and completely the injury heals.

Once the bleeding of an acute soft tissue injury is restricted a hematoma remains. The break down product from this needs to be transported away, and this is mainly done via the lymphatic system. The hematoma is often transformed into scar tissue, constituting a weakening of the tissue, be it a muscle, a tendon, a ligament or the like. Loading scar tissue too early may tear it and bleeding may occur again.

Sports injuries can take many different forms, and it is therefore impossible to set up a standardized chart of how they may best be dealt with. Some guidelines can be drawn up for how a sports injury should be treated on the spot, as soon as possible after it has occurred and a preliminary diagnosis is set.

Immediate management on site where the injury occurred

- A first quick examination of the injury extent can be made by the physiotherapist, the physician on the spot or occasionally by a coach.
- A more detailed analysis can be done off the field or in the locker room.
- The injured athlete should be undressed to allow a good overview of the injured area, orthotics and bandages are removed.
- The sequence of events is analyzed. Listen to the athlete's description of how the injury occurred and what problems the athlete has.
- The injury is inspected. Is there bruising, swelling, lacerations, etc.?
- A simple functional examination of the injured limb is made. Can the injured person perform normal movements with it – with or without load – without pain or a feeling of instability?
- The injured area is examined. Is there tenderness in the soft tissue or bone? Is it possible to feel a gap in any soft tissue?
- If there is swelling, tenderness and pain on movement or load, treatment should be given as described below.

Tip

In general, the smaller the bleeding, the faster the blood effusion will disappear and the less scar tissue is formed in the injured tissue.

Compression bandages

The basic treatments for soft tissue injuries are measures that reduce the extent of the hematoma, i.e. compression bandages, elevation, rapid cooling and rest. The type of bandage used depends on the severity of the swelling and how much pressure needs to be applied (Fig. 7.5).

A compression bandage is used with the intention of creating a counter pressure against the hematoma, which develops within the area. Compression therapy works by applying controlled pressure to the surface veins, keeping their diameter small and forcing blood back into the deep vein system. This allows the body's blood-clotting mechanisms to function more easily.

Compression bandages can be easily wrapped around the leg from the toes to the calf in the case of a lower leg/ankle injury. The compression should be applied as soon as possible (Fig. 7.6). A cold pack may be conveniently applied at the same time. It is possible to get both a cooling and a compression effect with a single dressing. If a cold pack is not in use (see below, Cold treatment) initially, i.e. 0–24 hours, a foam pad should be used between the skin and the bandage to provide a more anatomically correct compression. A light compression bandage should also be used during the night. The compression bandage is maintained for a few days after the cryotherapy has been completed if the injury location and size allows. Bandages may be left on or re-applied for several weeks until the

Figure 7.5 Immediate compression by using a compression bandage is an efficient treatment of an acute injury when it comes to limiting a swelling or an edema.

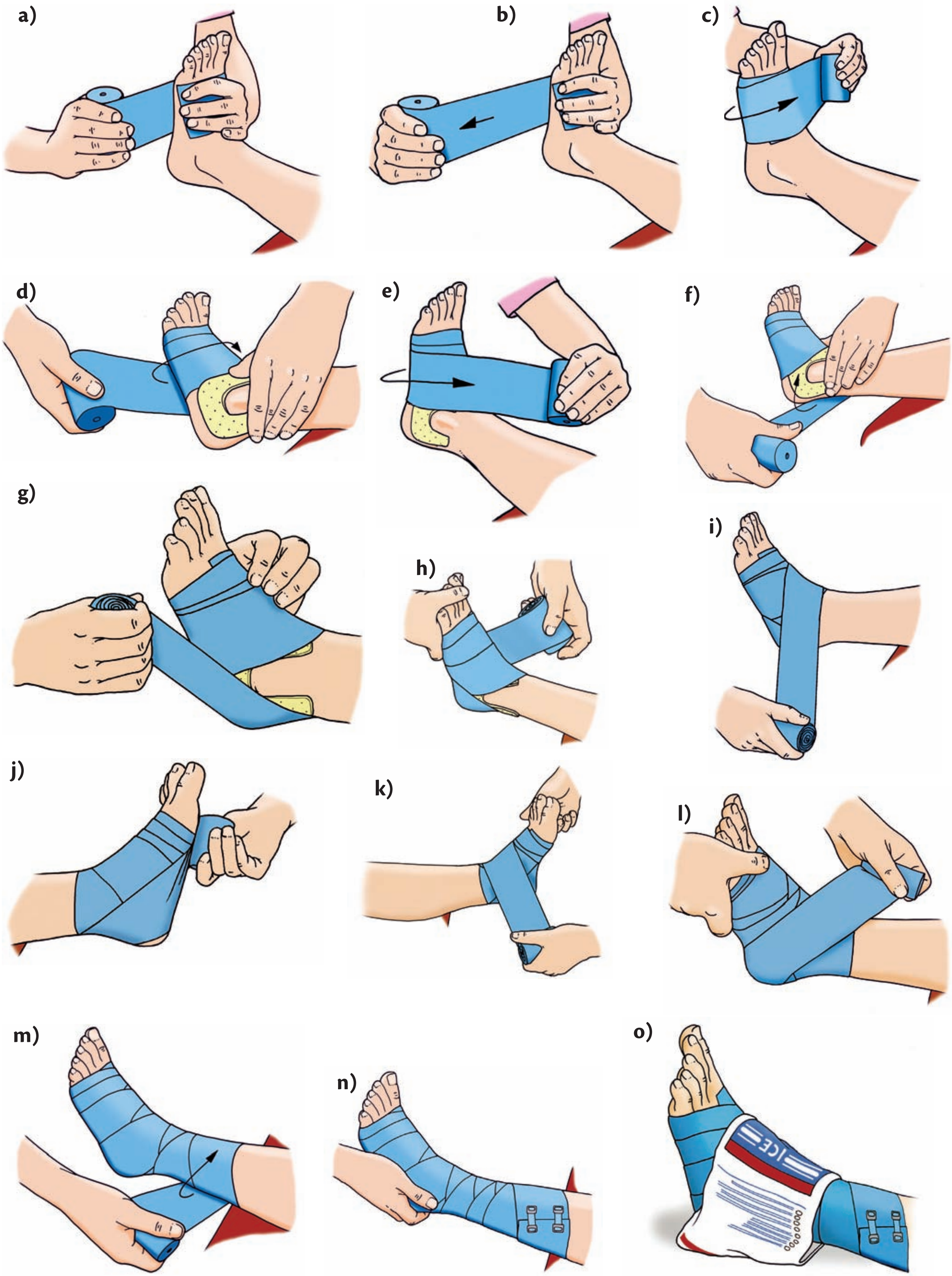
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Figure 7.6 Technique for application of a compression bandage.
a) With the foot in a neutral position start the bandaging from the outside (lateral side) of the forefoot leaving the toes free.
b) Pressure bandage: pull out the bandage to 75–90% of its elasticity.
c) Compression bandage: pull out the bandage to 50% of the elasticity.
d) Maintain a high compression from the distal foot to the area over the injury. Taper off the compression slightly proximally up the lower leg.
e) For maximum pressure over the injured ligament, place a U-shaped piece of foam rubber around ankle bone.
f) Apply bandage up the foot to the ankle.
g) Continue around the inside (medial side) of the ankle.
h) Go around the heel pulling diagonally behind and below the outer ankle bone (lateral malleoli).
i) Continue around the underside of the foot and up the inside (medial side) of the foot.
j) Go over the outer part of the ankle bone (lateral malleoli) around the heel.
k) Pull the bandage around the heel pulling diagonally behind and below the inner ankle bone (medial malleoli), under the sole of the foot and up the outside (lateral side) of the foot.
l) Thereafter around, covering the heel point.
m) Continue over the top of the foot.
n) Next continue with a figure of 8 bandaging, then up along the lower leg.
o) Secure the bandage with hooks or tape.
(With permission, from Torsten Larsson, Ostersund, Sweden.)

swelling has gone down. After compression treatment has been completed a support bandage can be used.

Optimal ankle wrapping with elastic or adhesive elastic bandage or self-adhesive elastic bandages is to provide support primarily to the outside (lateral side) of the ankle with pressure placed around the malleoli, instead of just a simple figure '8' wrap, that does not provide enough pressure behind the malleoli. This form of bandaging is suitable for using acutely when swelling is present and the foot is not in a stage of the healing process to be taped. The bandaging can be enhanced with a few figure '8's or sports tape, to achieve a good prevention for further injury.

An alternative method of applying a compression bandage (designed by Dale Reese, IFK Norrköping) is as follows:

- With the foot in a neutral position start the bandaging from the outside (lateral side) of the forefoot leaving the toes free.
- Pressure bandage: stretch bandage to 75–90% of its elasticity.
- Compression bandages: stretch bandage to 50% of the elasticity.
- Maintain the same degree of stretch until finishing on the lower leg with a tapering off of the compression.
- For maximum pressure over the injured ligament, place a horseshoe-shaped foam rubber piece around the outer ankle bone (lateral malleolus) and eventually inner ankle bone (medial malleolus) depending on the size of the swelling.
- Starting at the big toe bandage up to the front of the ankle with three laps.
- Continue around the inside of the ankle.
- Pull up behind outer ankle bone (lateral malleolus) and behind the heel (calcaneus) diagonally.
- Continue over the front ankle and then the underside of the foot and pull up on the inside of the foot, below the inner ankle bone (medial malleolus) and behind the heel (calcaneus) diagonally.
- Pull over the front of ankle and cover the heel bone (calcaneus) tip from the inside (medial side) and pull up on the outside.
- Proceed up the leg with a 'herring bone'-like pattern.
- Secure the bandage with hooks or tape.
- Note you can supplement with a figure of 8 immediately after step 6 before continuing with step 7.

Tip

A compression bandage should be put on as soon as possible after the injury because it is the most effective method to limit the bleeding and consequent swelling. The bandage should not be too tight.

Cold treatment (cryotherapy)

When soft tissue injuries occur there should primarily be an attempt to limit the bleeding, as it leads to swelling, pain and tenderness and a remaining hematoma. Applying a cold pack limits the bleeding to some extent, although its main effect is pain relief. The application of a cold pack reduces local muscular blood flow by approximately 50% after 10 minutes.[2] The area should be cooled as much as possible for the first 3–6 hours after the injury occurred, which limits the hematoma. Cooling should be repeated at 30 minute intervals every other or every third hour during the first day. During the second day, it is used only for pain relief.

Figure 7.7 Local cryotherapy (cold treatment) can be given in different ways. **a, b)** A cooling pack is a common way to apply cold to the injured athlete; **c)** an ice bandage is often given acutely to the athlete. (With permission, by Bildbyrån. Sweden.)

Tip

Cold treatment only has a minor effect on acute bleeding, so a combination of pressure and compression bandage as recommended above, will initially limit the bleeding and reduce the hematoma.

Cooling of body tissues may be of value and means that a local analgesic effect is achieved, so that the injured athletes feel better and may want to return to their sporting activities (Fig. 7.7). The treating person has a great responsibility. If an injury needs to be cooled down, the injury is often of such a degree of severity that it may impair the healing ability if the activity is resumed. Common sense must prevail.

The blood vessels constrict after a period of cooling, so that the injured area receives a decreased amount of blood. Through this, there will be less swelling and faster healing. The treatment effect is limited; research has shown that external cold treatment of, for example a thigh muscle, lowers to a certain extent both the temperature and muscle blood flow significantly at a depth of 2 cm after about 10 minutes, depending on the cooling method.[3] This reduction of blood flow in the deep muscle groups with an effective cooling treatment is not, however, particularly effective when it comes to stopping acute bleeding, when an external compression or pressure bandage as described above is more effective.

Tip

Local cold therapy after about 10 minutes can reduce temperature and impair blood flow to a depth of 2 cm in the underlying tissue.

When there is evidence of extensive soft tissue injury with bleeding or bone injury, the injured person cannot resume their sporting activities until the injury has healed. There is nothing to gain by compromising the athlete's future health.

Cold treatment is usually given once every hour for periods of 15–20 minutes per period during the first 24–72 hours following the onset of the injury. The athlete may feel at each treatment session first cooling, subsequently a burning sensation, aching and then finally numbness in the treated body part.

In conclusion, cold therapy can be used advantageously for injuries because:

- The injured person quickly feels an improvement in symptoms, mainly because of less pain.
- The treatment is easy to perform and well-tolerated by the injured person.
- There are few contraindications.
- This treatment is not costly.

Cooling treatment is primarily used for pain relief. There are different types of cold therapy and the effect is partially dependent on the cooling method. The use of large quantities of crushed ice directly on the skin or immersing the injured limb in ice slush gives good effect, while the so-called cooling sprays have no physiological effect on the muscle at all. It is important to be aware that there may be a risk of frostbite when treating with minus degree (Celcius) coldness.

Ice massage

Ice massage is primarily used after hard training of over-strained muscles/tendons as well as pain relief before range of motion training, as friction massage and local pain relief. The technique involves the use of small circular motions massaging the area with ice for 5–10 minutes until a numbing effect is achieved.

Cold packs and pre-shaped cooling bandage (cryo-cuffs)

Cold packs containing ice cubes or chips are popular because they are both effective and easy to use. The cold pack or cryo-cuff is applied for 15–20 minutes and should not be located directly on the skin. A clean handkerchief or similar can be placed between the skin and the cold pack or cooling bandage. An elastic bandage is often applied on top (Fig. 7.8). Cold packs can be adapted to the body shape and the injured area is often raised above the level of the heart to minimize swelling.

Pre-shaped cooling bandages use ice water flowing through an isolated form-fitting 'package', while some compression is maintained. That way it is possible to get a compression bandage with cooling effect. These are however expensive.

Figure 7.8 In a pre-shaped cooling bandage ice water is used flowing through an isolated form-fitting 'package', while some compression is maintained. In this way a combined effect is given: cooling and compression (c2014 DJO/LLC, used with permission from Aircast/DJO. All rights reserved).

Cooling gel packs

Reusable cold packs typically consist of a viscous substance (gel) enclosed in a sturdy vinyl case. It is activated by having it in the freezer (minus degree cooling). There are also disposable cold packs, which retain their efficacy at about 10°C heat. The package is activated by pressing hard on it or hitting the pack against a hard surface to get the liquid inside the bag to mix with crystals, which triggers the chemical reaction that produces the cooling effect.

The cold packs are easy to carry and bring along in a bag. They are easily shaped around the body part and may, just as the cooling units, be used in combination with elevation. However, they are expensive and do not retain the cold as well as real ice.

Ice bath, cold bath in the whirlpool

Ice bath and cold bath whirlpools combine the pain-relieving effect of cold with water's buoyancy to treat the inflammatory phase and enable early movement training. The water should have a temperature of 10–15°C, and the treatment time should be 5–15 minutes. When the pain is relieved the injured body part is taken out of the water and movement exercises are performed.

Cold water

Cold water may be used for cooling of injuries when cold packs are not available or when the injury covers a large area, which cannot be dealt with using the usual type of disposable cold packs (Fig. 7.9).

Tip

Cold water or cold packs should not be used directly on open wounds.

Cold spray

Cold spray could possibly be used where only local pain relief is sought, such as over areas where skin is close to the bones – tibia, knuckles, ankles, etc (Fig. 7.10). The cooling from a cold spray penetrates only 3–4 mm inside the skin and does not affect the underlying injured tissue. However, any reflex induced contractions of blood vessels deeper into the tissues is likely to have only a small and short-lived effect. When the cooling effect stops, i.e. when spraying the skin has ceased, the capillary perfusion increases in the cooled area, and there will be an opposite and undesirable effect. Risk for frostbite of the skin is also present when using cold spray.

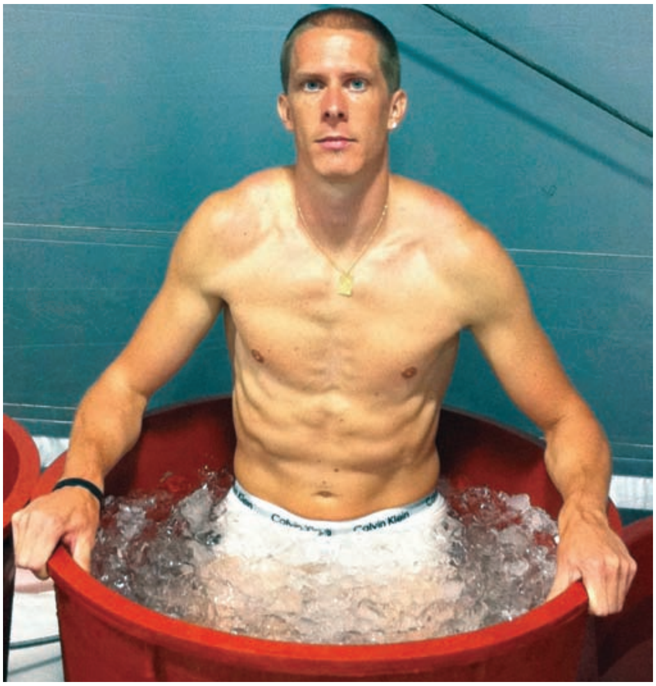

Figure 7.9 Ice or a cold bath is often used for recovery by top level athletes. (Courtesy of the Swedish Athletic Association, photo, Tommy Eriksson.)

Tip

Remember:

- Cold treatment is mainly used for pain relief.
- The cooling analgesic effects can hide the real extent of an injury.
- Thus returning directly and/or too quickly to sports can greatly aggravate the injury.

There are wide variations in the clinical use of cryotherapy, and guidelines continue to be made on an empirical basis. Review of the literature shows that there was marginal evidence that ice plus exercise is most effective after ankle sprains and post surgery. There was little evidence to suggest that the addition of ice to compression had any significant effect, but this was restricted to treatment of hospital in-patients. There was no evidence of an optimal mode or duration of treatment.[3]

Rest

Generally, an injured athlete should rest for 1–2 days, and the injured area should not be loaded. Thus, the injured athlete should receive help with transport from the injury location to home or to the physician. During the acute phase crutches may be very helpful.

Elevation

When an injured body part is placed in elevation it reduces blood supply to the injured area, and breakdown products from the hematoma can be more easily carried

Figure 7.10 Cold spray is used frequently in sport. Cooling relieves the pain but otherwise the spray has little effect. If the injury is determined by the first responder on the field not to be dangerous for the athlete, the athlete is in pain but could continue if the pain is alleviated, then the cold spray could possibly be used. (Photo, Erik Nexborn.)

away, causing the swelling to be less extensive. An injured leg placed in elevation should be higher than a 45° angle to the ground when the person lies on his back. This can be achieved using 4–5 pillows under the leg or a stool placed under the leg.

If extensive bleeding and swelling are present, the injured part should, if possible, remain in elevation for 1–2 days. Thereafter, the limb is placed slightly raised when possible.

Pain management

The above treatment of a soft tissue injury – cooling, compression and rest – usually provides good pain relief. Analgesic medications should not be used routinely in the initial stage, because they could hamper the ongoing assessment and the medical examination that may be needed.

Treatment of a soft tissue injury within 1–2 days

When a soft tissue injury is of such a nature that the injured person does not need medication but still has an effusion, pain and disability in the injured limb, treatment can be continued with:

- Compression bandage, which after a few hours is replaced with a supporting bandage.
- Additional cold treatment, if pain relief is being sought.
- Rest until the acute symptoms disappear.
- Elevation of the injured body part. With injuries to the lower extremities crutches should be used if the athlete must walk.

A body part that has suffered a soft tissue injury should not be loaded or used until a definite diagnosis has been made. If there is extensive sustained bleeding, lasting pain and functional impairment, and when uncertainty about the correct treatment exists, it is recommended to contact a physician. Injured athletes should see a physician within 1–2 days if:

- There are residual symptoms of muscle, tendon, joint, or ligament injury.
- There is severe pain.

Tip

Generally, a physician should be contacted if the diagnosis is not clear.

Treatment after 2 days

In addition to the treatments described in this section there are specific exercises that play an important part of the long-term treatment. They are described in Chapter 9.

Rest and unloading

When injuries happen, rest of the injured limb is in general necessary. Painful movements should be avoided. For best results to be achieved, it may sometimes be justified to have the athlete resting in bed. In overuse injuries and some ligament injuries with swelling, elastic adhesive bandaging or taping can be of value for the injured athlete to get support to rest the injured body part. After surgery, a shorter rest is often recommended. Generally rest is needed until soreness, swelling and pain have subsided when using the injured body part.

Even when an injured body part is treated with a cast or brace, the other body parts can be trained and endurance training can be conducted. An athlete with the lower leg in a cast can maintain their physical fitness by cycling or similar activity. A body part that has been treated with a cast should be elevated, and repeated isometric contraction of muscles should be made in the injured body part.

Tip

Rest and unloading is of great value in the acute phase after injury. In the longer term, however, rest and unloading have a detrimental effect on the tissues, and can cause weakness and atrophy. Early movement training is essential, as well as gradually increasing load when the condition allows.

Clinical treatment alternatives

Heat treatment (thermotherapy)

Heat has been used for thousands of years for the treatment of various pain conditions. Experience shows that heat has a positive effect on pain related to an inflammatory state. Inflammation is the body's own defense mechanism for both accidents and overuse injuries. Accidental injuries, e.g. ligament injuries in the ankle joint and muscle ruptures, are often treated acutely with cooling, and bandaging for bleeding in the injured area, which needs to be limited. Once that has happened, i.e. after about 2 days, heat treatment can be initiated to support healing. In the healing phase increased perfusion of the injured area may be of value, since the healing process is influenced favorably.

If an injury is treated with heat during the acute phase, however, the blood vessels are widened, blood clots more slowly and the amount of fluid in the tissue increases. This causes bleeding in the injured area with increased swelling and higher pressure in the surrounding tissues. The injured athlete may then feel a more intensified pain, and healing time is prolonged.

Tip

Heat treatment should not be initiated until at least 2 days after a soft tissue injury has occurred. The same is true with massage of the injured body part.

Perhaps the most important effect of heat treatment is that the collagen fibers are affected. A tendon comprises up to 90% collagen fibers and 10% of elastic fibers. Collagen is viscoelastic, which means that the faster a tendon is loaded, the more rigid (reduced elasticity) and less extensible (lower plasticity) it becomes. Heat increases the elasticity and plasticity. The collagen fibers will thus be more extensible after heating and more susceptible to conventional rehabilitation measures. Heat also has good effect on joint stiffness and muscle spasm. The risk of injury is also thereby decreased.

Heat can be used in preventive and rehabilitative phases of particularly overuse injuries, residual conditions after muscle and tendon ruptures, etc. Heat is also a valuable factor in the warm-up exercises before practice and competitions as well as in chilly weather, as heat increases the extensibility of the joints.

Tip

Heat treatment provides pain relief, increased perfusion, causes the collagen fibers to become more extensible, and has great importance for preventive and rehabilitative measures.

Heat treatment is used after acute inflammation to increase blood flow and therefore healing in the injured area. With increased blood flow the turnover in cells will increase, and at the same time counteract, for example, muscle cramps and minor pain in the surrounding tissues. Heat has a natural place prior to physical activity, because it makes connective tissue more extensible, so that the range of motion is expanded. How deep the heat penetrates is dependent on the treatment method.

Superficial heat treatment

Superficial treatment methods transfer heat by conduction, convection and radiation. The heat does not penetrate deeper than 1 cm. The whirlpool combines heat with water massage to increase the temperature of the surface of the skin, relieve muscle spasms and pain and facilitate movement training. The treatment lasts 20–30 minutes, and the body part to be treated is immersed in water with a temperature of 37–40°.

Hydrocollator packs

Hydrocollator packs provide superficial moist heat to a slightly greater tissue depth than whirlpool treatment. The packs consist of a silicone gel encased in canvas fabric compartments, and are stored in a thermostatically controlled water bath. The pack is wrapped in terry toweling or a commercially available hot-pack cover and placed over the injured area for 20 minutes.

Contrast baths

Contrast baths combine cryotherapy and thermotherapy to reduce edema and restore range of motion in sub-acute or chronic injuries. One whirlpool or container is filled with cold water and ice at 10–15°C (50–60°F) and the other is filled with hot water at 37–43°C (98–108°F). The injured body part is alternated between the two containers at a 3:1, 3:2 or 4:1 ratio of hot to cold for approximately 20 minutes, or 4 or 5 cycles. The treatment should end in the cold water.

It is perfectly possible even to use a shower head to achieve the effect. Use as cold water is tolerated and then as warm water is tolerated. The injured limb can simultaneously be activated, which enhances the effect.

Heat retainer

A heat retainer is made of synthetic material and provides protection and support. It retains the heat produced by the body in a specific area, and thereby aids healing. It can be effective at rest as well as in training and competition. Heat retainers are made of a fine, porous material with low fluid absorption and good heat retention. They have an elasticity, which keeps them in place without hampering movement in the bandaged part of the body. In addition, they give some support and exert counter pressure that may be of value when there is swelling. They are available in versions suitable for most joints and most types of injuries (Fig. 7.11).

Heat retainers have been tested clinically to assess their effect in prevention as well as treatment of sports injuries, and results have been good. By relieving pain, improving tissue elasticity, and maintaining and extending the range of mobility, they assist not only the

Figure 7.11 A heat retaining brace (called by some a neoprene sleeve) is often used by the athletes in order both to prevent an injury and to prevent recurrence of an earlier injury. (With permission by Bildbyrån, Sweden.)

rehabilitation of ligament injuries in the knees and ankles, but also the treatment of pain arising from muscle injuries and osteoarthritis.

Tip

Heat retainers are a simple form of thermotherapy and are a valuable addition to the range of treatments available. They can be useful at rest as well as in training for the prevention and treatment of injuries due to overuse and trauma, both in sporting and other activities.

Deep heat treatment

Ultrasound

Ultrasound waves are of a higher frequency than those detectable by the human ear, and can be defined as the sound wavelength with frequency higher than 20 kHz. The penetration of ultrasound is inversely proportional to the frequency (the lower the frequency, the deeper the sound wave reaches). As the ultrasonic beam travels through tissue the energy is absorbed, producing heat. Ultrasound energy can produce temperature increases in tissue as deep as 10 cm (4 in.). The indications for ultrasound treatment are pain and inflammatory conditions that are deeply located. The technique is especially suitable for the treatment of pain in tendon attachments.

Ultrasound can reduce the pain as well as increase the extensibility of the collagen fibers. It has been shown to be effective in combination with stretching. It may have some effect on calcium deposits in various tissues, but this is debated.

Phonophoresis

Phonophoresis uses the mechanical energy of ultrasound to introduce medications such as cortisone through the skin to deeper tissues. In one study 68% of those receiving phonophoresis with hydrocortisone cream obtained relief from pain and improved range of motion, compared with 28% of patients receiving ultrasound alone. This medication has been found 10 cm (4 in.) deep within the tissue after 5 minutes of treatment, but it is not known how long it remains. This procedure is used in the post-acute stage of inflammatory conditions such as tendinitis, bursitis, contusion or arthritis. The advantage of this treatment is that the medication is delivered directly to the injury site, but it is less invasive than an anti-inflammatory injection, and may be used where an injection is contraindicated.

Electrical stimulation

Neuromuscular electrical stimulation is increasingly widely used (Fig. 7.12). This stimulation is the application of electrical pulses to a group of muscles,

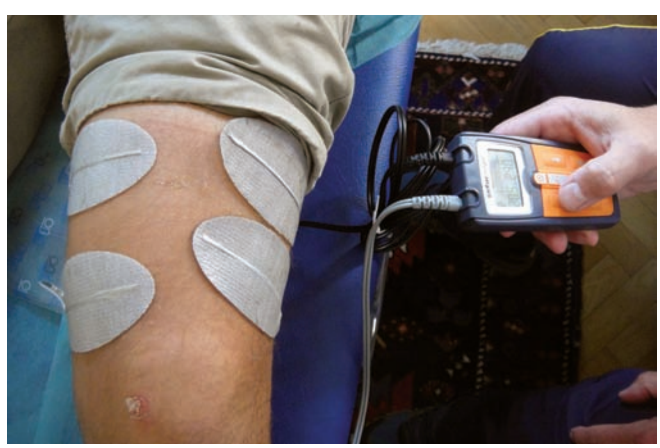

Figure 7.12 Neuromuscular electrical stimulation is increasingly used in the management of soft tissue injuries in tennis, for example. This treatment can be quite effective.

usually in conjunction with muscle rehabilitation. It has three recognized applications:

1. Transcutaneous electrical nerve stimulation (TENS/TNS): pain reduction is achieved by transcutaneous stimulation of sensory nerves. TENS treatment uses a battery-powered device to stimulate nerves close to the skin with a weak electrical current through electrodes attached to the skin over the body part that produces pain. TENS involves the stimulation of the body's own re-regulation of pain sensations. Response to treatment with TENS varies and for some it gives good pain relief. The effect of TENS is probably due to the activation of a 'gate mechanism' in the spinal cord that prevents the sensation of pain from reaching the brain.
2. Muscle activation: electrical stimulation is used in some post-operative cases, where grave regression of muscle mass is present.
3. Stimulation of healing: more research is needed on the healing effects of electrical stimulation. Although it is known that electrical stimulation can be used to control pain, caution when routinely using this approach in rehabilitation is recommended.

Tip

Treatment should primarily be performed by an experienced physical therapist.

Iontophoresis

Iontophoresis uses a mild electrical current to the skin. This aims to simplify the permeability of the skin temporarily, so that the medicine can go through the skin. Charged molecules of medication can be driven into damaged tissue. The medication is placed under the electrodes of the same polarity so that molecules are repelled by the electrodes and enter the skin of the damaged area. Anti-inflammatory medication, analgesic medication and medication with anesthetic effect may be used on conditions such as Achilles tendinopathy, etc.

Laser treatment

Lasers can be used for treatment of pain and inflammatory conditions in, for example, the back, neck, shoulder and knee joints. There is some evidence that laser treatment can relieve an inflammatory process.

Acupuncture

Acupuncture is a key component of Traditional Chinese Medicine. It is now increasingly used all over the world. Traditional acupuncture is based on the assumption that each half of the body has 12 meridians, representing certain organ systems. Along these meridians are a number of points that are connected with particular organs, and these points can be stimulated by needles of varying shape and length, effecting changes in the organs concerned. The connection between the meridians and anatomical nervous pathways has not yet been explained. The effect of the acupuncture needles is intensified by rotating them or connecting them to a low-voltage power source (electro-acupuncture).

Scientific evaluation of acupuncture is as yet incomplete and inconclusive. High-quality reviews suggest that acupuncture is effective for some but not all kinds of pain. It does, however, seem to benefit a significant number of people.

Tip

Acupuncture can be a very effective treatment for some people with a sports injury, but not for others. This means that both the injured person as well as the therapist must find their own way to recovery.

Massage

There is evidence that massage has been used in many ancient civilizations. It is widely used today in the world of sport. Massage involves treatment by rubbing, kneading, squeezing and pounding of muscles. 'Classic' massage uses five styles of strokes: effleurage (sliding or gliding), petrissage (kneading), tapotement (rhythmic tapping), friction (cross fiber or with the fibers) and vibration/shaking.

When treating overuse tendon injuries primarily deep cross friction massage is used, which means that the muscle and tendon are gently squeezed sideways to increase the elasticity of tissues, i.e. skin against subcutaneous, connective tissue membranes against muscle. The massage therapist works from the superficial layers down to the deeper structures in order to get all the layers to slide freely in the way they did before the tissue was overloaded.

In the past, many considered that massage could increase perfusion in the muscles, thereby relieving pain, stiffness and soreness. Massage is considered by some to prevent muscle injuries, accelerate healing and be part of the recovery after hard training sessions and competitions.

More recent studies, however, show no evidence that massage increases muscle blood flow although it may be possible to see that the superficial skin circulation is

Figure 7.13 Massage can provide good relaxation. **a)** Massage on the playing field (with permission, by Tommy Eriksson, Swedish Athletic Association); **b)** massage can allow the athlete to really relax when performed in a suitable environment (with permission, by Tommy Eriksson, Swedish Athletic Association); **c)** massage can also give a feeling of well-being and relaxation.

increased. In contrast, the stiffness, soreness, aches and the like can be alleviated.

Because different individuals react differently, depending on how hard the massage has been performed, it is recommended that the athlete uses the same massage that he/she was using before competition. If the athlete is not used to it he/she should avoid it. A scientific study on hard massage showed that immediately after the massage 1/3 was stronger in isokinetic strength, 1/3 was weaker, while 1/3 showed no difference.

Massage should not be too hard, but should be adapted to the individual and should be carried out from the more distal body parts and in the direction towards the heart. If it is performed by a trained and knowledgeable massage therapist the massage can result in an increased mobility in soft tissues and have an effect on the mental well-being by causing a feeling of general pleasure and relaxation (Fig. 7.13).

Tip

After a properly performed massage at the right time many athletes feel well, which can be of great value. It should be noted that there is no good knowledge of the real mechanism behind massage and its true effects.

Water massage

Water massage is usually carried out in hot water. The injured part is immersed for about 20 minutes during which time air is injected under high pressure into the water, providing an effect similar to that of manual massage. Use of a whirlpool or jacuzzi enables the whole body or individual part to be immersed alternately in hot and cold water, which is supposed to stimulate circulation and facilitate healing and rehabilitation.

Medications

In the treatment of sports injuries, such as injuries to soft tissues, sometimes medications are used. The main types of medications used in sports are those used to treat pain and inflammation.

Analgesic agents and anti-inflammatory agents

Acetylsalicylic acid is included in preparations such as Aspirin, etc. They have a good effect on pain, especially for headaches, joint pain, muscle pain and has an anti-pyretic effect. For more severe pain conditions, such as fractures, the effect of acetylsalicylic acid is insufficient. The agent may produce side effects in the form of local mucous membrane damage with pain and bleeding in the stomach.

Paracetamol (acetaminophen) has an equally good effect on pain as acetylsalicylic acid but has insignificant effects on inflammation. The agent has an anti-pyretic effect and minor side-effects.

Medications with both anti-inflammatory and analgesic effects

So-called combination agents are widely used in Sports Medicine. The most common agent is diclofenac sodium, which is effective against inflammatory conditions and also has some analgesic effect (may cause heartburn, indigestion, etc.). Naproxen and ibuprofen are also common and have relatively good pain relief and inflammation-inhibiting effect and are relatively long acting (may cause heartburn, indigestion, etc.). Nowadays, diclofenac and similar agents can be applied in gel form on the skin over the area and taken up into the tissue. This local treatment form reduces the risk of side-effects to the gastric tract.

Cortisone local injection

Cortisone injections can be of great value in certain overuse injuries. Such injections should not be given directly into the muscle or tendon, as this may cause a tissue weakening, and when loading can result in a rupture. Injections of cortisone could be given directly into a muscle or tendon attachment or the surrounding tendon sheath. After such treatment rest from loaded movements is recommended for 7–14 days, so that the risk of rupture is avoided. In some cases, a local anesthetic injection can be of value to diagnose the injury.

Tip

Corticosteroid injection:

- May be an effective alternative if other treatment options have not had the intended effect.
- Should not be given directly into the muscle or tendon.
- Usually has a rather short-lived therapeutic effect, e.g. 6 weeks with a tennis elbow.

Ointments, liniment and gels

In sports, ointments can be used for primarily skin problems, but also in conditions such as muscle aches and stiffness, and for shin splints. Some ointments increase circulation in the skin and provide a locally increased warmth feeling, but usually lack an effect at depth, e.g. on muscle perfusion. The psychological effect on athletes of the actual massaging of ointments and liniments cannot be denied. Gels containing medications enable local treatment in a simple way. The agent penetrates the skin and acts locally, see above.

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8

Treatment Principles and Options – an Overview

In this chapter the general principles that can be recommended as treatment of injuries of the musculoskeletal system are described with the various tissues as a basis. For detailed information on specific injuries, see the description of these in each chapter.

Skeletal injuries

Skeletal injuries are common in sports, especially in contact sports such as football/soccer, ice hockey, bandy, handball and floorball as well as individual sports such as skiing, gymnastics, horse riding and motor sports (Fig. 8.1).

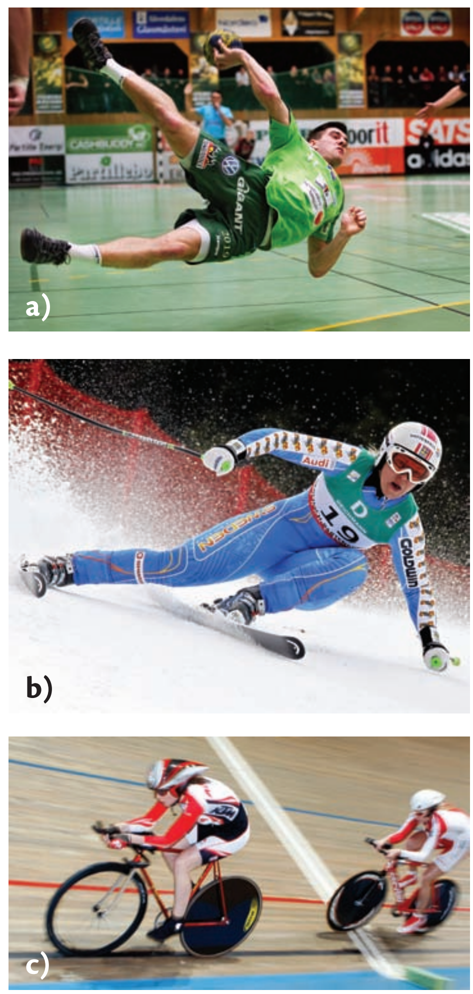


Figure 8.1 a–c) Some sports include risks for injury, such as handball, alpine skiing and cycling. (With permission, by Bildbyrån, Sweden.)

The functional anatomy of the bone

The bones of the skeleton have three main functions:

- The first is to form a solid base that carries the body weight and at the same time keep the body erect. These tasks are primarily for the pelvis, spine and lower extremities.
- The second function is to give a firm anchor to the muscles, tendons and ligaments, with the aim to provide efficient movement patterns.
- The third function is to protect the body's vulnerable soft tissue.

Bone is a living matter and can, according to Wolff's law from the 19th century (by Julius Wolff, 1836–1902, a German orthopedic surgeon), adapt to the loads under which it has placed itself in response to changes in the immediate environment: "If loading on a particular bone increases, the bone will remodel itself over time to become stronger to resist that sort of loading." This means that activity promotes bone strength, inactivity weakens it.

Running involves a loading movement towards a surface, causing the bones to become stronger. Bone also has an ability to respond to external stresses by becoming stronger, but also to break, e.g. fracture. The cells in the bone tissue can remove the bone tissue that died as a result of the fracture and replace it with new healthy bone. A certain degree of stress in the bone is beneficial to the healing process, but too much stress may harm the healing structures; a 'middle way' is sought. An interruption of the healing process can result in poor healing of the fracture.

Bones have greater resistance to pressure than to stretching and/or twisting. For that reason most fractures occur when a bone is twisted or bent. When bending the bone the outside is exposed to tension and that is where the fracture begins. Repeated tension can lead to stress fractures.

Tip

A certain amount of stress on the bone is favorable for the healing process and maintenance of its strength, but too much stress damages the healing structures.

Skeletal fractures

A skeletal fracture is considered a serious injury because it is not only the bone that is injured, but also the soft tissues around the fracture, i.e. tendons, ligaments, muscles, articular cartilage, nerves, blood vessels and skin. Fractures arise from direct trauma, e.g. a punch or a kick to a leg, or indirect trauma, such as if the foot gets stuck and the person falls so badly that the bone breaks.

Injury types

There are different types of skeletal fractures, such as transverse, oblique, spiral or splinter fractures (Fig. 8.2). If the bones of a fracture penetrate through the skin the fracture is classified as an open or complex fracture. When the skin remains intact it is classified as a closed or simple fracture. The risk for infection is high in open fractures and specific treatment is needed. If the fracture penetrates the adjacent joint surface it is called an intra-articular fracture. Avulsion fractures mean that the bone attachment to a muscle, tendon or a ligament has been torn off.

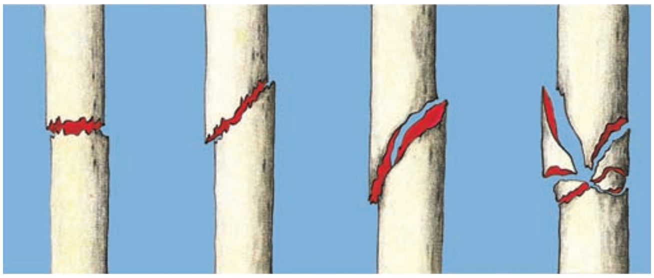


Figure 8.2 Types of skeletal fractures. From left: transverse, oblique, spiral and comminuted fractures.

Displacement of the bones is common in fractures. The displacement may be a lateral tilt, angulation, shortening and/or a rotation. In all cases the aim is to reduce the skeletal parts to the exact right position. Regarding fractures in children and growing individuals, see p. 564

Associated soft tissue injuries

The soft tissues around a fracture are often injured in association with the trauma because they are damaged by the sharp bone fragments (Fig. 8.3). At high energy trauma the risk of extensive soft tissue damage is greater. Soft tissue injuries can cause increased bleeding, which may complicate healing and can in itself be a bigger problem than the actual bone injury. It is rare that large blood vessels and nerves are damaged during skeletal fractures, but the risk of this exists in fractures of the extremities with severe displacements.

Location

In certain sports the injury picture is sports specific. Among football/soccer players fractures of the lower leg predominate, among gymnasts fractures of the forearm and for horse riders and cyclists fractures of the clavicle occur most frequently.

Symptoms and diagnosis

Characteristics of a fracture:

- Swelling and increasing discoloration of the skin in the affected area.
- Tenderness and pain at the fracture site in motion or load.
- Displacement and false movement of the broken bone.

Some fractures can almost be symptom-free, such as fractures of the femoral neck and the upper arm, where the bone ends are steadily wedged into one another and gives stability to the fracture.

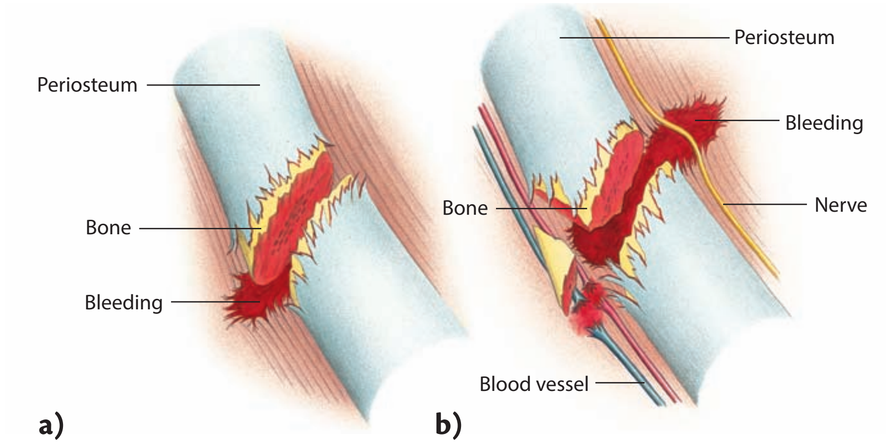


Figure 8.3 The soft tissues around a fracture are often injured in connection with a trauma. **a)** Fracture with a soft tissue injury and a bleeding; **b)** fracture after a more violent trauma can be associated with major soft tissue injury. This may cause increased bleeding, which may delay the healing process.

Treatment

All forms of treatment of fractures follow one basic rule:

- The broken pieces must be reduced back into position.
- Then prevented from moving out of place until healing.

When a suspected fracture exist, the athlete/coach should:

- Cover an open wound with sterile gauze, bandage or clean cloth.
- Fixate the injured limb by placing it in a splint.
- Place the injured limb slightly raised.
- Prepare for transport to the hospital, where an X-ray should be performed as soon as possible.

If a splint or dressing is not available it is possible to improvise with what is at hand: clean handkerchiefs, a belt, braces, some clothes and items from sports equipment. It is essential that the immobilization is so effective that the pain is not increased and the injury worsened. A typical procedure is to wrap a broken arm to the body or attach an injured leg to the other. Fixation with bandages or splinting should cover the joints on both sides of the fracture. The injured person must abstain from food and drink in case surgery becomes necessary. Physicians should quickly correct any severe displacement to limit the bleeding, reduce pain and improve blood circulation.

Fractures without displacement are immobilized by supporting the injured body part using a cast, a brace or a splint to support and protect injured bones. When pain, swelling or tingling occur in a patient with a cast, the hospital must be contacted so that the cast can be adjusted or replaced. The cast can be made of plaster, which can be heavy and must remain dry, or of fiberglass which is lighter in weight, longer wearing and more breathable than plaster (Fig. 8.4).

In some fractures a limited range of motion (ROM) training may have a beneficial impact. The treatment that is offered by the physical therapist often means a faster return to training and competition. Splints, orthotics (supporting bandages) and, in some cases, external fixation with a frame system are used for immobilization of the fracture.

In fractures with displacement the bone ends are put back in position either closed (without surgery)

Figure 8.4 Example of a functional 'walking boot' used today as treatment for many fractures of the lower leg, ankle or foot.

or open (with surgery). In the latter case, the fracture ends are fixed with steel wires, screws or plates, pins or nails, which are rods down through the marrow space in the center of the bone – so called open reduction and internal fixation. Fixation is still performed in many cases. Then a cast or splint may be needed but in such a case can often can be removed after a short time. In some cases mobilization can get started without treatment in a cast.

When the skin and other soft tissues around the fracture are badly damaged, an external fixator may be applied until surgery can be tolerated. In external fixation metal pins or screws are placed into the broken bone above and below the fracture site. The pins or screws are connected to a metal bar outside the skin. This device can be a stabilizing frame that holds the bones in the proper position while they heal. External fixation is often used in open fractures.

After treatment

All parts of the body, even those that are not encased in casts or braces, must be activated by muscle contractions or movement (see Chapter 20) so that a good circulation is maintained and the muscle mass remains intact. The muscles inside the cast can be trained isometrically; if movement is allowed dynamic muscle training may be performed.

The treatment duration of the cast or splint varies with each fracture's location, how serious the fracture is and how fast the healing process is. A wrist fracture is fixed in a splint for 4–6 weeks, while a lower leg fracture is fixed in a cast, brace or splint for at least 3 months. One should then expect an equally long time for re-training and convalescence. It is wise to remember that some fractures may take several months to heal.

Stress fractures (fatigue fractures)

Fatigue fracture of the bone is also called stress fracture or insufficiency fracture. A stress fracture is an overuse injury in high-impact sports such as long distance and hurdle running, high jump, basketball, volleyball and handball (Fig. 8.5). It is a small crack in a bone, i.e. a cortical infarction of bone due to repetitive submaximal load and occurs when muscles become fatigued and are unable to absorb added shock of repeated impact. Such fractures mostly occur after prolonged repeated loads and probably are preceded by an irritation of the periosteum (periostitis which is an inflammation of the periosteum, i.e. the connective tissue that surrounds the bone).

Causes

Stress fractures can occur due to normal load at high frequency (e.g. long-distance runners), due to high load at normal frequency (e.g. a runner who repeats a 100 meter race with a friend on the back as load) or due to high load, high frequency (e.g. performing intense weight training with high load). The latter combination is the most dangerous; both in terms of the risk of suffering stress fracture and the risk of getting overuse injuries in other tissues. The high incidence of stress fractures in the lower legs of athletes is associated with increased bone thickness and hip rotation. The risk of stress fracture is also greater if there is a leg length discrepancy or high or low foot arches. Anyone who trains more than 100 km of running per week and also plays basketball is more exposed to these injuries. It is mainly young people who suffer from stress fractures. The risk is higher in women in general, and it increases with disturbances in the menstrual cycle, with eating disorders and by intake of oral contraceptives. The female triad, i.e. amenorrhea, eating disorder and osteoporosis (see Chapter 2, p. 22) can result in low aerobic fitness, no menses in 6 or more consecutive months in the past year and <7 months of lower-extremity weight training, which are significantly associated with stress fracture incidence.

There are two theories on how stress fractures occur:

- Fatigue theory, is based on the fact that the muscles during prolonged and repetitive work, e.g. during running, get so exhausted that they are no longer able to relieve the load of the bone at foot strike. The load is then transferred directly to the bone, which gets fatigued and may sustain a fracture.
- Overload theory, is based on the fact that certain muscle groups contract in such a way that the bones are bent, which means increased load on them. A contraction of the calf muscles, for example, may cause the tibia to bend forward like a taut bow. After repeated contractions of the calf muscles the tibia fatigues and a fracture may occur.

Tip

Stress fracture may occur in otherwise healthy individuals of all ages from the age of 7 years and up, in normal bone and normal activity and without trauma to the bone.

Figure 8.5 Some sports can be risk factors in themselves for sustaining a stress fracture. **a)** Events with lots of jumping on stiff and hard surfaces may be a risk factor (with permission, by Tommy Eriksson, Swedish Athletic Association); **b, c)** distance running on hard and wet surfaces can be a risk factor. (**c**) with permission, by Bildbyrån, Sweden).

Poorly trained athletes are more likely than others to suffer from stress fractures. Athletes who complain of pain from the bones, and especially of pains in the legs during exercise, may suffer from a stress fracture.

Tip

It should be noted that people who do not exercise can also have stress fractures. If osteoporosis or other disease has weakened bones, normal daily activities may result in a stress fracture.

Location

A stress fracture affects the lower leg (tibia) in 44–50% of cases (see p. 479), the fibula in 12–16%, metatarsal bones in 16–20% and the femur in 6–8%. The calcaneus, tarsal navicular bone, humerus, pelvis and the vertebrae are less often injured. Stress fractures are double-sided in 25% of cases and multiple in 8–12%. They do not occur twice in the same place. Almost all of the body's bones can be affected by a stress fracture. Runners are prone to this fracture type in the lower third of the fibula, usually 5–7 cm above the lateral malleolus. High jumpers often suffer stress fractures in the upper third of the fibula.

The metatarsals can suffer from stress fractures (see p. 551), which should always be suspected when pain last more than 6–8 weeks. Infantry soldiers are prone to this type of skeletal injury, which is therefore also called 'march fractures'. This type of fracture was described by Breithaupt in 1855, when he found foot pain and swelling in military recruits. In runners, march fracture occurs most often in the metatarsal neck, while in dancers it occurs in the proximal shaft.

Of the remaining stress fractures in the foot a fracture of the proximal fifth metatarsal, Jones fracture (see p. 552), often requires treatment in the form of surgery or cast and non-weight-bearing. A stress fracture of the navicular bone (see p. 549–50) can be difficult to diagnose. A magnetic resonance imaging (MRI) scan can confirm the diagnosis and provide information of the nature and extent. The femoral neck is a vulnerable place where an athlete may sustain a stress fracture. Such fractures almost always require surgery to heal to avoid vascular damage with tissue death (necrosis) of the femoral head and displacement of the fracture.

Tip

Groin pain must not be ignored by the athlete, as it can be a sign of stress fracture.

Sports involved

Athletes participating in sports such as running, jumping, tennis, gymnastics, handball, volleyball, basketball and dancing are very susceptible to stress fractures. Stress fractures occur most frequently in running (69%), racquet sports (5%), basketball (4%), fitness class (8%) and other sports (14%).

A study of 54 top level football teams, comprising 2379 players found in total, 51 stress fractures occurred during 1,180,000 hours of exposure, giving an injury incidence of 0.04 injuries/1000 hours.[1] Therefore, in football/soccer a squad of 25 players can therefore expect one stress fracture every third season.

Symptoms and diagnosis

- In half of the cases the symptoms of a stress fracture starts acutely without being exposed to trauma. In the remainder of cases, the symptoms are more insidious.
- There is a relationship between pain and activity. During the first week when symptoms arise the athlete may experience pain during exercise, but are symptom-free at rest. Tougher training increases the pain, eventually producing a dull ache after training. The pain will often recur at nighttime.
- Local swelling and well-defined tenderness can be felt over the area of the fracture.
- An X-ray should be done if the symptoms above are present. It should be noted that X-ray images taken on a first examination do not always show signs of fracture in approximately half of the cases. The typical X-ray image of a stress fracture shows signs of healing – newly formed periosteum, a well-defined area with harder bone tissue and a callus formation or clear fracture line – and this picture emerges 2–3 weeks at the earliest after the first symptoms are noted. In only 40–50% of the images studied changes can be seen when the injury is fresh (Fig. 8.6). If no signs of stress fracture are visible at the first examination and the symptoms persists, the examination should be repeated after 2–4 weeks. In cases of a positive X-ray finding no second examination need to be conducted.
- An MRI scan involves no radiation and should be the method of choice to study the stress fractures in detail.
- If there is a strong suspicion of a stress fracture the physician may examine the bone with a nuclear scanning test to find abnormalities in bone (bone scan [bone scintigraphy], Fig. 8.7). A bone scan measures an aspect of bone metabolism or bone remodeling, which most other imaging techniques cannot do. With a bone scan it is possible to see changes in the bone as soon as 2–3 days after the first symptoms have appeared. A three-phase scanning has been considered to have 100% sensitivity. There is a risk that these can be a so-called false negative. The method's main disadvantage is the lack of detail, i.e. a skeletal fracture cannot be separated from other tissue injuries, caused by a tumor or an infection, with locally increased signal intensity. This technology is currently used less and less.

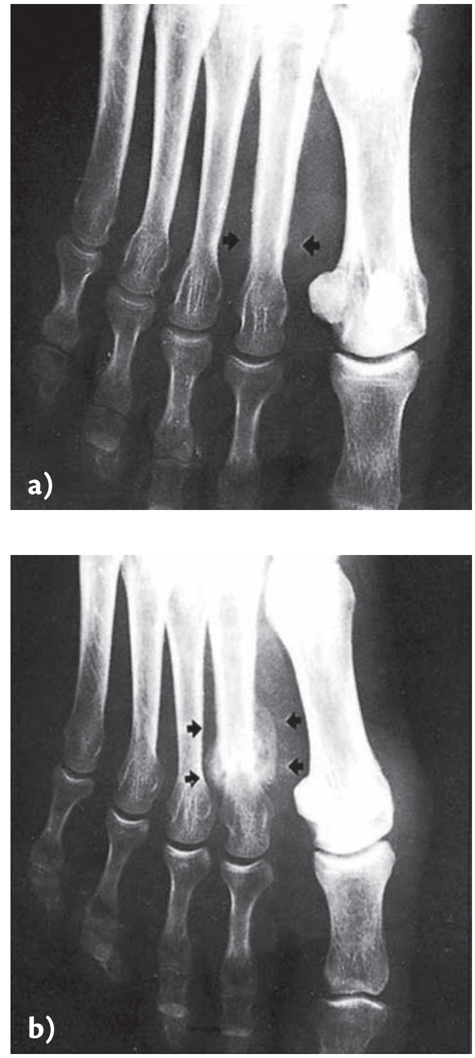


Figure 8.6 X-rays of a stress fracture. **a)** Image taken at the first examination showing signs of a stress fracture; **b)** image taken 1 month later; signs of healing with callus tissue around the stress fracture.

If there is a stress fracture all phases of the three-phase scanning may cause a positive reaction. Periostitis on the inside of the tibia will only become positive on a nuclear bone scan, which is a functional test measuring an aspect of bone metabolism. Problems like periostitis, which is an inflammation, can be located 3 hours after the injection of the radioisotope. This can be called the third or delayed phase. The diagnosis of a stress fracture is determined by a locally increased signal intensity.

- In some cases additional image analysis is performed with computed tomography (CT) and MRI. CT may be useful in estimating the extent of a stress fracture.

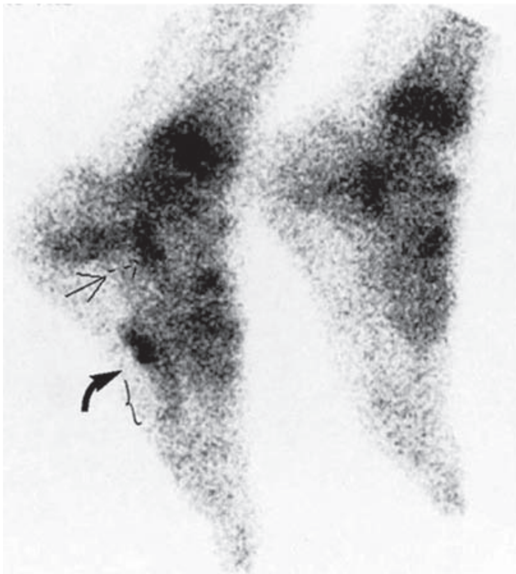


Figure 8.7 Bone scintigraphy can occasionally be valuable. The arrow shows an area with increased uptake of radioactive isotopes, a sign of a stress fracture.

CT provides an extremely fine detailed image of the bone, but should be reserved for specific indications as there is some radiation.

Treatment

When a stress fracture occurs, the athlete should:

- Rest for 2–8 weeks depending on the nature of the injury and until the pain has subsided and healing can be seen on X-ray.
- Do conditioning training with unloaded activities such as swimming or cycling.
- Gradually resume the daily movement patterns if these can be done without pain and when the local soreness has disappeared.

The physician may:

- Prescribe crutches for unloading, especially in a tibial or femoral fracture.
- Treat with a cast or an ankle orthosis for 2–6 weeks when the pain is severe and when a fracture is localized to the tibia, scaphoid bone in the wrist or navicular bone in the foot or the proximal fifth metatarsal bone.
- Monitor healing with X-ray.

Alternative management techniques include: increased calcium intake, resolve menstrual disorders, shock-wave treatment and pulsed low frequency ultrasound. Electro-hydraulic wave generation is being tried and some physicians use biphosphonate treatment, which inhibits activation of the osteoclast (bone cell) and reduces bone turnover.

If the athlete is to return to training within a reasonable time and without the risk of complications, surgery is usually required.

> **Tip**
>
> Special attention must be paid to the healing of stress fractures in the femoral neck, anterior-medial part of the tibia, proximal fifth metatarsal bone and the tarsal navicular bones; they are potentially serious locations with great problems because of poor healing, delayed union and risk for full fracture.

Prevention

Stress fractures can and should be avoided. Possible risk factors should be analyzed and eliminated. The athlete with his/her coach, physician and physical therapist should carefully review training methods and equipment, especially shoes. Remember that the body's tissues need time to adapt. Among the risk factors in women are 'the female triad', i.e. menstrual disorders, low bone density and inadequate nutritional intake (see p. 22). Furthermore, analysis of bone shape and biomechanical abnormalities should be performed.

> **Tip**
>
> Stress fractures can and should be avoided. Possible risk factors should be analyzed and if possible eliminated.

Periostitis on the inside of the tibia ('shin splints', medial tibial periostitis)

Medial tibial periostitis is a pain syndrome in the lower leg caused by a reaction of the periosteum on the back of the inside of the tibia. Tissue samples show signs of chronic inflammation. The condition is probably a precursor to a fatigue reaction or fatigue fracture (stress fracture) of the tibia. The term 'shin splints' is vague, but is still used for this condition.

The pain and tenderness are localized to the lower two-third of the tibia. It is generally considered that the cause of the injury is a chronic inflammation of the muscle attachment along the back of the medial tibia and changes in the bone tissue (a state that precedes stress fracture). For diagnosis and treatment, see p. 477. Another cause of pain in the leg is compartment syndrome (see p. 475).

Skeletal diseases

Brittle bone (osteoporosis)

Osteoporosis is the most common bone disease in a global perspective. It affects almost all women after menopause due to hormonal changes and a less active lifestyle. Half of all women over 45 years have radiographic osteoporosis, and at age 75 the incidence is increased to 90%. Osteoporosis also occurs in younger women as a part of the syndrome the female triad (see p. 22).

The bone's ability to absorb minerals is decreased in osteoporosis, with the result that bone density decreases (Figs 8.8, 8.9). The bones most often affected are the radius at the wrist, the vertebrae of the spine and the femoral neck. The risks of primary osteoporosis may be genetic, hormonal, dietary, or have to do with lifestyle, such as if the person is doing endurance training. Secondary osteoporosis can be caused by an underlying disease or from a drug reaction.

The skeleton is made up by a buildup of calcium and phosphorus (except for collagen fibers), which makes bone hard. Decalcification of the bones is caused by reduced activity, aging and in some hormonal imbalances and nutritional problems. The skeleton will then be more susceptible to injury, and as the bone loss increases the risk of both major fractures and microfractures (fractures that are not immediately detected) increases.

There are many risk factors for fractures, including hormonal factors, use of certain drugs such as cortisone, cigarette smoking, low physical activity, low intake of calcium and vitamin D, race and a personal or family history of fractures.

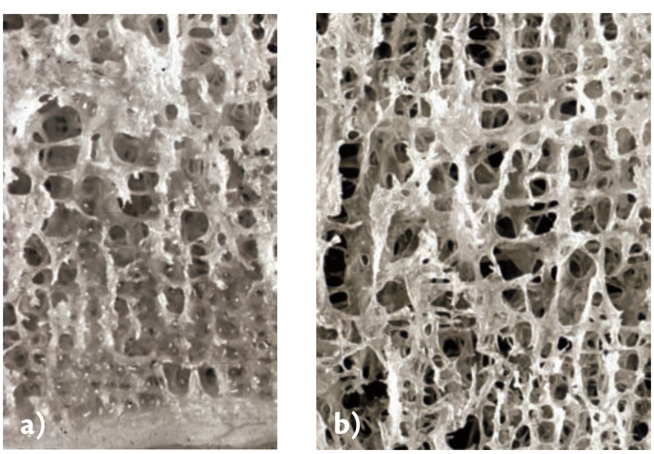


Figure 8.8 Skeleton structure. **a)** Normal trabecular bone; **b)** osteoporotic trabecular bone. (Courtesy of Professor Tommy Hansson, Sahlgren Academy, Gothenburg University, Göteborg, Sweden.)

Osteoporosis is preventable through a healthy lifestyle with regular physical activity and adequate intake of calcium and vitamin D. Physical activity increases bone density in most individuals, and should be, regardless of age, an important part of life style. Regular exercise promotes both bone mass and vigor in women after menopause. As a preventive measure, calcium is given as a complement to diet but only on medical advice. A balanced diet is very important. If osteoporosis causes pain, it is especially important to be in motion to prevent further weakening of the bones and muscles. Pain killers sometimes help.

The International Federation of Sports Medicine (FIMS) has compiled the following recommendations on exercise for osteoporosis, reproduced here with kind permission:

- Physical activity is an essential factor for the skeleton to develop normally and maintain its load-bearing function. Training designed to increase muscle strength is valuable especially for the bones that are not load-bearing.
- It has recently been demonstrated that the growing skeleton that is mechanically loaded during physical activity, responds better to this than the fully developed skeleton. This suggests that regular exercise during childhood and adolescence is an important factor in the prevention of osteoporosis in later life.
- Excessive endurance training can cause hormonal changes, including menstrual disorders, which ultimately affects the skeletal structure negatively.
- Training cannot be recommended as a substitute for estrogen therapy during menopause.

Figure 8.9 The degree of osteoporosis can be established in a dual-energy X-ray absorptiometry (DXA) machine, which measures bone mineral density (BMD). (Courtesy of Moria O'Brien, Trinity College, Dublin, Ireland.)

- The incidence of fractures in osteoporosis decreases as an indirect result of the training, because the risk of falling is reduced in the person who has trained strength, agility and coordination. Training programs for the elderly should be designed with this in mind.

Tip

Growing adolescents should be physically active because of the positive reinforcing effects on the skeleton that remains later in life.

Joint and ligament injuries

The joint consists of the articular cartilage along the joint surfaces between the opposing ends of the bones. Joints vary in construction. One end is usually convex and is called the joint head, while the other is concave and is called the joint socket, and these fit more or less closely together. In the hip joint the joint socket encloses the joint head almost completely, while it is much shallower in the knees, shoulders and fingers.

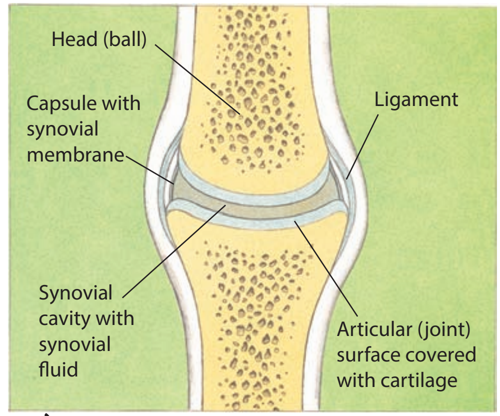
Bone ends are joined by a joint capsule, which consists of connective tissue. The joint capsule's interior is lined with a synovial membrane which secretes synovial fluid. In some places, where the stresses are large, the joint capsule is reinforced by tight bands, the ligaments of connective tissue that support and protect against the excessive movement. The joint is surrounded by muscles and tendons.

The stability of a joint is affected by both active and passive structures. Active stability is maintained by muscles during exercise, which the athletes can affect. The passive stability of a joint is primarily maintained by ligaments. Adequate passive stability of a joint is a prerequisite for the joint to have good function.

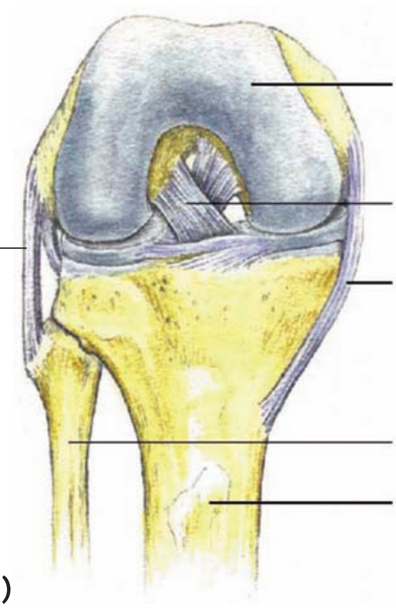
Ligament injuries

Ligament injuries are common in sports and primarily affect the knee and ankle. They also occur frequently in the shoulder joint, elbow joint and the hand, where the thumb especially is affected.

The ligaments are attached to the two bones which make up the joint (Fig. 8.10). Ligaments provide stability for the joint without restricting the normal movements. They cannot actively prevent the joint's movement, but are able to hold 'tight rein' in its outer ranges of motion. The ligament's microstructure protects well against tensile stresses, but is of little value as protection against pressure and impact.



a)



b)

Figure 8.10 **a)** Schematic sketch of a joint; **b)** knee joint seen from anterior.

The ligaments are injured when the external forces exceed the ligament's resilience, which in turn varies depending on the speed of the process. Ligaments are more resilient if the load is slow. That is why the relatively slow progress of the injury more often causes avulsion fractures (where a bone fragment is torn from the ligament attachment) than torn ligaments. In a rapid process the ligament is affected before the bone, so that the ligament's mid substance is torn apart.

Injury types

A ligament sprain can mean anything from a few torn fibers to a complete rupture of the ligament (Fig. 8.11).

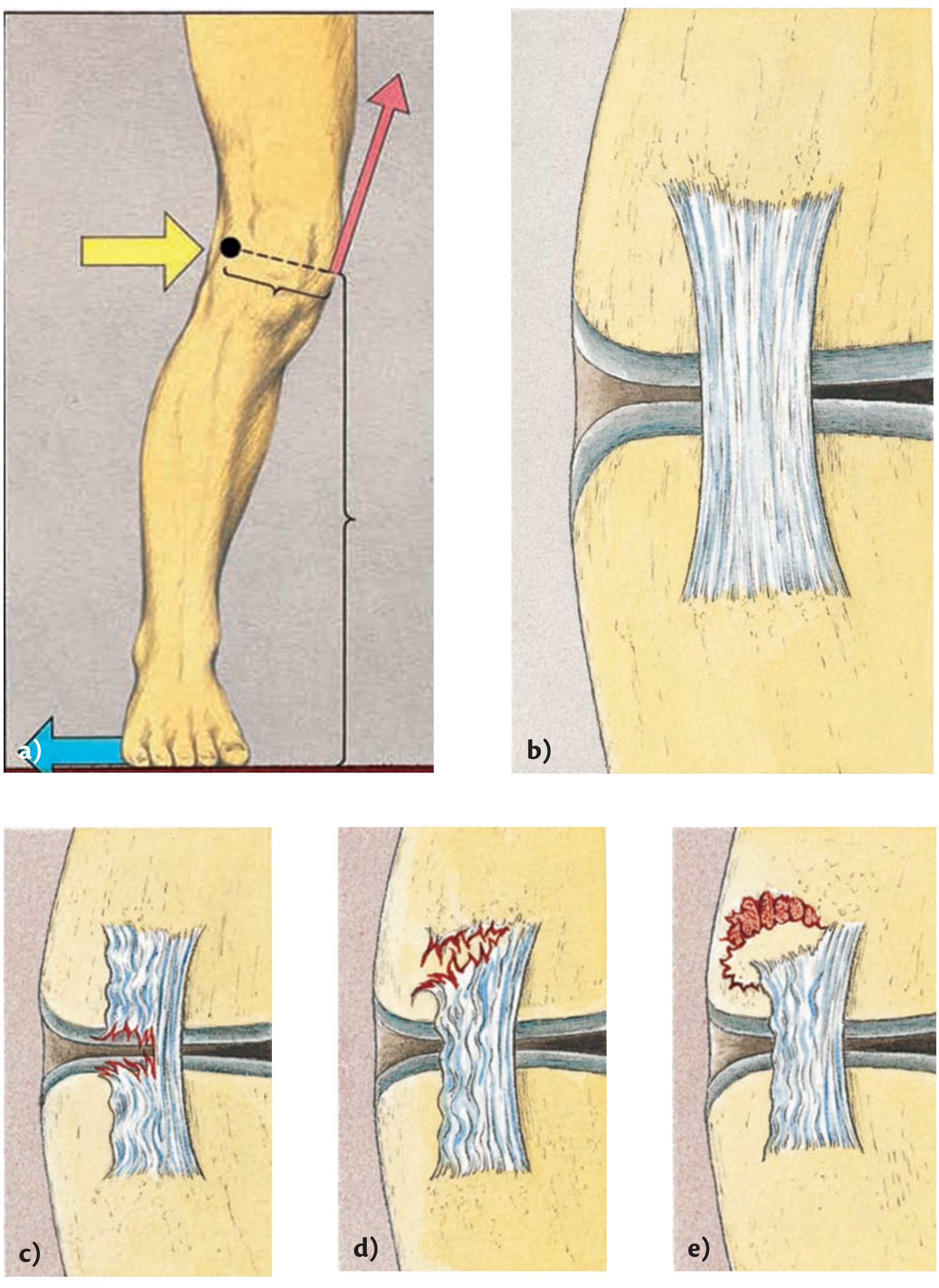
A useful distinction is made between a partial and a total ligament rupture, because the treatment and prognosis are different between the two groups. A partial rupture only affects a part of the ligament or ligament attachment and can sometimes affect stability.

- A portion of the ligament may have been ruptured in the tissue while the rest of the ligament is intact.
- A portion of the ligament attachment may have been torn off with or without a piece of bone.

A complete rupture of the ligament means that most or all fibers torn, and the joint is unstable.

- The entire ligament may have been ruptured and the ends can be separated from each other.
- The entire ligament attachment may be loose from the bone.
- The bony attachment of the ligament may have been displaced.

A partial rupture may be classified as a grade I rupture (only a few torn fibers) or a less severe grade II rupture (less than half of the fibers are torn off); in both cases



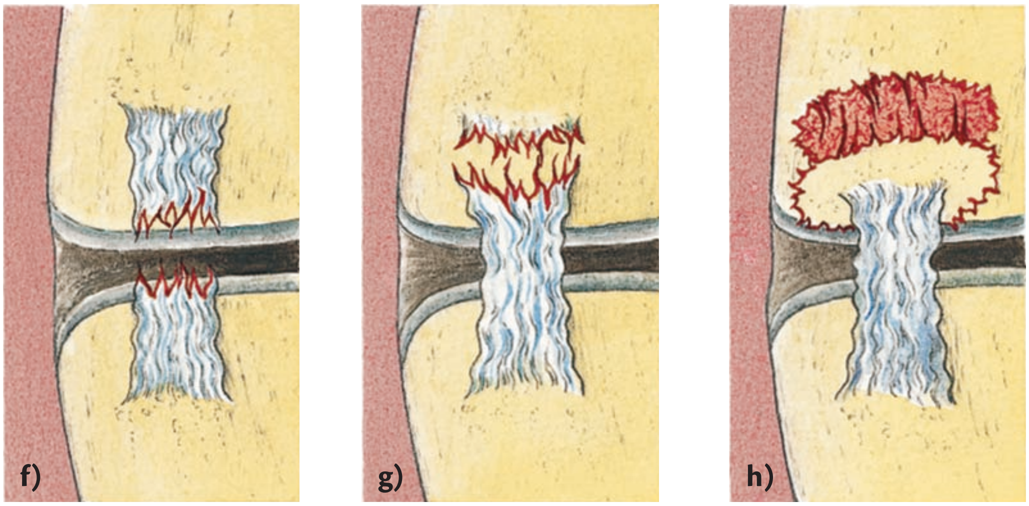


Figure 8.11 Ligament injuries. Forces acting from the lateral side of the joint can cause different types of injury. **a)** Biomechanical forces acting on the ligaments of the knee; **b)** Normal ligament; **c)** Partial tear of ligament in the substance; **(d)** Partial avulsion at the soft tissue attachment; **e)** Partial avulsion of the ligament bony attachment; **f)** Complete tear in the ligament substance; **g)** Complete avulsion of the ligament attachment in the bone; **h)** Complete avulsion of the bony attachment (origin).

the joint stability is maintained. A more severe grade II rupture corresponds with a tearing of more than half of the ligament, while a grade III rupture means a complete ligament rupture; in both cases the joint is more or less unstable.

Bleeding is frequently occurring in the surrounding tissues after a ligament rupture, causing a discoloration of the skin. When a ligament injury occurs in the joint or joint capsule, the bleeding can fill the entire area. Sometimes the articular cartilage can also get injured.

Symptoms and diagnosis

- Blueish discoloration, swelling and tenderness around the joint and ligaments due to bleeding.
- Pain during movement and load; palpation pain may occur.
- Instability, depending on joint type and extent of injury.

If the diagnosis is unclear the extent of the joint injury can be seen on MRI. If a ligament injury is suspected the joint stability must always be tested.

Treatment

When there is an acute injury the athlete/coach can treat as soon as possible with:

- Bandages (elastic bandage, orthotics or splint).
- Compression bandages for bleeding.
- Cooling of the joint (ice bags).
- Rest and unloading (crutches can be a valuable tool).
- Elevation.

The physician may:

- Examine the joint stability. When there is severe pain the stability may be tested under general anesthesia.
- Take an X-ray to rule out fracture.
- When the joint stability is preserved, treat with early movement training. Depending on the nature of the injury or location, taping or orthotic treatment can be of value. It is important with early onset of movement exercises.
- Determine whether treatment should be conservative or if surgery is necessary when there is joint instability present. Conservative management may include early careful movement training, whereby the joint is supported by orthotics, tape, splint or cast.

Rehabilitation

Active muscle and movement training is essential in the rehabilitation phase and should be done in cooperation between athletes, coaches, physicians and physical therapists. It takes a long time for a ligament injury to heal; it generally requires more than 6 weeks. If the ligament is part of a joint capsule (e.g. the knee's medial collateral ligament [MCL]) movement rehabilitation may start early provided that a supporting orthotic has been added. If the affected ligament is inside a joint (e.g. the knee's anterior cruciate ligament [ACL]) the joint may also be activated early. It is generally desirable to have early movement training of the joint, but the training must not intrude on the physician's intervention and should not affect the healing process.

All injuries that provide an effusion around the joint, like all sprains with bleeding, swelling and tenderness, should be treated as ligament injury.

Healing

The healing of ligament injuries occurs by the same reaction as in the healing of other tissue injuries. An accumulation of inflammatory cells initiate repair work in the area by clearing away dead tissue and preparing for new tissue formation. Blood vessels then invade the area so that formation of new cells can get started, and eventually supportive tissues are formed between cells. The new tissue is still immature, and a maturation process is therefore necessary for complete healing, which, thus can take several months. As early as 6–12 weeks after the injury the tissue has in most cases become so strong that the athlete can start with exercises to strengthen the joint. In partial ruptures training can begin much earlier.

Dislocation

All joints are surrounded by a joint capsule and ligaments. For a dislocation to occur, parts of the joint capsule and ligaments around the joint have to rupture. A dislocation leads thus naturally to joint capsule and ligament injuries, and sometimes even injuries to the articular cartilage and bone. Healing time is dependent on the extent of the tissue damage.

Complete dislocation (luxation) means that the opposing joint surfaces have been separated completely. A non-complete dislocation (subluxation) means that the joint surfaces partially are in contact, but that they are not correctly located in relation to each other. This can also result in joint capsule and ligament injury and sometimes cartilage injury.

Location

Complete dislocations occur most often in the shoulder joints, elbow joints, finger joints and kneecaps, while non-complete dislocations are most common in the knee and ankle joints. The joint between the collarbone and shoulder blade may suffer a complete or a non-complete dislocation.

Symptoms and diagnosis

- Pain with movement.
- Abnormal contour of the joint.
- Swelling and tenderness.
- Varying degrees of joint instability.
- X-ray examination reveals the presence of fractures and can also determine whether the dislocation is complete or non-complete.

Treatment

A reduction is performed by the physician, i.e. the dislocation is put back into position. This is done under local anesthesia, or in some cases under general anesthesia. Further treatment is aimed at restoring joint stability and function. Depending on the degree of instability the physician suggests the appropriate treatment. Surgery may be performed when severe instability is present. The treatment may consist of early mobilization, including weight training, or immobilization, i.e. cast or other fixation treatment for 1–6 weeks, followed by exercise or surgery when severe instability persists. Dislocations could recur in the shoulder and kneecap especially in young athletes and especially when training and rehabilitation have been unsatisfactory. Dislocations can sometimes be complicated by neurological and vascular injuries.

Meniscus and disc injuries

Meniscus injuries in the knee are described on p. 425. The shoulder's acromioclavicular and sternoclavicular joints are sometimes furnished with a meniscus or disc (see p. 245). A small disc exists in the wrist in the joint between the distal radius and ulna. The intervertebral disc is discussed on p. 344.

Joint cartilage injuries

The bone joint surfaces are covered by smooth, white and shiny cartilage. Articular cartilage can be damaged due to external trauma, but the most common injuries are repeated minor impact damage that can lead to osteoarthritis (worn joints).

Articular cartilage injuries are common problems among athletes. Through a more active treatment of ligament injuries and the use of examination methods such as arthroscopy and MRI, the incidence of joint cartilage injuries proved to be much more common than previously believed. Among people who had surgery for acute and chronic knee injuries more than 40% has been found to have cartilage injuries down to the underlying bone.

In people with chronic symptoms after an injury to the ACL joint cartilage injuries occurred in 20–70% of cases. Damage to articular cartilage is a serious condition, especially in young athletes, and continued sporting activities can both ruin the joints and make a sports career impossible.

Cartilage functional anatomy

The smooth movement of the joints is made possible thanks to the articular cartilage that coats the joint's bone surfaces, where the cartilage reduces friction between the bone ends and increases joint shock absorbing ability. Articular cartilage is composed of cartilage cells (chondrocytes) and the supporting substance (matrix) which surrounds the cartilage cells. Cartilage cells, which make up only about 5% of the cartilage tissue, are located in rows of round cells in the deeper layers and flatter cells at the surface (Fig. 8.12).

Cartilage cells form the supporting substance consisting of protein fibers, collagen. This stringy, cohesive substance gives tensile strength to the tissue. The chondrocytes produce proteoglycans, a combination of proteins and carbohydrates (mucopolysaccharides), which attract water, resulting in cartilage having a 70% water content. The proteoglycans' water binding ability contributes to the shock absorbing function of the cartilage tissue. The water coming from the joint fluid (synovial fluid) is drawn into the supporting tissues by proteoglycan activity when the joint is unloaded. During loading the joint fluid is pressed back to the joint, so that the water content of the cartilage decreases. Synovial fluid, formed in the synovial membrane, transports nutrients and oxygen to the cartilage tissue. The synovial fluid's other important function is to lubricate the joint cartilage surfaces so that friction between them decreases. The friction between the cartilage surfaces is lower than ice against ice.

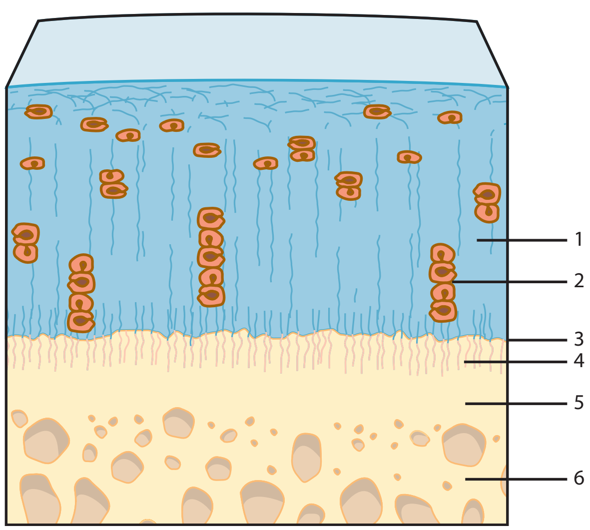


Figure 8.12 Cartilage and bony structures. 1: Supporting structure (matrix) of the cartilage; 2: chondrocytes (cartilage cells); 3: border to calcified cartilage; 4: calcified cartilage zone; 5: bone joint surface (joint plate); 6: trabecular bone. The bone located beneath the cartilage is the subchondral and trabecular bone (spongious bone).

The joint cartilage tissue is unique in that it lacks the supply of blood and lymph vessels and nerves. The lack of blood supply means that the cartilage cannot be repaired by inflammatory tissue processes, making healing dependent on the inflow of nutrients and oxygen through the synovial fluid. Metabolism is slow. The absence of nerves in the area means that damage to the cartilage tissue does not cause pain. Pain therefore comes from the surrounding tissues, such as the synovial membrane, the bone tissue closest to the cartilage or the periosteum, when these tissues are affected.

Injury mechanisms

Damage to the articular cartilage may occur as a result of sprains, dislocations, and contusions (blunt trauma). Subluxations as well as meniscus and ligament injury often cause damage to the cartilage. The articular cartilage may be damaged by repetitive micro-trauma, i.e. recurrent, smaller trauma. Permanent defects in the joint can be caused by fractures, which include cartilage tissue. Anatomical abnormalities in the joint may be a contributing factor to repetitive micro-trauma and overload of the joint surfaces, which can eventually result in overuse injuries to the cartilage.

Recurrrent trauma can cause cartilage damage in joints.

Classification of joint cartilage injuries

Injuries to the joint cartilage can be superficial (partial), deep (complete) or even include the underlying bone (osteochondral lesions) (Fig. 8.14).

Superficial joint cartilage injuries extend down to half the cartilage depth. These injuries do not heal, but they do not get worse either, not unless they are within an area that is exposed to stress.

Deep or complete cartilage injury runs through the entire cartilage tissue, but not through the subchondral bone. The damaged cartilage tissue does not heal, but wears down more and more and eventually results in osteoarthritis. Osteochondral injuries (including both cartilage and bone) extend down through the subchondral bone plate into the trabecular bone tissue and causes bleeding. This bleeding causes an inflammatory process, which starts an ingrowth of newly formed blood vessels and fibroblasts (connective tissue cells) and stem cells from bone marrow, which are involved in the healing of tissue.

Joint cartilage injuries are clinically classified according to Outerbridge's classification (Fig. 8.13).

Joint cartilage injuries can also be classified according to the International Cartilage Repair Society (see Fig. 8.14) where grade IV includes damage to the bone plate and the underlying bone. With joint cartilage injuries, loose bodies can separate and then disrupt normal joint function.

Healing and repair

Articular cartilage has little or no capacity to heal and repair injuries. In both superficial and complete cartilage injuries a degradation of the tissue's supporting substance (matrix) occurs by mechanical wear and by enzymes released from the damaged cartilage cells. Cartilage cells do form repair tissue during the first 10–14 days after a joint cartilage injury, but for some unknown reason this repairing activity stops.

The degradation of the cartilage tissue's supporting substance eventually results in osteoarthritis (see p. 441), which is a serious condition if the joint's two opposing cartilage surfaces are injured. If the affected person maintains a high level of activity despite ligamentous instability or anatomic malaligned joints, the cartilage injuries quickly develop into severe overuse injuries.

The cartilage tissue's lack of ability to repair is due, in part, to the fact that cartilage cells are encapsulated in the matrix, and therefore cannot move to the affected area in order to form the repair tissue. An injury in the bone and cartilage can heal by connective tissue cells from the bone marrow invading the injury. The fibrous repair tissue thus formed has poor resistance to wear, and it has less shock absorbing properties; osteoarthritis may be a result.

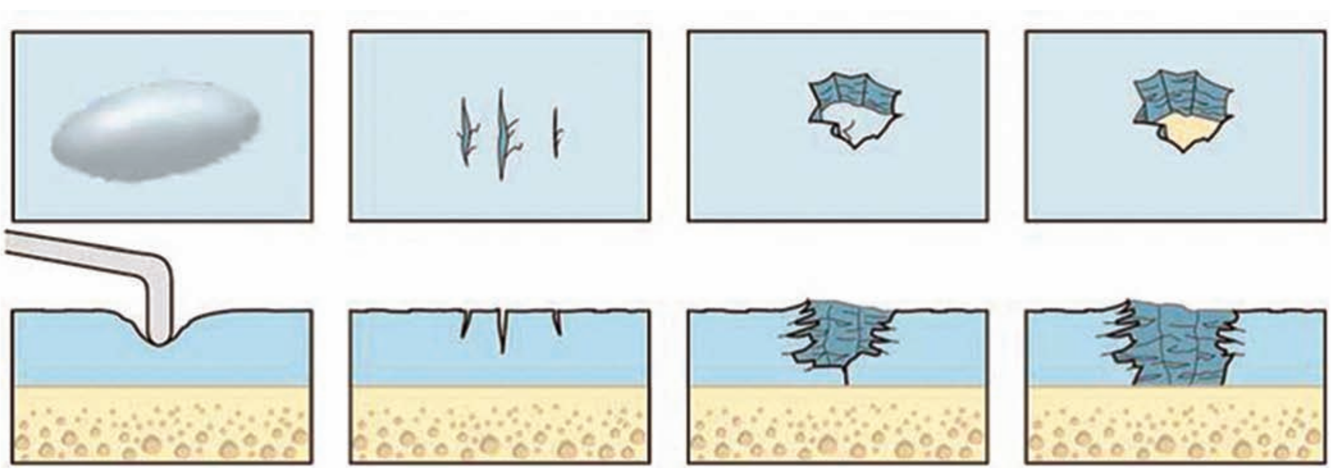


Figure 8.13 The articular cartilage is clinically graded according to Outerbridge's classification. The top figures show the injury obliquely from the top and the lower figures show the injuries from the side. Left to right: Grade I: Fissures in the cartilage surface only; Grade II: increased fraying of the cartilage surface with cracks in the cartilage tissue's upper half; Grade III: increased fissuring in the cartilage, but without exposure of the bone; Grade IV: complete absence of cartilage and exposure of bone.

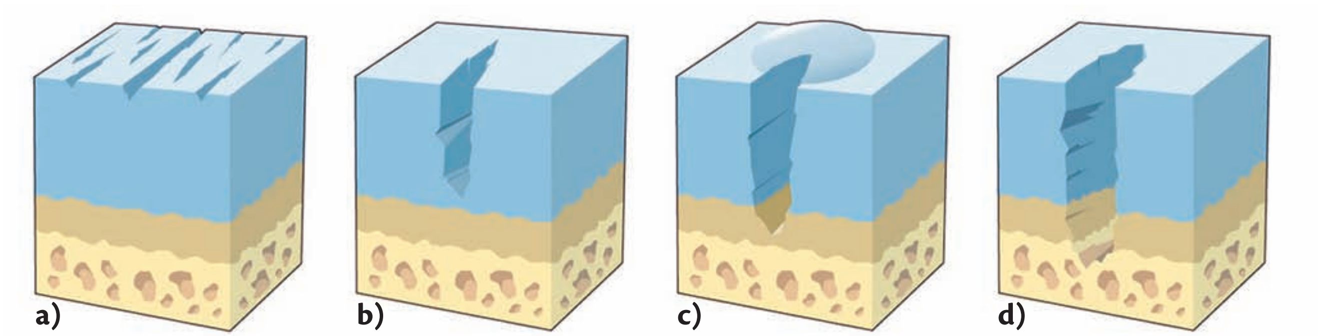


Figure 8.14 Classification according to International Cartilage Repair Society (ICRS). Blue shows pure cartilage, brown calcified layer and yellow subchondral bone. **a)** Grade I: Nearly normal, superficial injuries: softened tissue and/or superficial fissures (cracks); **b)** Grade II: abnormal; the injury extends down to 50% of the height of the cartilage; **c)** Grade III: severely abnormal; the injury is deeper than 50% of the height of the cartilage (Grade IIIA); the injury may extend into the calcified layer (Grade IIIB); and even down to the subchondral bone plate but not through (Grade IIIC); formation of blisters at the surface involving the cartilage and its attachment to the subchondral bone plate (risk for cartilage delamination) (Grade IIID); **d)** Grade IV: extremely abnormal; the injury is engaging the subchondral bone plate and the trabecular bone.

Location

Joint cartilage injuries most often occur in the knee joint, but can also affect the ankle, elbow, shoulder and hip joints. Joint cartilage injuries may often be combined with ligament injuries and anatomically malaligned joints.

Acute cartilage injuries

Cartilage injuries can be diagnosed in both the acute and chronic phase.

Symptoms and diagnosis

- The joint may have suffered sprain, dislocation and/or contusion.
- Swelling due to bleeding.
- Pain with movement or loading of the joint.
- Locking, catching in movement or load.
- Crepitations may be noticed during movement of the joint.

Treatment

The athlete should:

- Cool down the joint with ice.
- Use elastic support and compression bandages.
- Rest and restrain from loading activities of the affected area, sometimes crutches can be of value.
- Put the affected limb in elevation.
- Seek medical advice.
- Exercise without exposing the joint for load or impact.

The physician may:

- Perform a clinical examination, that includes stability test of the joint.
- Order an X-ray or MRI to rule out fractures or avulsions of cartilage or bone–cartilage fragments.
- Empty possible joint fluid with a syringe if the swelling is painful.
- Inspect the joint with arthroscopy to confirm the diagnosis and to remove any loose bodies.
- Attach or remove loose bodies of bone or cartilage, a few days after the injury.
- Treat with early movement exercises during the first 6–8 weeks to train the range of motion and allow careful loading of the joint.

Chronic joint cartilage injuries

If the athlete still has symptoms even after 2–3 months, further diagnostic and therapeutic measures should be taken.

Symptoms and diagnosis

- Pain and swelling during and after activity.
- Locking, catching of the joint in activity.
- Tenderness over the affected joints and effusions with swelling and pain with loading.
- X-ray, MRI and bone scan may be of value.
- Arthroscopy is done to assess the size, depth and location of the damage (Fig. 8.15).

Conservative treatment

Conservative treatment is aimed at reducing or altering exercise and sports activity, training muscular strength, endurance and neuromuscular control (proprioception), and providing anti-inflammatory agents.

Surgical treatment

Bone marrow stimulating treatment

Firstly it is necessary to remove loose cartilage flaps affecting the joint function. This measure can be followed by drilling, micro-fracturing or making the bone joint surface raw to allow ingrowth of blood vessels for connective tissue healing of the injury (Fig. 8.16). The treatment is carried out most frequently arthroscopically.

The following techniques are used:

- Drilling with several holes through the underlying bone in the injured area into the marrow space.
- Micro-fracturing: small round fractures (holes) are made in the underlying bone to allow bleeding into the injured area to form connective tissue. Suitable for small injuries 1–3 cm^2.
- Abrasion arthroplasty, which includes making the superficial surface of the bone raw to allow bleeding from small blood vessels in the underlying bone for connective tissue healing of the injury.

Tissue engineered treatment – autologous chondrocyte implantation

Autologous chondrocyte implantation (ACI) is suitable for cartilage injuries especially in the knee joint (Fig. 8.17).

During the arthroscopic examination of the joint, small cartilage pieces are extracted (biopsies) from uninjured, less loaded cartilage, for the cultivation of cartilage cells. The patient is operated on 2–5 weeks later and the

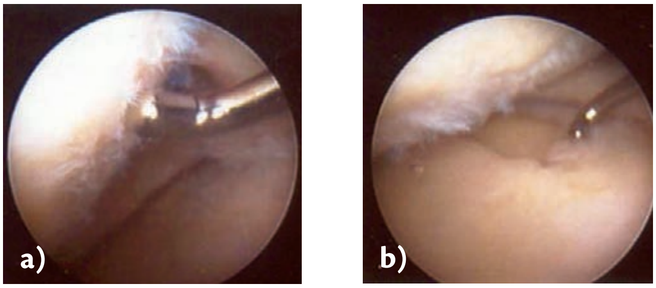


Figure 8.15 Articular cartilage damage assessed by using a probe. **a)** Cartilage injury on the femoral condyle. **b)** cartilage injury on the tibial condyle.

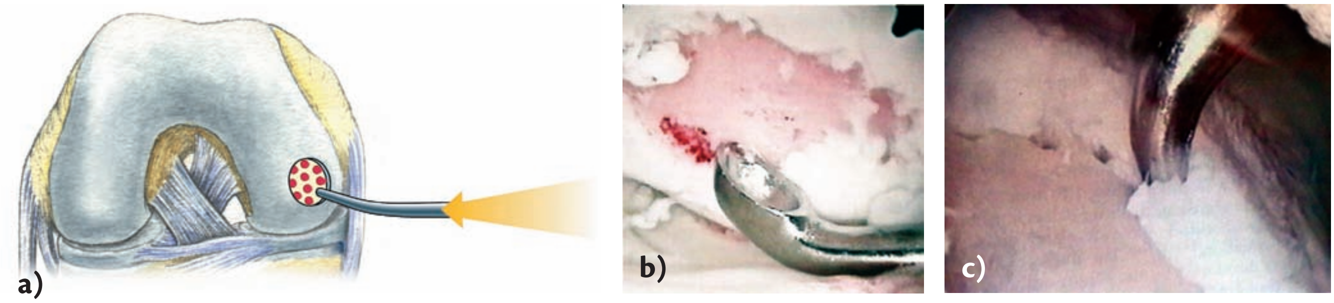
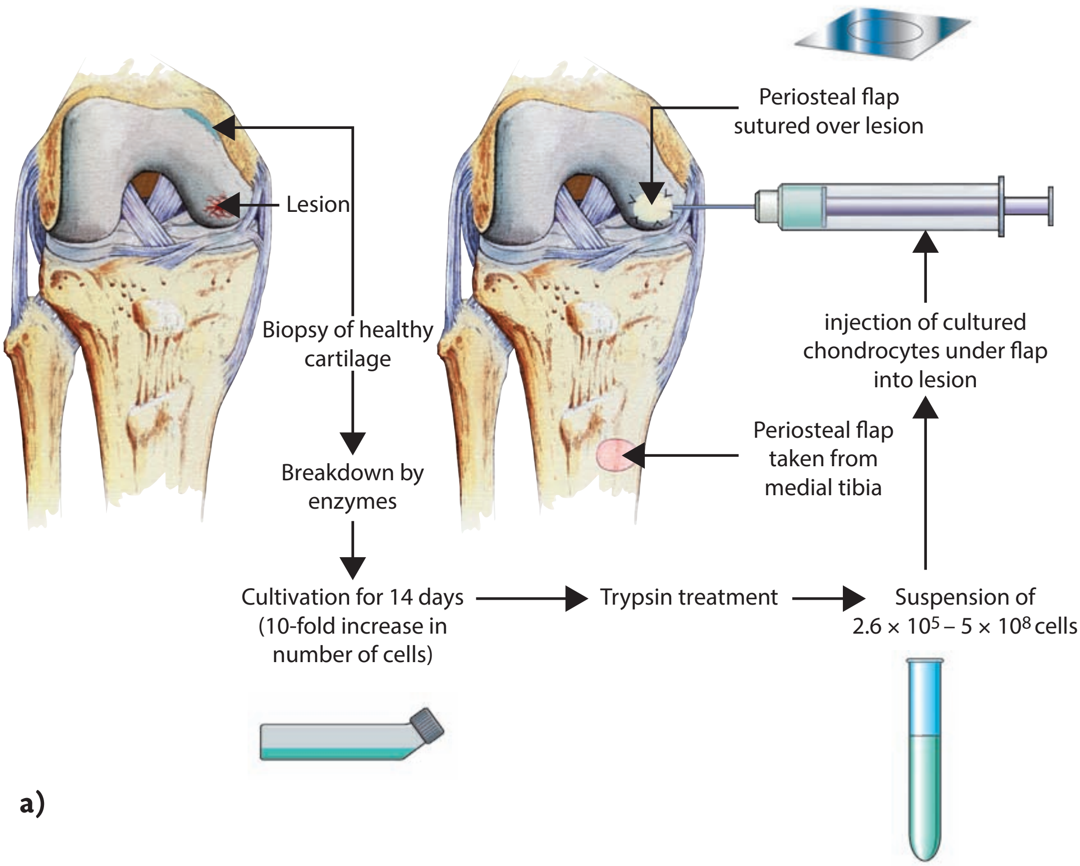


Figure 8.16 Micro-fracturing of cartilage injury by making small rounded holes in the underlying bone to create bleeding in the injured area. **a)** Schematic diagram of micro- fracturing on the underside of the thigh bone (femur) in the knee joint; **b)** corresponding injury seen at arthroscopy. All damaged cartilage tissue is removed down to the underlying bony plate with superficial easy bleeding and with stable edges to the surrounding cartilage; **c)** a special instrument is used to create millimeter large holes through the bony plate at 4 mm intervals in the bone marrow. (Courtesy of Dr Richard Steadman, Dr Bill Rodkey, Vail, Colorado, USA.)



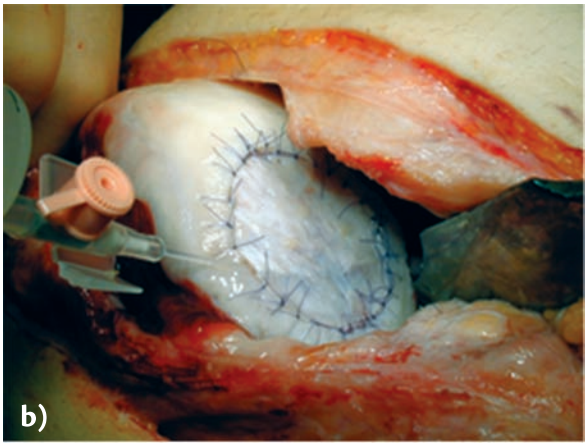


Figure 8.17 Autologous chondrocyte implantation (ACI) is effective in many joints, but perhaps mostly in the knee joint. It was first introduced by Prof. Lars Peterson. **a)** Schematic description of the technique ACI with the use of periosteum; **b)** surgery showing ACI with the use of periosteum. Today an alternative is the use of artificial degradable membranes.

damaged cartilage tissue is removed. The cultured cells are then injected into the injured area that is covered by periosteal or artificial degradable membranes. Long-term results are good. ACI is suitable for major injuries 2–16 cm².

Autologous osteochondral cylinder graft bone and cartilage cylinders

These cylinders can be taken from less loaded parts of the knee and moved into the corresponding drill holes in the damaged area with good results (Figs 8.18, 8.19). The technique is suitable for injuries 1–4 cm².

Rehabilitation

It is of utmost importance to exercise early the ROM. This is done in cooperation with coaches, trainers, physicians and physical therapists. The training program should include strength training, gradually increased load on the joint and on the body weight. These programs should be

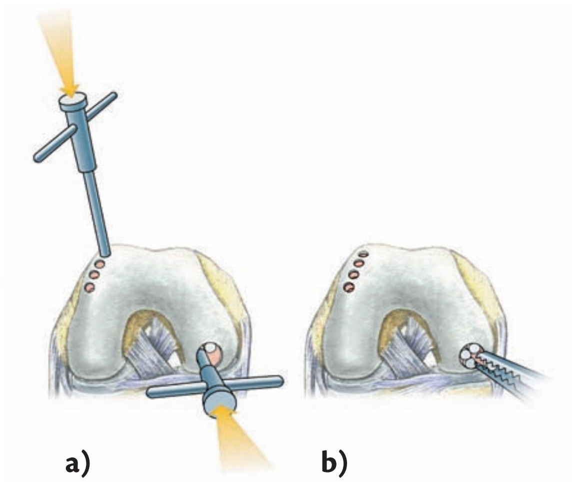


Figure 8.18 Cartilage injury can be treated by moving bone and cartilage cylinders. **a)** These can be taken from areas that are less loaded; **b)** thereafter they are moved to corresponding drill holes in the injured area.

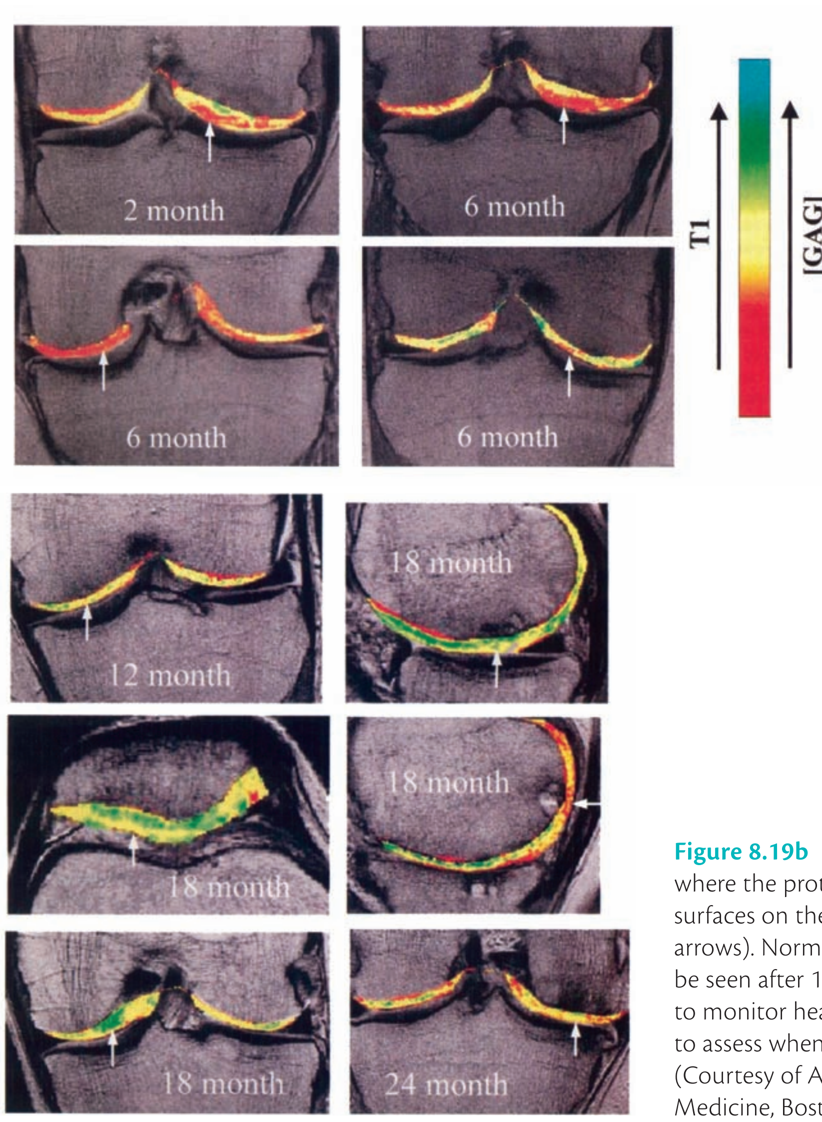


Figure 8.19a Evaluation of the proteoglycan content after an autologous chondrocyte implantation (ACI). Contrast is injected intravenously. This contrast is searching for negatively-loaded proteoglycans in the joint cartilage (dGEMRIC). After the loading with contrast a magnetic resonance imaging (MRI) examination is carried out. The concentration is read by the scale on the right, where red represents low content and blue high content of proteoglycans. a: an MRI examination 2 months after the ACI; b–d: MRI examination after 6 months. It can be read that the concentration of proteoglycans is low in the joint surfaces on the femur as well as in the transplanted area (see arrow at 2 and 6 months).

Figure 8.19b MRI examination after 12 and 24 months, where the proteoglycan content has normalized in the joint surfaces on the femur as well as in the transplanted areas (see arrows). Normal bone content in the patella joint surface can be seen after 18 months. This MRI technique can be used to monitor healing and maturation of the tissue after ACI, to assess when an athlete can return to competitive sport. (Courtesy of Arnold Sheller MD., Tufts University School of Medicine, Boston USA.)

designed individually, considered the athlete's return to regular training and for future competitions.

Prognosis

Untreated joint cartilage injuries will progress into osteoarthritis due to the mechanical and chemical breakdown of the joint. If the diagnosis is made early and the joint cartilage injury treated optimally the athlete has a good prognosis.

Detachment of bone/cartilage pieces in joints (osteochondritis dissecans)

Detachment of bone and cartilage pieces in the joint means that a segment of bone and cartilage is detached from their surroundings. If the bony part of the fragment is subjected to necrosis, i.e. dies, no healing can take place and the separation becomes permanent (Fig. 8.20).

Osteochondritis dissecans (OCD) is a relatively rare disorder, with an estimated incidence of 15–30 cases per 100,000 persons per year. OCD is localized in 75% of cases to the inner femur joint surface of the knee joint. The condition can also occur in the elbow (6% of the cases), ankle (4% of the cases) and more rarely in the knee cap (patella), shoulder and hip joints. It affects people from ages 5 to 10 years and can occur up to 40 years of age. However, it usually occurs at 10–20 years of age and is 2–3 times more common in men. OCD may be divided into a juvenile and adult forms.

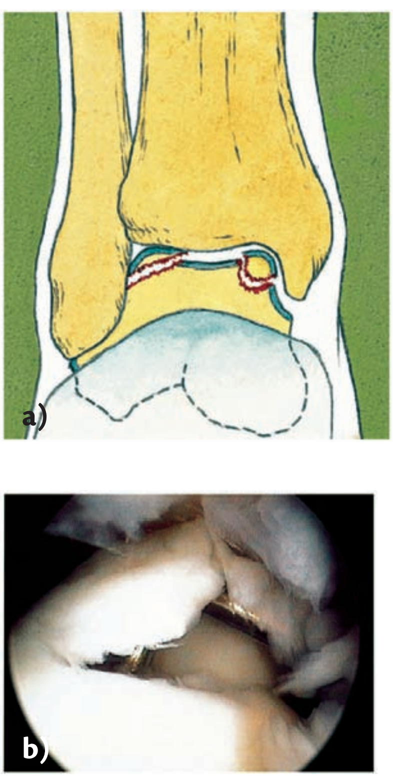


Figure 8.20 Detachment of bone and cartilage pieces in joints (osteochondritis dissecans) in an ankle joint. **a)** Detachment both laterally and medially; **b)** cartilage injury seen at arthroscopy of the ankle.

- The juvenile form affects growing individuals until the growth of the long bones is finished, i.e. when the growth plates (epiphysis) have joined.
- The adult form also affects young people after the growth plate have closed.

Tip

The younger a person is, and the earlier the condition is detected, the better the treatment outcome and prognosis.

Injury mechanisms

Many causes of OCD have been proposed. When the condition affects the knee joint, the cause of injury is considered to come from trauma or repeated micro-trauma to the tibial plateau, where it meets the outer portion of the rounded inner joint surface (medial femoral condyle), and where it impinges. Detachment of bone and cartilage in a joint can be seen in both sprains as in repeated overloading of a joint, e.g. ankle or elbow (compare 'throwing elbow', p. 272). Another background factor that has been discussed is the vascular changes with reduced blood supply to the bone. Since OCD occurs in young, active people it is considered to be sport related. Heredity may also contribute.

When discussing the detachment of bone and cartilage pieces in a joint, it is important to distinguish between attached embedded and detached fragments. A complete detachment as a loose body will leave an open defect in the surface.

Symptoms and diagnosis

- Diffuse pain over the joint.
- Local tenderness over the fragment.
- It is common with catching, locking or 'giving way'.
- Recurrent effusion in the joint: X-ray and MRI can provide the diagnosis.
- Arthroscopy can guide treatment. Any free fragments tissue and flaps can be removed. Stability of the fragment can be tested.
- Bone scan, which is rarely used today, can prove the diagnosis and provides guidance for the treatment.

Treatment

In young still growing juvenile athletes with stable fragments physicians may:

- Prescribe rest and simultaneous training of muscle strength.

- Cast or brace, and with juvenile athletes advise not to play sports for 3–4 months until healing is completed
- Operate if the symptoms are not reduced after conservative treatment.

In juvenile and adult athletes with unstable fragments:

- In acute cases when free bodies or partially detached fragments are diagnosed in the joint, fresh up the bony surfaces, sometimes bone graft the area, secure an unstable fragment with pins or screws that can be resorbed by the body during the healing process, particularly in growing individuals.
- Remove any free bodies.
- For minor injuries, drilling, micro-fracturing and roughening up the underlying bone should be used. This procedure may enhance the healing potential of the subchondral bone; bone–cartilage cylinders can also be used and moved to drill holes in the damaged area.
- When the injuries are either small or large, ACI can be tried, i.e. use the body's own cartilage cells.
- Post-operative rehabilitation is usually a two-stage process of immobilization and physical therapy.

Healing and return to training

After conservative treatment of the juvenile form of OCD a follow-up of the healing has to be done with MRI or arthroscopy and sometimes bone scans before return to sporting activity. It is important that the athlete has trained the muscle strength and mobility of the joint.

In the adult form and/or after surgery MRI or arthroscopy should be done before the athlete returns to their activities.

Prognosis

The prognosis is better in the juvenile form, especially if treatment is begun early. If the condition affects a loaded joint surface of the knee, osteoarthritis has been reported in 80% of cases after 20–30 years. If the cartilage–bone piece came loose and had to be removed, the risk of osteoarthritis is nearly 100% after 20 years.

Joint diseases

Bone ends in the joints are covered with cartilage which has no blood supply, which means that damage to cartilage heals poorly. Articular cartilage reduces friction and increases shock absorption between the bone ends. The nutrient supply to the articular cartilage occurs through the synovial fluid, formed in the synovial membrane (synovium), i.e. the joint capsule's innermost layer. Synovial fluid also reduces friction during movement of the joint.

Osteoarthritis ('worn out joints', osteoarthrosis)

Osteoarthritis (OA) means, above all, that the joint surface's cartilage breaks down and wears, and changes may eventually occur in the underlying bone. The condition develops and worsens with age. OA can be classified as primary or secondary.

Primary OA is most common in women and in people with diabetes. The cause is unknown. Obesity appears to be irrelevant for the onset of OA, but obesity accelerates the deterioration of the injury.

Secondary OA can occur after injury or disease of the joints. It may be such reasons as joint surface fracture, including cartilage injury, ligament injuries and dislocations, posttraumatic OA or infections and rheumatoid arthritis (RA). Repetitive or improper load on the joints, e.g. in football/soccer players, can lead to OA in the hip or knee.

Pathological changes

Joint changes in the final stages are similar in primary and secondary OA (Fig. 8.21). In primary OA the cartilage is softened. Eventually the cartilage surface will get uneven and become frayed. Cracking occurs, as in the start of

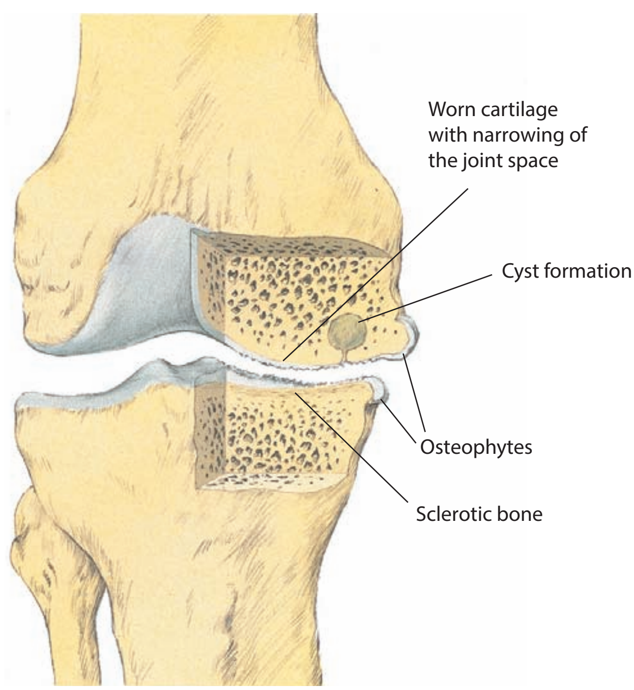


Figure 8.21 Osteoarthritis (OA) in the knee joint. The cartilage is worn down to the bone, which then will serve as a loading surface in the joint. The bone becomes more dense (sclerosis) and cysts are formed. Osteophytes (bony growths) will be formed as the joint capsule will become bony (see Fig. 19.63).

the secondary, and may go down to the underlying bone. Gradually, the cartilage wears down to the bone, which will then serve as the loading surface of the joint. At the same time, there is a densification of the bone (sclerosis), and in some areas cysts can be formed. Bony outgrowths (osteophytes) occur due to reforming the cells of the synovial membrane to bone, deforming the joint. OA occurs most often in the knee and hip joints. Ankles are rarely affected. The changes can be detected by X-ray examination of the joint when it is loaded.

Symptoms and diagnosis

Pain. Pain is the most important symptom. Although the pain may be absent during daily activities, pain can suddenly start with overloading of the joint. In the beginning the pain increases slowly. In athletes, the pain may disappear with warming exercises and then come back after training or competition. Pain at rest occurs when OA has reached advanced stages. Night sleep can be disturbed.

Joint changes. The arthritic joint exhibits several symptoms. These may include swelling, stiffness, atrophy of muscles, soreness, crepitations, local hyperthermia and instability causing abnormal joint movement due to laxity of the ligaments.

Stiffness. Morning stiffness and startup pain occur in the affected joint. Gradually reduced joint motion and limping may also occur.

Imaging changes. The diagnosis is confirmed by images showing reduced joint space because of worn cartilage, bone cysts, osteophytes (bone spurs) and sclerosis (increased skeletal density). Signs of increased secretion of synovial fluid may occur.

Arthroscopy can provide early diagnosis.

MRI can provide a detailed description of the character and structure of the OA. In recent years, a significant advancement of technology has been made to study the osteoarthritic changes and development on MRI.

MRI with the use of contrast agent (dGEMRIC technique, i.e. gadolinium magnetic resonance imaging of cartilage), has relatively recently been developed. This technology has increased the sensitivity to detect joint cartilage injuries and matrix components.

Treatment

Osteoarthritic changes are not reversible, i.e. they do not heal. To relieve symptoms and inhibit the degradation of articular cartilage there are several treatment pathways.

- The load of the damaged and painful joint should be reduced. Rest and restrain from, for example, running are recommended if a knee or hip is affected. Physical fitness can often be maintained by cycling or swimming.
- Active motion and strength training should be carried out under the direction of a physical therapist and can sometimes be performed in a swimming pool. Passive motion, i.e. movements performed by another person moving the joint, should be avoided.
- Heat treatment such as ultrasound, shortwave or hot packs may provide some psychological effect. A neoprene sleeve with therapeutic warmth may be used.
- If either the knee or hip joint is affected by OA, the injured persons can get support from a cane, used on the healthy side. Light walking poles can have a shock absorbing effect.
- Bandages/orthotics/braces of various types can be used to unload the joints.
- Anti-inflammatory and pain-killers can be used.
- In severe cases, surgical treatment may be necessary (see Figs 19.65, 19.66, p. 443).

Osteoarthritis and sports

Athletes who suffer from arthritic changes should first be subjected to medical examination and then recommended which sport may be appropriate in the future. The assessment is individual. As a rule, there is no reason to recommend athletes with incipient OA to stop playing sports, but a change in the forms of sport is often required. Cycling and swimming, for example, can be more appropriate than running to reduce the load on the joint that exhibits changes. Sufficient time should be given to active movements and active muscle training, so that deterioration is delayed. Physical activity after a hip or knee arthroplasty should be conducted in consultation with the treating physician.

Rheumatoid arthritis

RA is an autoimmune disease (a disease of the body's own immune system), where the triggering cause is unclear. The clinical picture is a chronic inflammatory condition that affects the joints, tendons, tendon sheaths, bursae and muscles and other tissues in the body. RA is three times more common in women than in men and usually appears when the affected is 20–30 or 45–55 years old. However, it may arise in childhood and can have a more severe course. Special risk factors are smoking and genetic factors.

Pathological changes

The pathological change of RA is predominantly inflammation of the synovial membrane (synovium) with a precipitation of some proteins (fibrin). As a result of the inflammation a fluid secretion starts, resulting in a swelling of the joint. The inflammatory tissue grows inward toward the joint space (where it is frayed) and settles like a carpet over the cartilage surfaces (pannus) and surrounding ligaments and tendons. At the same time, cartilage destruction increases from the surface and into the bone and cysts form in the bone.

Eventually the inflammatory reaction heals with a variable amount of scarring. In doing so, the proportion of connective tissue in the joint capsule increases and thickens and thus can be a restriction to movement and healing, while the swelling increases.

Symptoms and diagnosis

- Pain and swelling of the joints.
- Stiffness of the joints most pronounced in the morning.
- Malalignments of the joints, some muscle weakness and tendon changes.
- Typically, the disease proceeds in periods of worsening (relapses). In between, there are more or less symptom-free periods (remissions).

RA is evident if three or four of the following criteria are met:

- Morning stiffness.
- Pain or tenderness in at least one joint with concomitant fatigue.
- Soft tissue swelling or fluid accumulation in at least one joint.

When 2 or 3 exist:

- Swelling in at least one other joint.
- Symmetric joint swelling.
- Knot shaped thickening of tendons under the skin in places that are typical RA.
- Radiographs show changes typical of RA.
- Blood test shows changes typical of RA.

Treatment

Like OA, RA cannot be cured. However, the extent of the periods of deterioration can be limited and symptoms can be relieved by:

- General physical training and physical therapy.
- Anti-inflammatory medication.
- Corticosteroid treatment.
- Continuous medications that ease symptoms, such as non-steroidal anti-inflammatory drugs (NSAIDs) and/or medication that slows disease activity such as corticosteroids and disease-modifying anti-rheumatic drugs (DMARDs), etc.
- Local treatment with cortisone and gold in advanced disease.
- In severe cases, surgery.

Rheumatoid arthritis and sports

RA need not be an obstacle to the sport. Adjusted physical activity should be encouraged as soon as possible because it has a positive effect. Athletes with RA should mainly engage in active movements, i.e. movement with muscular activity. Walking, swimming and cross-country skiing is recommended.

Other joint diseases

Joint infections

Infections can reach the joint through blood vessels from other centers of infection, such as for urinary tract infections, sexually transmitted diseases, respiratory, sinusitis, dental and intestinal infection. Joint infections can also arise in the context of open joint injuries as well as in surgery or sampling from the joint. Joint infections should be treated by a physician.

Gout

Gout is due to uric acid crystal precipitates in the joints, and 95% of those who suffer from gout are middle-aged men. It is usually the first metatarsal joint (big toe), that get affected, and the acute symptoms are characterized by intense pain and redness, increased heat and swelling. Symptoms persist from a few days up to a week. A chronic form of gout can attack multiple joints and is similar to the other chronic diseases of the joints. The diagnosis can be supported by a blood test of uric acid.

Medical examination is advised for gout, treated with special medications, including anti-inflammatory drugs, diet and active rest.

Muscle injuries

The muscles are by their contractility (contraction) essential for many of man's vital functions such as breathing, work, transportation, movement in sport and physical activity as well as for balance and position.

Muscle injuries are among the most common of all injuries in Sports Medicine, but they are also the most commonly misinterpreted and often receive inadequate treatment. Since most athletes can continue their daily activities shortly after the time of injury, it is easy to underestimate the extent of the injury. There are studies showing that muscle accounts for 10–30% of all injuries in most sports. It has also been found that over 30% of all injuries occurring during soccer games are muscle injuries. Injuries to the hamstring muscles on the backside of the thigh have in recent years become the most common injury in many sports such as soccer, etc.

Muscles can be injured by both direct trauma as well as instantaneous, severe overload. The injuries that occur are divided into ruptures and hemorrhages (hematomas):

- Strains (rupture) may be total or partial, and can be further divided into distension (muscle strain due to stretching) and compression ruptures;
- Hemorrhages (hematomas) as a result of the injury can be either intermuscular (outside the muscle) or intramuscular (within the muscle); diagnosis and treatment differs significantly if the hemorrhage is inside or outside the muscle.

Muscle injuries are usually benign, but are often troublesome for athletes because inadequate treatment can lead to a long-term interruption in the sport. To understand how muscle injuries can be prevented and treated, it is necessary to have knowledge of normal muscle structure and function.

Muscle structure

The human body has about 340 well-defined muscles. The largest muscle in the body is the gluteus maximus, i.e. the large muscle in the buttock. Skeletal muscles make up about 44% of the total body mass. A muscle has an upper origin (head), a lower insertion, and in between, the muscle belly which is the muscle's active contractile part. The muscle is attached to the bone with tendons.

A skeletal muscle consists of thousands of slender muscle cells, known as fibers, containing contractile elements, myofibrils. These are composed of smaller components, myofilaments, which in turn consist of two types: the actin and myosin filaments located in the muscle fibers, which are the force generating structures. When a muscle is shortened (contracted) the actin is pulled in between the myosin. Muscle fibers are bundled together into a muscle bundle (fascicles), which in turn are joined to form the muscle belly (Fig. 8.22). In some muscles, the belly is divided into several smaller bellies. Each muscle has its head or origin. A muscle that has two origins is called two-headed (biceps), one that has three is called three-headed (triceps), and one that has four is called four-headed (quadriceps).

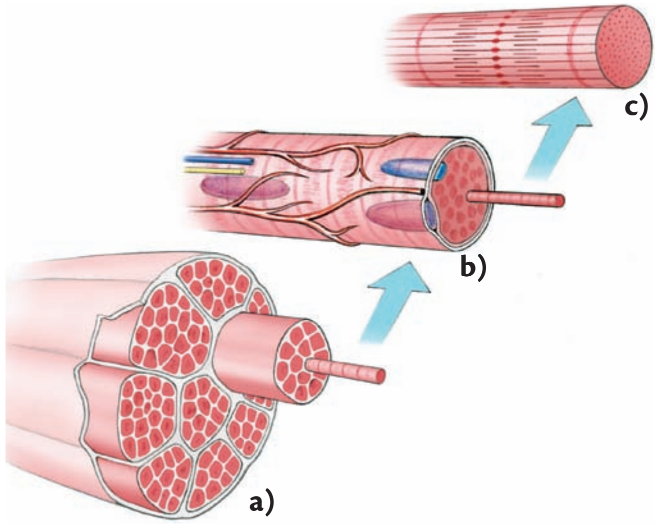


Figure 8.22 Schematic drawing of the structure of a muscle. **a)** Muscle bundles; **b)** muscle fibers with blood vessels and nerves; **c)** myofibrils (contractile elements).

There are two different types of muscle fibers, slow twitch (type I or red) and fast twitch (type II or white). The slow twitch fibers get their energy from fat, making the muscle more durable and suited to endurance training such as long-distance running. The fast twitch muscle fibers are supplied by the glucose present in the muscle's glycogen store and converted to energy without using oxygen (anaerobic energy). The slow twitch fibers are smaller than the fast twitch muscle fibers, they have lower strength and contract relatively slowly; they have a large network of small blood vessels, capillaries, but fewer nerves and poor stamina. The slow twitch fibers respond very well to static, low dynamic training, while the fast twitch fibers respond better to dynamic exercise at high intensity.

The fast twitch fibers are grouped into two subdivisions, type IIa and IIb. The fast twitch fibers of type IIa are characterized by high strength and good endurance, while the fast twitch fibers of type IIb are characterized by explosiveness with very poor stamina. When a muscle is activated the slow fibers of type I are switched on first, then the fibers of type IIa and finally the type IIb. There is also a type IIc that is still being studied. It is possible that muscle fiber type II, after very prolonged endurance training, can learn to use oxygen for energy, and is then called type IIc.

There are large individual variations in muscle composition. Most common is when there are equal amounts of fast and slow twitch fibers. In an athlete, who is successful in endurance sports the muscles are predominantly composed of slow fibers, whereas a sprinter predominantly has fast fibers. Knowledge of fiber distribution in the muscles is important when the athlete wants to practice a particular kind of sport.

The muscles have a large number of small blood vessels, called capillaries. Normally, there are about 3000 capillaries per square millimeter in a muscle cross-section. When the muscle is at rest about 95% of them are closed. When the athlete is exercising they gradually open to have an abundant blood flow in hard-working muscles.

Through exercise the athlete can achieve the following effects on the muscles:

- The activity of muscle enzymes increases.
- The units (mitochondria) where combustion takes place in the cells increase in number at aerobic exercise.
- Storage of fuel for the energetic processes increases.
- Muscle capillary net increases.
- Muscle volume increases (hypertrophy) with strength training.

Taken together, these effects increase the muscles strength, durability, endurance and 'explosiveness'. Various types of muscle training are described on p. 200.

Figure 8.23 Injuries to the muscle–tendon complex. Injuries may occur in the insertion of a muscle to bone, in the muscle belly, in the transition from the muscle to tendon, in the tendon and in the tendon origin and attachment of the bone and periosteum.

Injuries in the muscle–tendon complex

Muscles and tendons serve as a unit. Injuries can in principle occur in a muscle attachment to the bone, the muscle belly, in the transition between muscle and tendon, the tendon and the tendon origin and insertion to the bone and periosteum. In practice, muscle injuries most often occur in the transition between the muscle and tendon regardless of load (Fig. 8.23).

To prevent injuries to the muscle–tendon complex it is important to maintain a good level of strength and to be thorough with warm-up exercises. Isometrically trained muscles can handle more loads and have a greater length increase ability than unprepared muscles.

Muscle strains

A muscle fiber is a highly specialized, complex entity that sensitively responds and quickly adapts to changes. Injured musculature can heal in a short time, and fibers are formed within 3 weeks. When injury occurs bleeding may occur, which may be more or less extensive. This bleeding may mechanically affect the healing process by impairing contact between the separated muscle fiber ends. If the bleeding can be limited it increases opportunities for rapid and complete healing. Therefore, an acute treatment in the arena with a pressure bandage and concomitant cold treatment is of great value.

In sport different types of muscle ruptures occur:

- Distension rupture, or muscle strain due to overstretch or eccentric overload. Such ruptures are located in the superficial portion of the muscle or muscle insertion and origin (Fig. 8.23). These strains occur as a result of the force buildup in the athlete's muscles during contraction, and often at the change over between the eccentric (decelerating) and concentric (accelerating) muscle work.
- Compression rupture, or muscle injury due to direct trauma. The muscle is usually under contraction and is then compressed by the trauma against the underlying bone and an injury may occur because of this, e.g. when a knee hits a thigh in football/soccer (see Fig. 8.25). Such rupture can cause a large bleeding, which often is deeply located close to the bone.

There is a distinction between a complete muscle rupture, when all fibers in a muscle have been torn and muscle function is lost, and a partial rupture, when only part of the muscle fibers have been torn and the function remains partially intact.

Factors, that may contribute to muscle ruptures include:

- The muscle may be poorly prepared through poor training or lack of warm up.
- The muscle can be weakened by previous injury, followed by inadequate rehabilitation.

- The muscle may previously have been exposed to extensive injury, which has resulted in formation of scar tissue in the muscle. Such scar tissue has less elasticity than the muscle in general and, therefore, a risk that a new injury will occur.
- A muscle that is overloaded or fatigued is more easily injured than a rested one.
- Tight muscles, which do not allow full range of motion in joints, can be injured during sports that require agility.
- Muscles that have been exposed to cold for a long time have a decrease of normal contractility, and thus increase the risk of injury.
- Muscle strain due to overload – distension rupture.

Distension ruptures occur in sprinters, jumpers and football/soccer players, i.e. in sports where a maximal, explosive muscle contraction (tension) in a short time is required (Fig. 8.24). When the tensional force is so high that it exceeds the muscle strength a rupture occurs, e.g. overload during eccentric muscle action (i.e. the muscle decelerates while it is stretched). Other examples are sudden stops or deceleration (eccentric work), rapid acceleration (concentric work), or a hazardous combination of both, at turns, jumps, etc.

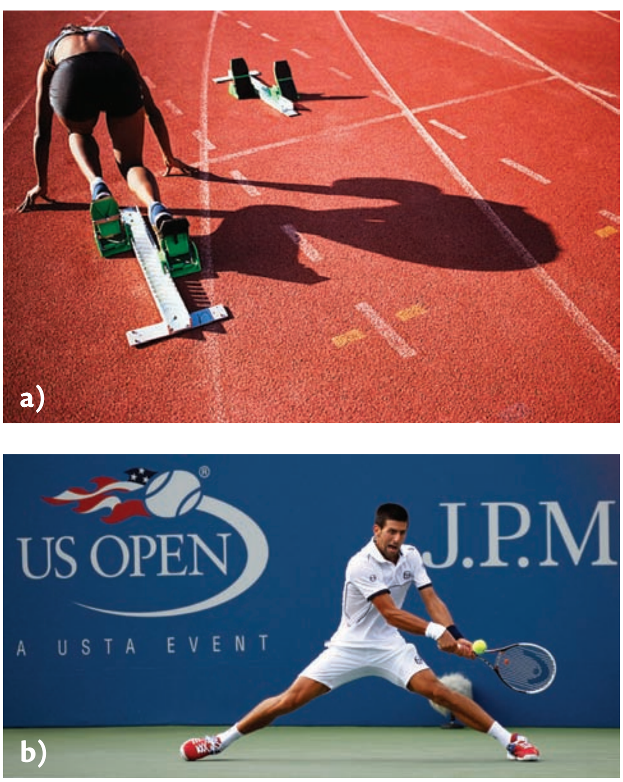


Figure 8.24 a, b) Among the risk factors for distension muscle rupture the following can be included: sudden stops, deceleration (eccentric work), quick accelerations (concentric work) or a dangerous combination of both at starts, sudden stops, turns, jumps etc. (With permission, by Bildbyrån, Sweden.)

This type of rupture is often localized to the superficial muscles working across two joints, such as muscles at the back of the thigh (hamstrings) that bend the knee and extend the hip joint. During sprints hamstring muscles do not have enough time to simultaneously perform these two functions controlled by a sensitive neuromuscular system.

If this system is disturbed it increases the risk of muscle strains. Distension ruptures can also affect the four-headed extensor muscle in the front of the thigh (quadriceps muscle), calf muscles (gastrocnemius muscle) and the flexor muscle on the front side of the upper arm (biceps).

Distension ruptures can be classified into first and second degree (partial) muscle ruptures, and third degree (complete) muscle ruptures. Distension ruptures of:

- First degree (mild) is described as a rupture of the muscle with less than 5% of the muscle fibers. The loss of strength and movement restriction is minor. Active or passive stretching movements, however, causes pain and some discomfort in the area around the injury. Remember that for the athlete, a small muscle rupture can be perceived as just as troublesome as a more extensive injury.
- Second degree (moderate) implies a significantly larger muscle rupture, which is still not complete. Any attempt to muscle contraction triggers pain.
- Third degree (severe) means a complete muscle rupture.

Symptoms and diagnosis

- Sharp pain from the muscle during the injury mechanism. The same pain is experienced when contracting the muscle. At rest, muscle pain is usually minimal.
- At a partial rupture it may be impossible for the muscle to contract because of the pain. The muscle cannot contract in complete ruptures.
- When the rupture is partial, it is possible to feel a gap, which includes a portion of muscle belly. When there is a complete muscle rupture it is possible to feel a gap, covering the entire muscle range. The muscle can ‘belly up’ and form a localized swelling.
- Tenderness and swelling often occur in the affected area.
- After some days, a bluish discoloration of the skin may occur, often below the injury. Discoloration is a sign of bleeding in the muscle.
- A spasm may occur in the injured muscle.
- Inspection and palpation of the injured area determines the degree of the muscle strain. A functional test, with or without resistance, is usually the best way to confirm the diagnosis.

Healing

A muscle that is stretched too much tears, i.e. muscle fibers and blood vessels in the area break. The severed ends retract from each other in the injured area, which is filled with blood. Following the initial inflammatory reaction with revascularization with vascular and cellular ingrowth , the resorption of blood and necrotic tissue and the repair starts. Repair of the injured muscle is ongoing in two phases simultaneously and they can compete with each other:

- Formation of new muscle fibers (regeneration) and
- The production of scar tissue (granulation).

A skeletal muscle has high regeneration ability, but the newly formed muscle fibers are shorter than originally, and are mixed with inelastic scar tissue. If scar tissue covers a large area it restricts muscle contractile ability. Within the muscle, different portions with varying elasticity occur, increasing the risk of new strains. Muscle injuries should therefore always be followed by a long period of rehabilitation.

Tip

An injured muscle may need to be trained throughout the athlete's active period, as an old injury often poses an increased risk of new injury.

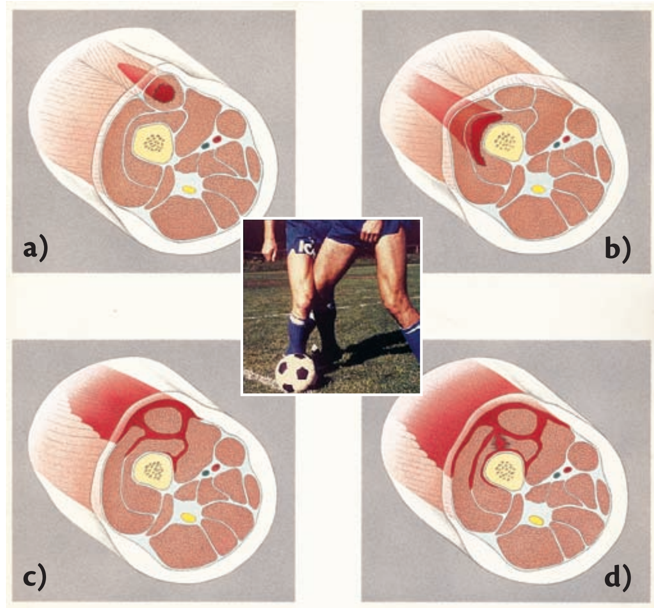


Figure 8.25 An external trauma against the thigh may cause a bleeding in the muscles. A knee against the thigh will compress the muscle against the bone and can thereby cause a muscle hematoma , a so-called contusion injury. **a)** Example of a superficial intermuscular hematoma; **b)** example of a deep intramuscular hematoma; **c)** example of an intermuscular hematoma; **d)** example of a deep intramuscular hematoma with intermuscular spread.

Muscle rupture after trauma – compression rupture

Direct trauma to a muscle often causes a rupture and a hemorrhage in the deep muscles as the muscle is contracted and, through the trauma, compressed against the underlying bone. Compression ruptures also occur in superficial muscles, and symptoms are similar to the symptoms caused by a distension rupture (see above).

Types of muscle hematomas (hemorrhages)

When an athlete engages in physical activity there is a massive redistribution of the amount of blood the heart pumps out (cardiac output). The blood perfusion in the muscles is increased from approximately 0.8 liters per minute (15% of the cardiac output) at rest to about 18 liters per minute (72% of the cardiac output) at hard muscular work. Blood flow in the muscles is therefore excellent during activity such as sport (Fig. 8.25). The extent of the hemorrhage in a muscle is directly proportional to the muscle perfusion and inversely proportional to the degree of muscle tension. The injury effect, however, depends on where the bleeding is located and on its magnitude. The treatment, healing and rehabilitation will depend on the type, location and size of the muscle hematoma and the overall tissue damage.

Intramuscular hematoma

A hematoma inside a muscle can be caused by a muscle strain or contusion to a muscle (Fig. 8.25). The bleeding starts inside the injured muscle surrounded by the uninjured fascia. The pressure within the muscle increases until it reaches a level when blood vessels are compressed and the bleeding stops. The swelling persists or increases hour by hour as do the symptoms such as soreness, pain and restricted motion and reduced or lost muscle function. The swelling occurs because the hematoma draws fluid from the environment by osmosis. With increased swelling the pressure increases and if there is no circulation to the tissue it will undergo necrosis, an acute compartment syndrome (see p. 475). This is an emergency situation that needs acute surgical intervention. Muscle function can be reduced or completely eliminated. If the muscle fascia (membrane) is damaged the hemorrhage spreads into the spaces between the muscles (see below) or into the surrounding tissues and the pressure will not stop the circulation and the situation is not so serious for tissue necrosis (see below).

Intermuscular bleeding

A hemorrhage may occur between the muscles when the muscle fascia with surrounding blood vessels are damaged. The hemorrhage results initially in an increase in pressure, resulting in a spreading of the bleeding between the muscles. Thus, the pressure drops rapidly. Characteristic of an intermuscular hematoma is a blood effusion, which shows itself 1–2 days after the injury in an area below the injured area due to gravity. The pressure from the bleeding is quite small and easily spread, and the swelling passes quickly. Strength and other functions in the muscle will return shortly after the time of injury. There is the opportunity for rapid recovery after an intermuscular hematoma without significant reduction of muscle strength if active treatment is used.

Treatment of muscle ruptures and muscle hematomas

The athlete/coach can, regardless of the cause of the bleeding, stop or reduce it by:

- Rest.
- Compression bandage around the injured area, pressure bandage to stop bleeding.
- Cooling of the affected area to relieve pain.
- Elevation.
- Unloading – if the rupture is located in the lower extremities, the injured person needs to use crutches until a definite diagnosis has been made. In cases of injury to the arms, some form of plastic or plaster splint may be useful to unload the injured area.

The body's own defense mechanism against bleeding, coagulation, starts immediately when an injury occurs and is active for several hours. This mechanism is still operable for 2–3 days. During this period the inflammatory repair process starts with revascularization of the blood clot. This repair tissue is, however, very vulnerable for new bleeding after new trauma or new strain or stress.

Tip

A muscle injury should be treated initially with immobilization of the injured muscle and muscle activation avoided, to limit the extent of the injury and to avoid disturbing the critical early healing process.

Massage, which includes repeated, minor trauma, and thermal treatment is not recommended during the first 1–3 days after a muscle injury has occurred.

With a muscle strain and bleeding, the injured always need rest and unload for 1–3 days to limit scar formation and to allow the muscle cells an opportunity to regenerate. It is clearly shown that a brief period of rest after injury followed by training results in better healing and strength of the injured muscle.

If a larger muscle rupture or muscle hematoma is suspected, the injured should see a physician.

The physician may admit the injured to hospital for observation at a major muscle hematoma center. The bleeding and swelling can accelerate, so that the blood supply gets reduced and the pressure within the muscle increases. Without treatment, complications can arise. If the bleeding is minor and when there is uncertainty about the nature and extent of the injury, the physician may prescribe rest for 1–3 days. It is difficult in the acute phase to ensure the type of damage that exists. During the first 3 days it should therefore be assumed that there might be a serious muscle injury.

Tip

- Continuous repeated examination of the injured area is necessary in order to be able to differentiate an intermuscular hematoma from an intramuscular.
- Fast decreasing swelling and rapid recovery of muscle function suggest an intermuscular hematoma.
- Unchanged or increasing swelling and a permanent reduction of muscle function indicates an intramuscular hematoma.

Measures 48–72 hours

After 48–72 hours questions 1–4 below should be posed:

- Has the swelling decreased? If not, this indicates that the injury is an intramuscular hematoma.
- Has the bleeding spread and discolored the skin distant from the injury site? If not, this indicates that the injury is an intramuscular hematoma.
- Has the damaged muscle's ability to contract returned or improved? If not, this indicates that the injury is an intramuscular hematoma.
- If a bleeding is a symptom of a partial or complete muscle rupture?

It is important that the correct diagnosis is reached, because too early activation of a muscle with extensive intramuscular hematoma or complete rupture can cause troublesome complications of further bleeding and in some cases increased scarring. This increases the risk of a prolonged healing process and possibly permanent changes. The continuing treatment depends on the diagnosis.

Measures after 72 hours

After initial acute treatment minor partial ruptures, intermuscular bleedings and minor intramuscular hematomas can be actively treated with:

- Continued compression wrap with elastic bandage.
- Local heat treatment; alternating treatment with heat and cold can have a good effect.

Tip

Muscle training should start after 2–5 days of rest depending on type of injury.

The active muscle training should be carried out according to certain principles and order as specified below:

- Static muscle training without a load.
- Static muscle training with a light load.
- Limited dynamic muscle training with active movements to pain threshold.
- Dynamic exercise with increasing load. To relieve pain and swelling cold therapy can be performed after exercise.
- Increase ROM with stretching. It is important that the muscles that have opposite function to the injured muscle (antagonists) are trained.
- Neuromuscular exercises – coordination training/function and proprioception training.
- Gradually increased activity and load on the injured muscle. If this is located in one leg the athlete can start with cycling and swimming and other water training before starting to run.
- Specialized training.

If the pain from the injured muscle remains unchanged, there is increasing suspicion of intramuscular hematoma and tissue damage. In order to diagnose, physicians can perform:

- Renewed local examination.
- Measurements of the intramuscular (intra compartmental) pressure.
- Use a thick needle to penetrate the joint if fluid occurs in the injured area, after which existing fluid can be withdrawn for analysis.
- Ultrasound or MRI: ultrasound provides adequate information on the extent of damage and the healing process, is easy to perform and in the acute phase gives full and detailed information. Ultrasound examination may be performed dynamically, i.e. during movement, so this examination has great value in the monitoring of muscle injury.
- Surgery.

Once the diagnosis is established there are several treatment options:

- In most cases, the recommended elastic bandage and rest with unloading for 1–3 days after which the active muscle training starts as soon as the pain and movement allow, and sometimes anti-inflammatory medication.
- Surgery in rare cases.

If an excessive hematoma is present, especially if it is intramuscular hematoma.

In complete ruptures, and in partial ruptures that include more than half of the muscle belly, especially if the injured muscle is of a type where there are few other muscles with the same function or cooperating muscles are completely missing (compare the large pectoral muscle), it is important that the muscle fiber ends are brought together by removing the hematoma and suturing the muscle ends to one another. Healing with scar tissue causes the muscle to have areas with varying elasticity, which increase the risks of new injuries in the scarred muscle. Therefore, it is important that the bleeding is removed and the damaged muscle fibers are brought together and sutured to each other. This usually requires treatment with a cast or other bandages for a period after surgery.

Rehabilitation

Rehabilitation after surgery is planned in consultation between physicians and athletes, taking into account the injury location and severity. If training starts at an early stage the healing will be faster, circulation in the muscle is then good and muscle resistance improved. Static muscle training can be initiated shortly after the surgery after consultation with the physician. Thereafter, the injured person gradually builds up muscle strength and mobility by moving to dynamic movement training, initially with no load (Fig. 8.26).

Tip

A customized exercise program is essential for proper healing.

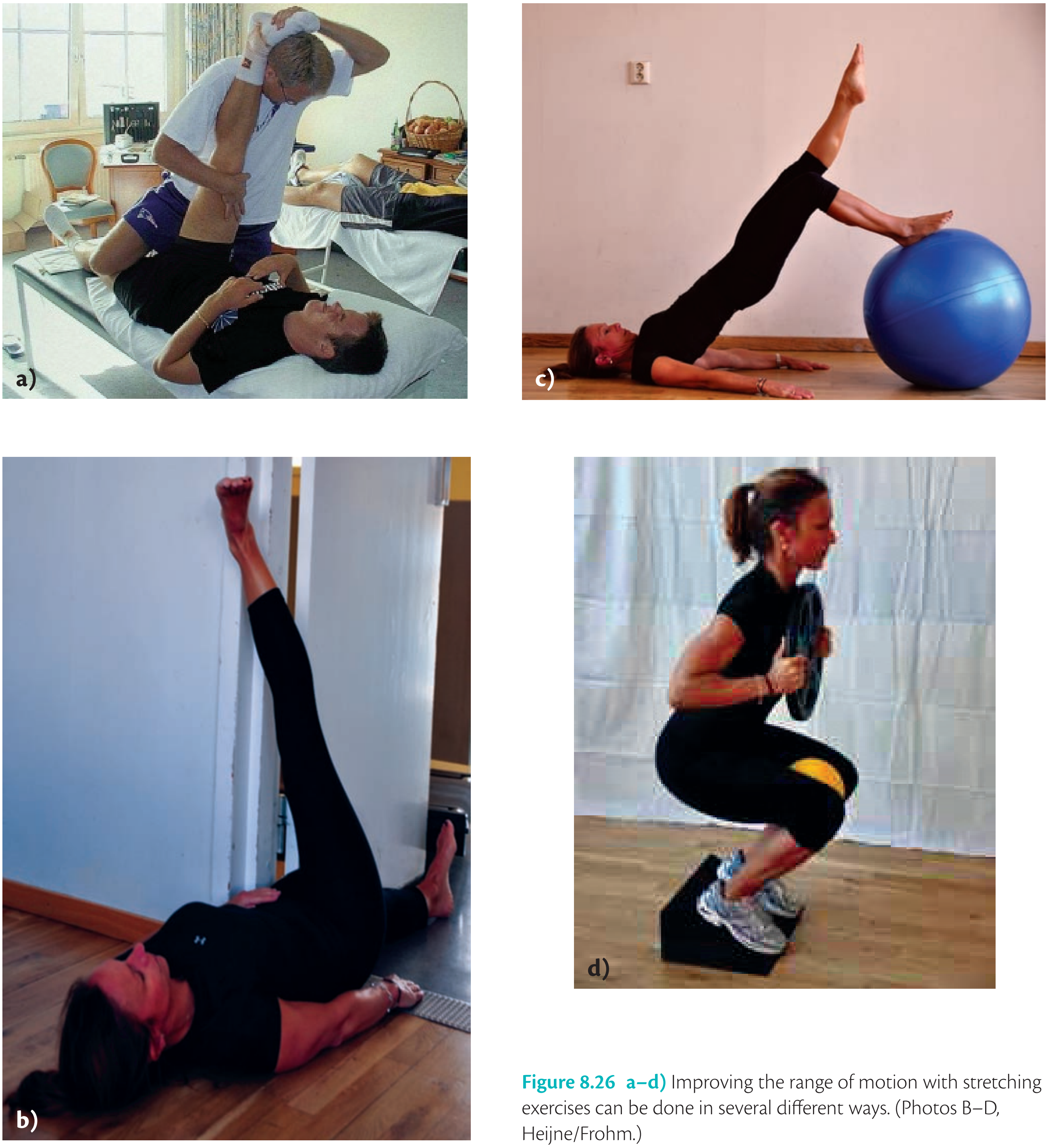


Figure 8.26 a–d) Improving the range of motion with stretching exercises can be done in several different ways. (Photos B–D, Heijne/Frohm.)

Healing

A muscle is considered to be cleared if there is no soreness and no pain occurs at maximum load of the muscle. When the injured has regained full muscle function, full mobility of the surrounding joints and otherwise normal movement patterns, he/she can resume full training.

Healing time in a smaller and mild muscle injury can be quite short, often 1–3 weeks. In a moderate muscle rupture healing time varies from 3 to 16 weeks, depending on the size of the rupture and where it is located. Intramuscular hematoma is often associated with a small tissue injury. In such cases, the healing time can be estimated to be 2–8 weeks. The injured can then usually return to their sporting activities after 1–2 weeks. When there is large muscle tissue damage the healing may take several months for safe return to sports. Healing should be checked with MRI or ultrasound before a decision is taken.

Cardiovascular exercise and gradually increased muscle training with load should start before speed training when the athlete resumes sports activities after being injured.

Tip

An athlete who has suffered a muscle injury should not compete until the injury is fully healed, i.e. the athlete is completely symptom-free when associated with tougher training. The risk of re-injury otherwise is high.

Complications with muscle injuries

Healing with scar tissue

Muscle fibers that have been injured when overloaded, with muscle bleeding and muscle rupture, as a result have less contractility. The spacing between the torn muscle fibers is filled with blood clots and is transformed to connective scar tissue. Healing with scar tissue causes the muscle to have areas with varying elasticity, and a new injury – rupture or bleeding – can occur if the muscle is subjected to severe stress in an early stage. If troubles persist with scar tissue this may need to be removed surgically (Fig. 8.27). This is however seldom done.

Complications to muscle hematoma – myositis ossificans

If the early, acute treatment of tissue damage and bleeding is not adequate, deep, intramuscular hematoma can eventually calcify and transform to bone. Ossification continues as long as the healing process is disrupted by repeated trauma or stress. The development of this calcification and ossification leads to areas with varying elasticity and strength in the tissue, which increases the risk of further bleeding with trauma. Ossification is a chronic, inflammatory process, which has meant that physicians have been refraining from active treatment (Fig. 8.28). If the affected athletes have severely impaired muscle function and stiffness in the area for more than 6–10 weeks and there is radiographic evidence of ossification characterized with sharp bony edges, an operative treatment should be considered. Such an operation has been controversial because there has been considered to be a risk of recurrence of bone formation. Experience suggests that surgical removal of bone formation after 6–8 weeks is perfectly possible with very good results. A return to sporting activity is possible after 8–10 weeks.

Muscle strains can be interpreted as tumors

Complete muscle ruptures may in later stages sometimes be mistaken for tumors. On examination, a swelling can be found, that the injured patient believes has grown in size. It is essential to investigate such cases so that the injured person is given the correct diagnosis. A typical example of such a case is as follows:

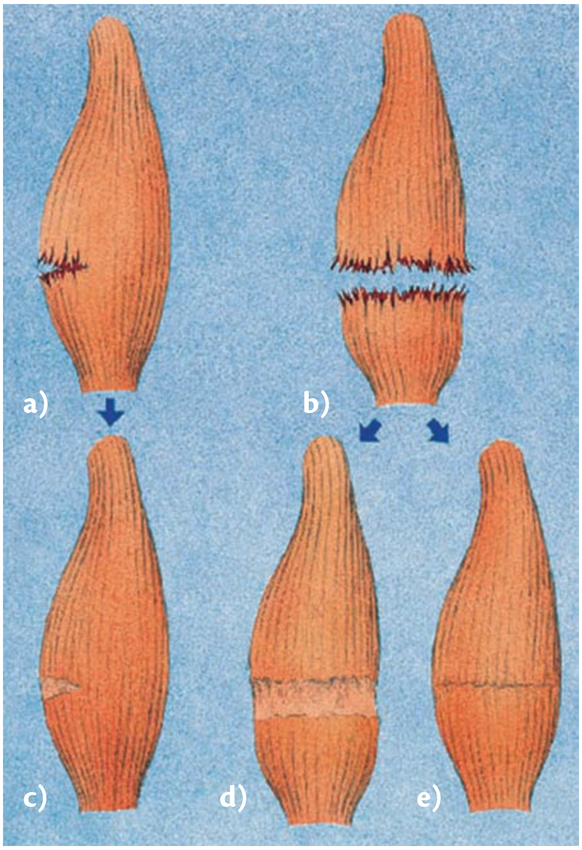


Figure 8.27 Principles for healing after a muscle injury. **a)** Partial muscle tear; **b)** complete muscle tear; **c)** healed partial muscle tear that has not been operated on; **d)** healing with scar tissue of a complete muscle tear that has not been operated on; **e)** healing of a complete muscle tear that has been operated on; the hematoma has been removed and the torn muscle ends have been sutured together.

Figure 8.28 Myositis ossificans. X-rays showing bony formations around the upper parts of the femur.

Adductor longus is a muscle that runs on the inside of the thigh (medial) and moves the leg inward (adduction). It originates on the pubic bone and attaches to the femur. Partial rupture of this muscle usually takes place at the origin on the pubic bone, while complete ruptures usually occur at the insertion on the femur. A complete rupture of the adductor longus muscle can occur without causing pain or other major problems. Eventually, the patient notices a growing nodule on the thigh. This increase in muscle size may erroneously appear to be a tumor but is probably a compensatory growth. The injured muscle, which shortened after the rupture, is forced to work more because of a shorter distance than normal between the origin and insertion. A new attachment is formed by scar tissue (p. 361). The diagnosis of 'old, complete rupture of the adductor longus' in this case is not difficult to make. The clinical examination must be done with the muscle in both relaxed and contracted states.

Muscle inflammation (myositis)

Myositis or muscle inflammation is unusual. The condition affects mostly the thigh, back, shoulder and calf muscles.

Symptoms and diagnosis

- At exertion pain occurs in the affected muscle group.
- Symptoms increase if the load becomes more intense and frequent.
- The examination finds sore, fixed portions in the muscle.
- Muscle cramp.

Treatment

The athlete can:

- Use anti-inflammatory medication.
- Rest the muscle or reduce exercise thereof.
- Treat locally with heat and use regular relaxation exercises.
- Massage can be tried.

Muscle cramping

Muscle cramp is characterized by sudden cramps and painful muscle contractions and difficulties in using the muscles. Muscle cramp affects most people at some time in their lives. Athletes can get cramp in a muscle during and after hard exertions, such as a football/soccer match with extra time, or a long-distance race. Muscle cramps often occur in tennis players and other athletes who compete in conditions when it is very hot.

Causes

The type of muscle cramping seizure that may affect a football/soccer player at the end of a match is probably caused by changes in the muscles; these may include the residual condition after muscle bleeding, small ruptures in the muscles or the athlete's general condition including nutritional deficiencies. Research data are accumulating that support the 'altered neuromuscular control' hypothesis as the principal pathophysiological mechanism for the etiology of exercise associated muscle cramps.[2]

In prolonged exertion when the weather is very hot, the athlete can encounter severe fluid loss (dehydration), which can lead to cramp. The exact causal relationship is not known, but emptied glycogen stores and salt deficiency can contribute to the condition arising. It should be pointed out that there is very limited scientific evidence in support of the 'electrolyte depletion' and 'dehydration' hypotheses for the etiology of exercise associated muscle cramps.

The direct causes of muscle cramping are unclear, but factors that impair circulation can have an effect: tight socks, too tightly laced shoes, lactic acid accumulation in muscles, varicose veins, cold and infections.

Treatment

The athlete can:

- Prevent muscle cramps with basic training, warming up, stretching exercises and using the right equipment.
- Be sure to have a good nutrient balance with well-filled fluid and salt depots and plenty of glycogen stores, loss of fluid and salts (electrolytes) to be replaced, especially at high temperatures.
- Terminate athletic activity at acute cramping and activate the opposing. If, for example, the athlete is having cramping in the calf muscle, which bends the foot down, the knees should gently be bent and the foot moved to be perpendicular to the leg. Light stretching of the muscle will resolve the cramp. This can be combined with gentle massage with light pressure on the muscle affected by the cramping (Fig. 8.29).

Physicians can: recommend a general medical examination when an athlete repeatedly suffers from cramping.

Figure 8.29 Cramping in the calf muscles is common. Cramping can be stopped by activating the muscle with the opposing action to the cramping muscle.

Delayed onset muscle soreness

Delayed onset muscle soreness (DOMS) or delayed muscle pain as the condition is called by many, i.e. pain, tenderness, stiffness and sometimes swelling in muscles, can occur a few hours after harder workouts. The pain arises in both active and passive movements, and the muscles may feel weak. Many athletes get sore during the late fall and early spring, when they change surface, start their training too vigorously or do not adjust the shoes to the surface. Symptoms occur especially during exercise when the muscle lengthens during co-contraction (eccentric-negative work).

Muscle contraction (contractile) capability involves the smallest muscle fibers, the so-called myofibrils. Soreness in untrained individuals may occur 1 to a few days after exertion. The pain is considered to be caused by 'tearing' of the so-called Z-discs in the muscles. Researchers have recently been able to discern broader and doubled Z-discs after exertion and an increased amount of sarcomeres (this is the smallest contractile unit of a myofibril). These changes then disappear when the muscles have rested. Z-discs do not contain any sensibility receptors and therefore do not produce any pain, but when they rupture a simultaneous tearing of the muscle's small blood vessels (capillaries) occurs. This combined with the small bleeding, which can cause swelling, can in turn cause soreness. The mechanism is not well known in detail. In summary, the recent findings show that the change in the muscle fibrils, in fact, is an adjusted re-modeling of the same. Muscle soreness is harmless and usually disappears after a few days.

Muscle soreness can be prevented by adapting the training to the athlete`s fitness level and to the surface. Proper equipment is essential.

- Active warming up or massage can reduce DOMS acutely.
- Even if the athlete has sore muscles showing some initial stiffness in the muscles, the athlete can mostly continue exercising, although often at a somewhat reduced intensity.
- Exercise intensity should gradually be increased, especially during the initial stage.
- Heat and light movements can contribute to pain reduction.
- Compression garments can be an effective method to reduce the muscle damage in DOMS.

Tendon injuries

In Sports Medicine, tendon injuries are a recurring diagnostic and therapeutic problem. If the treatment of these injuries is not adequate, problems may become chronic or long-lasting.

A muscle usually transitions into a tendon, which attaches to a skeletal part to which the effect of the muscle contraction is transmitted. The tendons' main function is to transmit muscular force to the bone. Muscle force is generated only when the muscle is contracted, resulting in a tensioning effect on the tendon. The anatomical variability of the tendons is great in terms of shape, length, vessel amount and tendon sheath extent. There are also biochemical and biomechanical variations. Sporting activities strengthen the tendons that are thus used. The maximum force in the Achilles tendon during running has been estimated to be nearly 9,000 N (N = Newton; force of 1 N corresponds to the weight of mass 0.1 kg), i.e. in this case, almost 900 kg or 12.5 times the body weight. In tendon injuries, however, the speed of the force is more decisive for the extent of damage than the size of the force. Tendons have a relatively high resistance to tensile stress but not shear stress (compare the stresses that paper is exposed to by the shanks of a pair of scissors: shear stresses in tissues can give flake rupture), and the compressive stress resistance is small in tendons. Tendons consist of collagen, which provides mechanical strength, and elastin, which gives the tendon it's elasticity.

The collagen tissue in a tendon in rest is usually wave shaped, but if it is pulled out and extended by more than 2% the wave pattern disappears when the collagen fibers are stretched. In an extension of 4–8% cross bands of the collagen molecule begin to rupture while the collagen fibers slide past each other. When the extension reaches

8–10% the tendon function ceases and the weakest fibers rupture (Fig. 8.30).

The tendons' vulnerability is the greatest in the following situations:

- The tendon is unprepared and without adequate warm up when exposed for tension.
- The tendon is subjected to stress from an angle.
- The tendon is stretched when trauma occurs.
- Associated muscle is maximally activated and tensed.
- Muscle group is stretched by external forces.
- The tendon is weak relative to the muscle.
- The above risks are for athletes of all ages.

Tendon injuries are common in sports, because sports activity results in the force of the muscle–tendon complex being concentrated to the tendon. Tendon tissue adapts quickly to current circumstances. A tendon can be subjected to overload (a rapid increase in resistance) or overstrain (constant repetitive movement without increasing the resistance). A tendon injury occurs when the supporting tissue (matrix) surrounding the cells is unable to adapt to the load, either of sudden or cumulative overload due to repeated strain (Fig. 8.30).

Classification of tendon injuries

Tendon injuries are classified broadly into ruptures (complete and partial), overuse injury with degenerative pathological conditions in the tendon (tendinosis), a clinical overuse injury in the tendon (tendinopathy) and an overuse injury in the attachment to the bone (tenoperiostis) and in the tendon sheath (tenosynovitis).

'Tendinitis' is a term that traditionally has been used for painful conditions in the tendon area, i.e. the tendon, tendon sheath and the adjacent bursa. However, it has been clarified that the inflammatory response is very limited in tendon injuries. Mostly, the injury is associated with a degeneration process, which increases with the tendon's decreased elasticity. Fatigue injuries in tendon fibers are probably a contributing factor to tendon pain and can, especially in young athletes, progress to a chronic tendon disease (tendinopathy).

Degeneration (degradation) is characterized by the breakdown of the individual tendon fibers consisting of collagen (the protein that builds up the tendon), which becomes fragmented and loses its orientation. Cell metabolism changes and there is a formation of other collagen molecules and proteoglycans, the expansion of the network of small blood vessels (capillaries) and a minimal infiltration of inflammatory cells. Degeneration causes small ruptures that leads to disintegration of the tissue. The end results are cells of smaller size (cell hypotrophy) (Fig. 8.31).

Inadequate oxygen supply, malnutrition, hormonal changes, chronic inflammation and higher age are contributing factors to the degeneration process of the tendon. This process is caused by overload, fatigue, weakness and possibly vascular changes. Most spontaneous ruptures of the tendon (97%) are preceded by lesions of the tendon tissue.

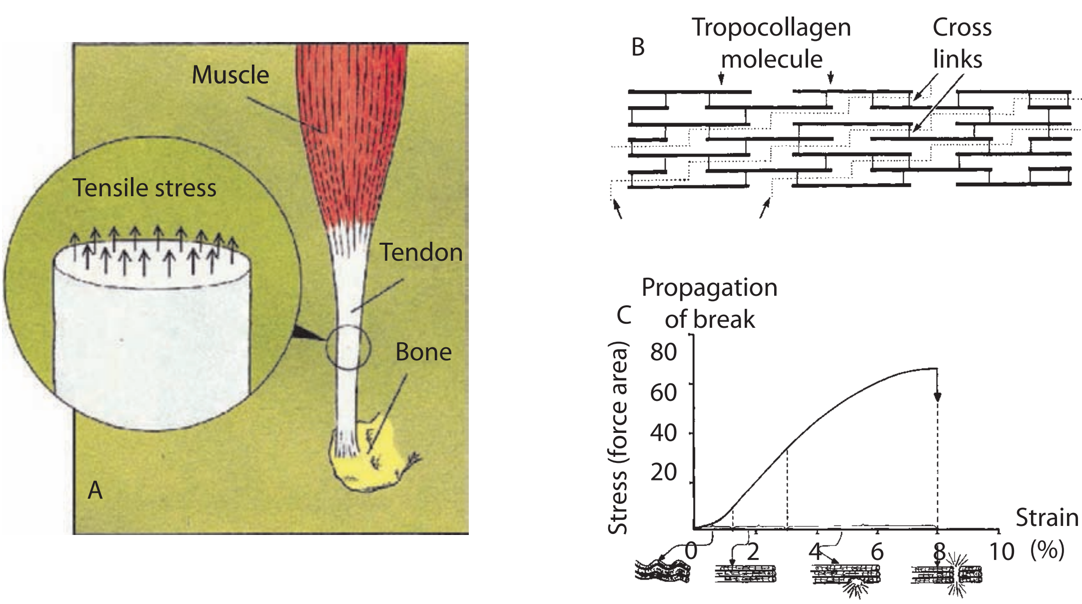


Figure 8.30 **a)** Example of tension in a tendon; **b)** molecular level of the collagen in tendons. Cross-links keep the collagen (tropocollagen) together. A tear in the cross-links can during loading in the fiber direction cause an injury of and a translation of the collagen and thereby a tear in the fiber direction of the tendon; **c)** stress and strain curve from unloaded tendon to a complete tear.

Tendon degenerative injuries often occur in areas of poor blood circulation. So, for example, Achilles tendon injuries occur 2–5 cm above the tendon attachment on the heel bone and tendon injuries to the supraspinatus muscle, 1–2 cm from the tendon attachment on the upper arm (humerus) in the shoulder. Because of the reduced blood supply the body's inflammatory repair capacity has a minor effect.

Based on tendon anatomy, three categories of lesions may be identified:

- Degeneration of the tendon tissue (tendinosis).
- Inflammation of the tendon sheath alone (peritendinitis).
- A combination of tendinosis and peritendinitis.

Tendinopathy is the clinical name for pain, swelling and decreased capacity to use the tendon.

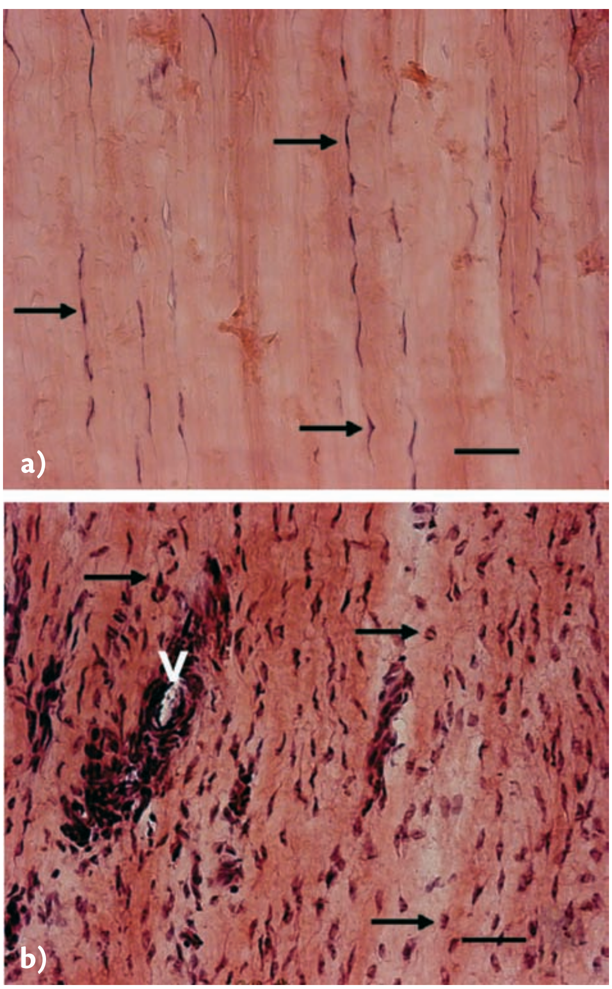


Figure 8.31 A microscopic picture of a normal and an injuried tendon (tendinosis). **a)** Normal tendon, showing parallel collagen fibers and a uniform collagen structure, which is oriented along the axis of the tendon; **b)** pathological (degeneration) changes in the tendon, i.e. tendinosis, with hypercellularity (too many cells), a wavy collagen structure and increased vascularity.

Background factors to tendon injuries

Most musculoskeletal injuries in the tendons are caused by improper training, e.g. sudden increase in running distance or altered activity. Increased training frequency, running on uneven, hard or slippery surfaces or soft sand are other risk factors. Under the principle of injury on transition to other training conditions,[3] injuries arise mainly when the athlete is changing training style or using other muscle groups. Transition injuries are related to an increased training frequency and among specific risks are an attempt to raise the level of performance, improper training, new or modified equipment, changes in the environment (e.g. new surface or other altitude), changes in training routines of frequency, duration and intensity, new techniques, body growth, inadequate periods of recovery and re-training after injury and intense training.

Tendon injuries can also occur during correction of anatomic abnormalities in the lower leg. Excessive outward (external) rotation of the foot sole (pronation of the foot,) as in flat feet, can increase the local tensioning of the Achilles tendon, which increases the risk of musculoskeletal injury. Excessive pronation increases the risk of posterior tibial syndrome, as described on p. 528.

Diagnosis

Good results require proper treatment based on accurate diagnosis, which requires a careful history and a thorough clinical examination. Thanks to the development of the MRI the understanding of tendon injuries and other soft tissue injuries has improved significantly. This computer-based image analysis not only provides support for a correct diagnosis but also makes it possible to evaluate the extent of the injury. Soft tissue images appear in multiple layers and a detailed analysis of the internal abnormalities can be made in tendon injuries around, for example, the ankle. Through MRI, a tendinosis can be revealed, and tendon process depicted in detail (Fig. 8.32). The examination, however, is expensive.

Ultrasound is another increasingly commonly used method of diagnosing tendon pathology. It is functional, i.e. it can be used to examine a body part during dynamic activity and to follow the healing process. The method is inexpensive. Ultrasound technology is valuable as a diagnostic tool, but it requires that the person doing the examination is skilled and experienced; in addition it does not reflect the full range of pathological change.

Tip

Ultrasound examination of a tendon provides very valuable information.

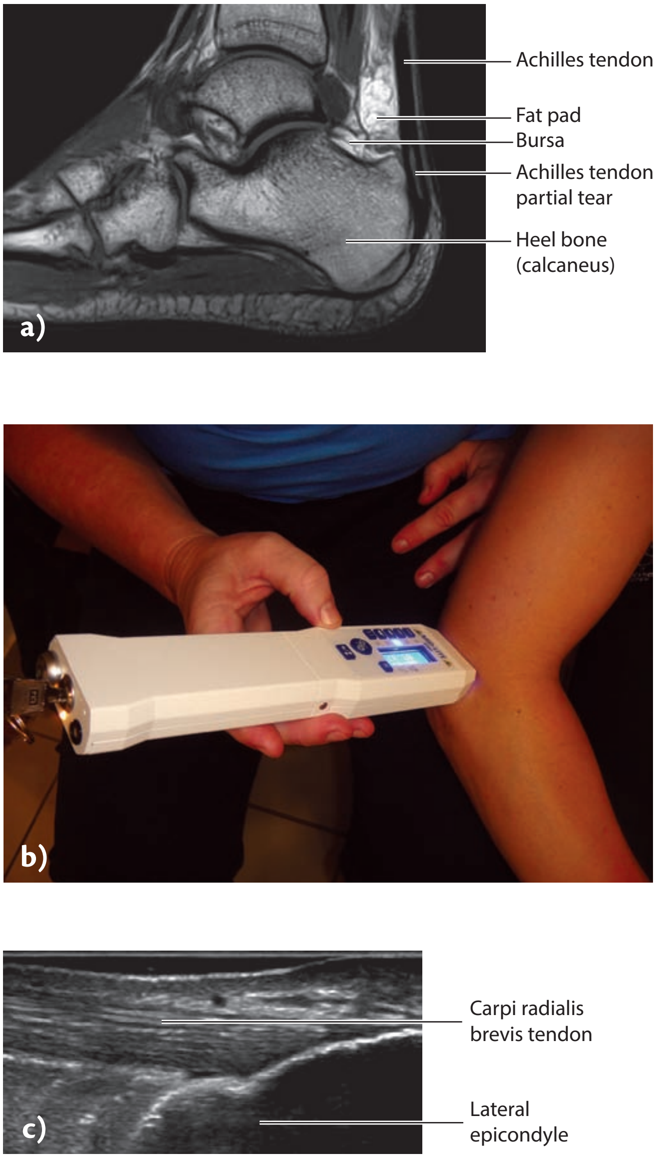


Figure 8.32 Diagnosis of a tendon injury can be made in several ways. **a)** Magnetic resonance imaging of an Achilles tendon is usually a very safe examination securing a correct diagnosis; the arrow shows a partial Achilles tendon injury; **b, c)** Ultrasound of the carpi radial brevis tendon that inserts on the lateral epicondyle of the elbow. Injuries in 'tennis elbow' are located at this site and involves mostly this tendon.

Treatment principles

The diagnosis determines how the tendon injury should be treated. Treatment varies as the healing progresses. Tendon strength is directly dependent not only on the number and size of collagen fibers but also on their orientation. Since the fibers respond positively to being pulled out and be in motion, it is important that the tendon is gently stimulated as early as possible with appropriate movements. Early activation is therefore sought. The movement can be limited by various braces to reduce the force exerted on the tendon. Motion training should begin within 2 weeks after the injury when possible.

Eccentric training of tendons

The exercises in the training program are designed for the most cases with the level of pain as a guide; in chronic tendon injuries pain is critical for functional loading and level. Table 2.1 shows the relationship between pain and sports performance.

After an injury has healed, a period of weakness remains in the tissue. For chronic problems, it is the history of pain that determines which follow-up is appropriate and what adjustments are required to perform the activity. If the training program is carried out properly, the athlete may pass the pain threshold during the last ten repetitions. If pain doesn't occur, the athlete may not be loading the tendon enough. As the tendon strengthens pain decreases.

Isometric and concentric work have their place in the rehabilitation program, but in chronic cases eccentric work is most effective (Fig. 8.33). Eccentric work may enhance the therapeutic effect to the tendon and stimulate regeneration after overload injuries, and the eccentric exercises appear to be so effective that surgery can be avoided in some cases.

The following programs are designed to strengthen the tendon's resistance to extension moments during the eccentric load:

- Stretch – hold the stretched position for 15–30 seconds, repeat 3–5 times.
- Eccentric work – advancing from a slow tempo during days 1 and 2, to moderate pace during days 3–5 and quick pace on days 6 and 7. Then increase the external resistance and repeat the program.
- Perform static stretching.
- Use ice for 5–10 minutes to reduce swelling and pain.

Stretching

Stretching probably plays an important role in the treatment of musculoskeletal injuries (Fig. 8.34). The theoretical foundation for the method is defined, but the epidemiological and scientific evidence is scarce. When studying the biomechanical effects there are possibly some improvements in flexibility and increased strength in the muscle–tendon complex. It is not clear which technique or procedure can provide the greatest possible agility. Experiments conducted to evaluate different stretching techniques have shown that techniques using the method 'contraction–relaxation–antagonistic contraction' in general are better than those

Figure 8.33 Eccentric exercise. **a)** Eccentric exercise of the Achilles tendon, an effective training technique; **b–f)** eccentric exercise for the patellar tendon, often carried out on an inclined plane.

that consist of 'contraction–relaxation' or 'contraction–retention–relaxation'. The differences between the methods are small.

There is currently no strong evidence that stretching before training or competition reduces the risk of injury. During static stretching the mechanical properties of the muscle–tendon unit are affected during that stretch, but this mechanical effect disappears within minutes. Stretching gives some improvement in the maximum ROM.

Surgical treatment

Persistent pain and reduced performance after a tendon injury may be an indication for surgery when conservative treatment fails. These have become increasingly rare since conservative treatment has made

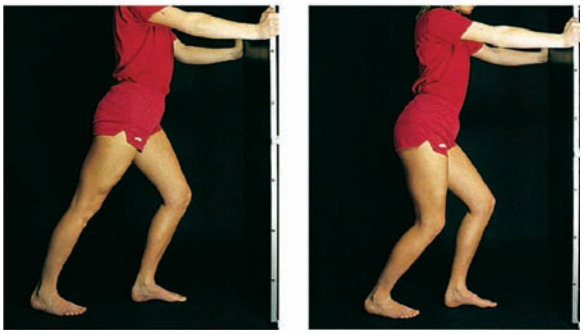


Figure 8.34 Stretching techniques are adjusted to the size and location of the (right) injury. Stretching of gastrocnemius (left) and soleus.

great progress and is often effective enough to get the tendon injury to heal. The current surgical technique aims to remove the pathologic tissue and reactivate the healing. Today selected surgery can be performed endoscopically, i.e. with keyhole surgery. A surgical procedure involves a significant stimulus to the tissue to trigger its biological repair mechanisms. The result is a reconstituted, not rejuvenated, tendon. There is not yet any scientific evidence for when and how the surgical treatment of overuse injuries of the tendons should be performed. There are however, numbers of well-documented cases that indicate a successful surgery and this, together with the lack of success with conservative treatment, is the reason why operation is indicated as a first treatment in top athletes and after failed conservative treatment.

Summary

To treat athletes with chronic tendon injuries requires long experience and collaboration with a physical therapist is mandatory. If treatment is to be successful it is important that the diagnosis is correct. The underlying causes of the injury should be addressed and corrected. Often the key to successful treatment is a review of the training routines and improvement of them. Orthotic devices are often used for correction of anatomic abnormalities. In people with tendon problems around the ankles insoles can be helpful. Tendon injuries as a result of overload requires careful treatment.

Tip

Chronic tendon injuries remains one of the major challenges in orthopedic Sports Medicine.

Complete tendon rupture

A complete tendon rupture is a serious injury in the young athlete but often affects tendons with degenerative tissue changes and are particularly common in older athletes, who have had a couple of years break in their training and then resuming their sport activity. Tendon ruptures primarily affect tennis and badminton players as well as football/soccer, handball, and basketball players, long, triple, and high jumpers and runners (Fig. 8.35).

Symptoms and diagnosis

- Athletes can experience a sudden 'pop', accompanied by intense pain, when the injury occurs.
- The injured person cannot perform the normal movements of the tendon and its associated muscle.
- Often a gap can be felt with marked tenderness in the tendon.
- Relatively soon it becomes swollen and possibly a skin discoloration, indicating a bleeding.
- A careful examination confirms the diagnosis.

Location

The tendons most commonly injured by complete rupture are the Achilles tendon, the supraspinatus tendon in the shoulder, the long biceps tendon of the two-headed muscle (biceps of the upper arm), the patellar tendon distal to the patella and the quadriceps tendon proximal to patella.

Treatment

The athlete/coach treats the injury acutely according to the guidelines in Chapter 5. The physician can choose between different treatment options depending on the injury localization.

Non-operative treatments are sometimes preferred in recreational and older athletes, e.g. the complete rupture of the long biceps tendon in the upper arm, which is usually treated conservatively. In these patients complete Achilles tendon ruptures can also be successfully treated conservatively, i.e. with adjusted functional training after plaster or orthosis treatment. Generally, however, movement training should be initiated as early as possible.

Surgery is recommended for the most part, because the tendon can be activated early with appropriate stretching exercises. The collagen is then straightened out, and with the right fiber direction strength can be built back up in the tendon and loss of muscle mass is reduced. The treatment may vary from case to case.

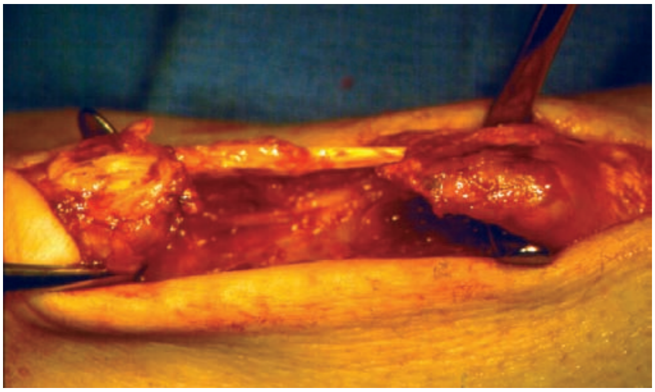


Figure 8.35 Complete Achilles tendon rupture. A complete rupture during surgery; the tendon seen between the tendon ends is the plantaris tendon.

Partial tendon rupture

For partial tendon rupture (first- and second-degree ruptures) only a part of a tendon is torn. The injured athlete is not always aware that the injury has occurred, but believes they have suffered an inflammation of the tendon. Partial tendon ruptures can be divided into acute and chronic injuries.

Symptoms and diagnosis

An acute partial tendon rupture can cause the following symptoms:

- Sudden pain usually elicited in certain situations or with certain movements.
- Pain from the injured area under load when tested against resistance.
- Marked local tenderness in the injured area.
- Swelling and possible skin discoloration due to hemorrhage.
- A small tender gap in the tendon can be felt when the injury has occurred recently.

The chronic symptoms of a partial tendon rupture may include the following:

- The injured person has noticed sudden pain for a long period of time, while the injury event is often forgotten.
- Pain during warm-up exercises, which then disappears but later returns with greater intensity.
- Pain occurs in the injured area when adjacent joints move against resistance.
- Local intense tenderness and thickening.
- Sometimes swelling may occur.
- Ultrasound and MRI are used to assess the location and extent (see Fig. 20.24).

Location

The tendon that is most commonly affected by partial ruptures, acute and chronic, is the Achilles tendon. The patellar tendon, rotator cuff of the shoulder and adductor longus tendon may also suffer partial rupture.

Treatment

In acute partial tendon rupture the athlete/coach should take the following immediate measures:

- Ensure that the injured area is cooled with ice, a compression bandage is applied, and that the injured limb is placed in an elevated position and rested. Sometimes crutches can be a good support.
- Seek medical advice when uncertainty about the diagnosis and treatment exists.

Physicians may:

- Cast, advise on foot support or supporting bandages in the acute phase.
- Prescribe an exercise program with gradually increasing intensity.
- Prescribe an anti-inflammatory drug.

If an acute partial tendon rupture is not treated properly damaged tissue is formed in the injured area, which often is very difficult to get to heal. If healing is delayed the injury will result in the same symptoms as in chronic tendinopathy. It is therefore essential that the tendon is treated in a correct manner from the beginning. Most neglected tendon ruptures cause chronic degenerative and some inflammatory conditions, which are among the most difficult of all sports injuries to treat.

In a chronic tendon tendinopathy secondary to a partial rupture (tendinosis) the athlete/coach can:

- Use an exercise program where stretching and eccentric loads are included.
- Receive physical therapy treatment.
- Use support bandage, tape or splint to unload the injured body part.
- Use a heat retainer.

Physicians can treat with:

- Anti-inflammatory agents.
- Surgery if symptoms are prolonged with limited function.

To prevent the formation of scar and granulation tissue requires great care even in the treatment of small partial tears. In other cases, the condition can become chronic and thus extremely difficult to treat. The need for surgery increases the longer the time that has passed since the tendon injury occurred. If more than 22 months have passed since the appearance of an Achilles tendon injury the probability of surgery is 38%. Approximately 10–20% of athletes suffering from an overuse injury to the Achilles tendon undergoes surgery sooner or later, and about 70–80% of them will return to competition. However, it takes 6–8 months before the athlete is fully recovered. For 10–20% of those affected a new operation is necessary, while 3–5% of them are forced to discontinue their sporting career.

Inflammation of the tendon sheath (tenosynovitis)

With constant repeated, unilateral movements or repeated mechanical loading, an inflammatory reaction occurs in the tendon sheath and a minor inflammatory reaction in the tendon, often causing chronic symptoms, that can be difficult to treat.

Location

Tenosynovitis affects mainly the Achilles tendon (also named paratenonitis). Other tendons and tendon sheaths that are prone to inflammation are the long tendon of the two-headed (biceps) muscle of the upper arm, the tendon of the supraspinatus muscle and the extensor tendons around the wrist and ankle.

Symptoms and diagnosis

- Pain during and after the exertion of the affected tendon in the acute phase.
- Tendon crepitations can be felt.
- For chronic conditions the initial pain will often disappear during warming-up exercises.
- Tendon/tendon sheath is swollen, thickened and diffusely tender.
- Reduced function.
- X-rays, ultrasound and MRI of the tendon can show swelling and sometimes calcification of the inflammatory changes in the tissue.

Treatment

When a tenosynovitis occurs the athlete/coach can:

- Cool the injured area during the acute phase.
- Employ active rest until pain-free.
- Use warming treatment locally and use a heat retainer.
- See a physician if the problems persist through the above treatments.

Physicians may treat with:

- A training program that begins as soon as healing permits: initially isometric exercise without load, then, dynamic exercises can be initiated and includes eccentric exercises and gentle stretching. The exercises are discontinued when the pain threshold is exceeded.
- Casts or other bandages.
- Anti-inflammatory agents.
- Galvanic high voltage stimulation.
- Ultrasonic or short wave treatment.
- Surgery.

Inflammation of the muscle–tendon attachment (insertion) to bone (tenoperiostitis, apophysitis)

The muscle attachment to the bone is a gradual transition from the muscle's tendon to cartilage, and from mineralized cartilage to bone. The cartilage forms a filamentous 'barrier' that inhibits blood supply to the connection between bones and tendons. This explains why tendon injuries often have a long healing time and sometimes become chronic.

At repeated tears in the muscle or tendon attachments to bone and periosteum, small ruptures with bleeding may occur, which can lead to an inflammatory reaction. Growing individuals rarely suffer from inflammations in muscle or tendon insertions to bone, because their tendons and muscles are stronger than the bone. Instead, they suffer inflammation and avulsions of bone, for example Osgood–Schlatter's disease in the knee (see p. 458) and inflammation of the calcaneus (insertionitis) (see p. 496).

Location

Inflammation of muscle and tendon attachments to bone occurs most often in the elbow area ('tennis elbow', 'throw-'/'golf elbow'), the attachment of the muscle group that pulls the leg inward (the adductors of the thigh), at the tendon's proximal and distal attachments to the patella, the Achilles tendon's attachment at the calcaneus and at the plantar fascia's origin in the calcaneus (plantar fasciitis, 'heel spur').

Symptoms and diagnosis

The condition is characterized by:

- Pain in the muscle or tendon attachment to the bone.
- Slight swelling and reduced function may exist.

- A distinct, localized tenderness occurs when a finger is pressed against the muscle or tendon attachment.
- Increased pain at the muscle–tendon attachment at contraction of the actual muscle group.

Treatment

The athlete/coach can:

- Avoid activities that trigger pain (crutches may be helpful).
- Cool down the injured area with a cold pack to reduce pain and swelling in the acute phase.
- Add supportive bandage or tape.
- Use warming treatment locally and use heat retainers after the acute phase.

The physician may treat with:

- Bandages, tape or casts.
- Anti-inflammatory agents.
- Prescription of exercise programs, such as static muscle training.
- Prescribe splint for the injured body part to use at night.
- Local cortisone injections when symptoms persist followed by 1–2 weeks of rest.
- Provide shockwave therapy.
- Surgery for persistent pain and if the condition is prolonged.

Prevention

- Proper technique should be practiced.
- Proper equipment for each sport should be used (new equipment such as shoes should be 'broken in').
- Clothing and equipment should be designed specifically for the athlete to use.
- Solid general basic training and training for risk areas should be implemented.

Injuries of the bursa

Bursae are usually located over areas exposed to pressure or friction, such as between bone and tendon, between two tendons and between bone/tendon and the overlying skin (Fig. 8.36). Bursaes reduce friction by providing sliding synovial surfaces, distributing the pressure on the actual area. There are several permanent bursae in the hip, knee, foot, shoulder and elbow regions. Sometimes there is a connection between a bursae and the adjacent joint. The bursa on the back of the knee, bursa semimembranosa-gastrocnemica (Baker's cyst), is in connection with the knee joint,

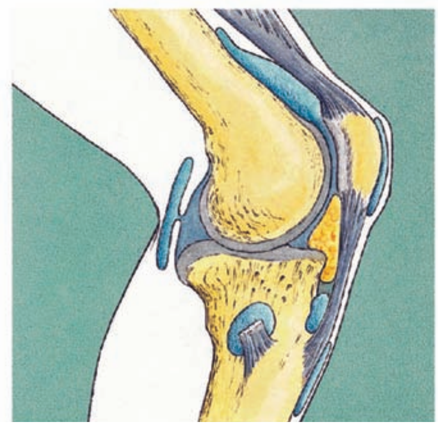


Figure 8.36 Bursae in connection with the knee.

and the bursa behind the hip joint's flexor muscle, iliopectineal bursa, is in connection with the hip joint. Bursaes can form when an area is subjected to repeated pressure or friction, such as over protruding bone parts, metal implants or prostheses.

The pathological conditions in the bursa can be classified into inflammatory conditions, bursitis, and conditions caused by trauma resulting in hemorrhages, hemobursa.

Inflammation of a bursa (bursitis)

Bursa inflammation can be classified into friction bursitis, chemical bursitis and septic bursitis (caused by infection with bacteria), depending on what triggers them. A bursitis can be included as a part of a syndrome in general, inflammatory or infectious diseases, such as RA, gout, tuberculosis or Bechterew's disease.

Friction bursitis

If repeated tendon movements pass a bursa, a friction bursitis occur, especially if the area is exposed to pressure. Sporting activities involving repetitive movements, such as tennis or jogging on roads, can cause friction bursitis. It is primarily bursae in the shoulder, elbow, hip, knee, heel and toe that are affected.

Symptoms and diagnosis

The mechanical stimulus provokes inflammation. As a result of the inflammatory response the bursa secretes fluid, causing swelling and tenderness. A fluctuation can often be palpated (i.e. feeling that liquid moves from side to side) when examining with the fingers in the bursa. If the inflammation is large, heat and redness can occur in the skin area above the bursa, especially if it is superficial. The symptoms are:

- Swelling.
- Local heat.
- Redness.
- Tenderness.
- Pain at the slightest movement or pressure.

Treatment

The athlete should:

- Rest until pain relief occurs.
- Use a cold pack to cool down the injured area.
- Apply a bandage that compresses the bursa.
- Relieve the bursa area from external pressures (e.g. by applying a foam dressing with central gap).
- Use chloroprene or neoprene cuff as pressure bandage.
- See a physician if the swelling is extensive, redness is present or the pain is severe and does not subside.

The physician may:

- Prescribe rest. The injured body part may be placed in a splint for a few days.
- Puncture and empty the bursa. Afterwards sometimes a pressure bandage is applied.
- Provide local corticosteroid injections.
- Prescribe anti-inflammatory agents.
- Surgery to remove the bursa, if the problems persist. Sometimes it is necessary simultaneously to chisel off the bone that may be the cause of the friction bursa inflammation.
- Perform bursoscopy (inspection of bursa using an arthroscope) and remove the bursa if necessary.

Chemical bursitis

Chemical bursitis is caused by substances that are formed as a result of an inflammatory or degenerative condition (degradation state) in the tendon tissue, e.g. calcification or uric acid deposits and it is these conditions that are primarily treated. Symptoms and treatment are largely the same as stated above for friction bursitis. Bursitis can be treated immediately by a physician puncturing and injecting cortisone. Chronic, inflammatory conditions often lead to removal of the bursa.

Chemical bursitis is most common in athletes who have reached the age of 30, and who for many years has been active in racquet sports or throwing sports. Chemical bursitis is sometimes found in the subacromial bursa located between the acromial process of the scapula and rotator cuff covering the humeral head in the shoulder. The inflammation may be caused by a calcification in the supraspinatus tendon draining itself into the bursa (bursitis calcaria). Bursitis can sometimes occur secondarily as a precursor for 'false gout' (pyrophosphate depositions).

Septic bursitis

Septic bursitis may be caused by bacterial spread by the blood or entering through the damaged skin, such as abrasions. Superficial bursae, e.g. over the elbows and kneecaps, are affected more than others by septic bursitis. Septic bursitis occurs in athletes who often encounter dirty abrasions, e.g. the soccer player who plays on clay courts.

Symptoms and diagnosis

- Very severe pain with intense soreness.
- Fever can occur.
- Large swelling with redness of the surrounding area.
- Substantial reduction of body part function.
- If the infection is prolonged an X-ray of the skeleton should be done to be able to determine if the underlying bone is affected.

Treatment

The athlete should:

- Rest and unload the infected area.
- Keep the affected area clean by washing it with soap and water.
- See a physician as soon as possible.

The physician may:

- Start direct treatment of the infection by aspiration and antibiotics.
- Possibly immobilize in a bandage or cast for a few days.
- Treat with antibiotics intravenously if there are signs of cellulitis (inflammation of connective tissue beneath the skin).
- Insert drainage in the infected bursa.
- Surgery to remove the bursa if the infection is prolonged.

Bleeding in a bursa (hemobursa)

The most common cause of hemobursa is direct trauma, e.g. if the athlete falls. Hemobursa can also result from indirect trauma, e.g. by a rupture in a tendon causing bleeding in the bursa or by a bleeding that occurs in a joint, which has a connection with the bursa. Bleeding in the bursa causes a chemical inflammation, and if the bleeding is severe clots can be formed with adhesions of connective tissue and loose bodies. These adhesions and loose bodies can cause recurrent inflammation, which may be long term or chronic.

Location

Hemobursae are common among athletes who often hit body parts to the surface, e.g. handball and volleyball players. This type of injury is common on the tip of the elbow (olecranon bursa), the upper outer end of the femur (trochanter bursa), in front of the patella (prepatellar bursa) and in the subacromial bursa.

Symptoms and diagnosis

In acute injury is the following present:

- Swelling when the bursa is filled with blood.
- Intense tenderness.
- Pain and functional impairment of the body part.
- Sometimes redness or skin damage, even open wounds.

Treatment

The athlete should:

- Treat with ice to limit the bleeding; bandage if an open wound.
- Put on compression bandages.
- Unload the injured bursa.

The physician may:

- Puncture and drain the bursa (see Fig.17.27).
- Put on a compression bandage and possibly a plaster splint.
- Suture an open wound.

Bleeding in a bursa can cause adhesions and loose bodies (see Fig. 19.88). If untreated, it can become chronic.

Peripheral nerve injuries

Peripheral nerves may be motor, sensory or compound motor–sensory and thus if injured cause both muscle effects and sensory disorders. Injuries to the peripheral nerves are relatively common, and if these injuries are not treated the results can be devastating to the athlete. The body's peripheral nerves are injured especially when they are compressed or overstretched. When nerves such as the peroneal nerve (often called the fibular nerve) passes over the upper part of the fibula or the ulnar nerve passes on the inside back of the elbow, both running between the skin and bone superficially, they may be subjected to powerful compressions or blows (Fig. 8.37). A bone fracture or dislocation can damage the nerves in the affected area by being exposed to overstretching.

The ulnar nerve in the elbow can be overstretched during throwing, such as in baseball (see p. 276). Excessive internal rotation (inversion) of the sole of the foot can cause an injury to the fibular nerve. If the nerve is stretched by 30–70% it can break mechanically. Decreased blood flow is a more rare cause of nerve injury, which, however, can occur in nerve entrapments, compartment syndrome or related to fractures or dislocation. Unusual nerve injuries can be caused by direct trauma, such as by falling or hitting a hard surface, causing lacerations including ruptures of the nerve, for example the peroneal and ulnar nerves, but these injuries can also sometimes occur in contact sports from tackles such as in ice hockey and bandy.

Symptoms and diagnosis

These symptoms are not always prominent in the acute phase, therefore it can be difficult to diagnose the nerve injuries. Symptoms can be insidious; the athlete may complain of numbness, tingling and pain that radiates into the limb, or muscle weakness.

- Pain and also transmitted pain (referred pain) is present at times, which can result in reduced muscle strength.
- To make a full assessment of muscle strength anesthetics can be injected that temporarily removes the local or transferred pain and confirms the diagnosis.
- It is important to test strength against resistance; nerve injury can cause weakness or paralysis if a motor branch is affected.
- Decreased muscle mass (hypotrophy/atrophy) can begin to occur after a few weeks and gradually becomes extensive (atrophy).
- Reflex testing is mandatory in cases of suspected injury to the peripheral nerve or nerve root.
- Abnormal sensations, such as numbness, tingling and pain can occur.
- There are special tests for different types of nerve injuries; one test is the Tinel's sign, which means that a light tap with the finger over the injured nerve causes tingling or numbness, which spreads along the nerve segment.
- Electromyography (EMG) is an examination method that can identify the peripheral nerve injury and draw a conclusion of the prognosis. EMG examination consists of two parts: mapping of the nerve's conduction paths (both motor and sensory) and recording of muscle electrical activity using electrodes inserted.

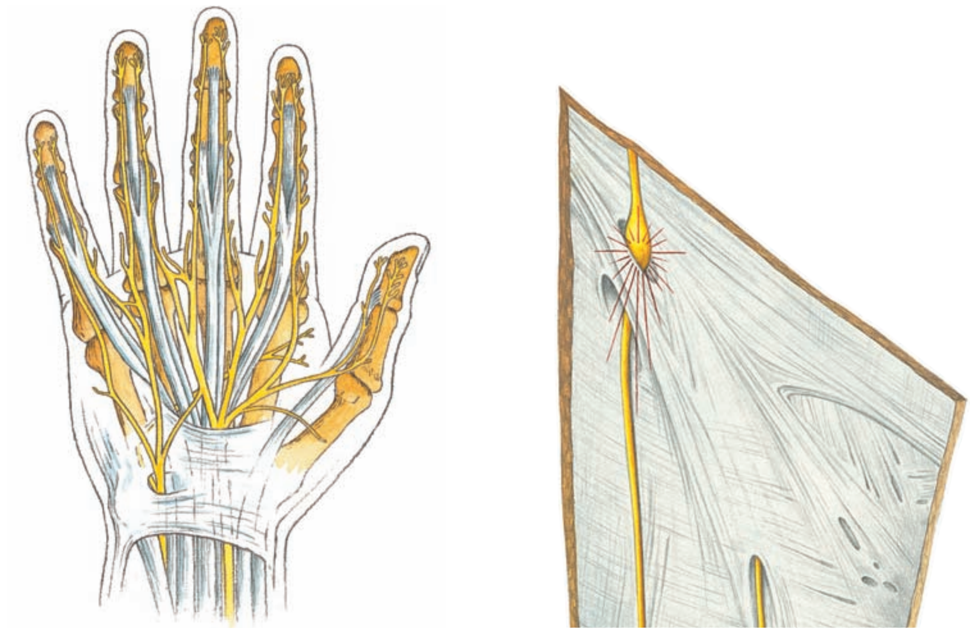


Figure 8.37 Example of nerves that can be subjected to pressure or compression resulting in tingling, inflammation and swelling in the hand, groin, etc.

These conditions should be examined 3 weeks after injury. An EMG examination is performed in cases of suspected injury to a peripheral neural net (plexus injury) or a nerve root. Examination finding confirms the potential nerve injury and shows its severity and extent. EMG examinations are normally conducted by a neurologist.

Treatment

For the most part, these injuries may heal spontaneously, but sometimes they can give permanent loss of function. Injury caused by compression or entrapment is treated by relieving the pressure on the nerve. Treatment depends on the underlying mechanism of injury, type of injury, location and symptoms.

Prognosis and return to sport activity

A proximal (closer to the body center) nerve injury generally has a poor prognosis for the nerve to recover. There are many factors affecting the healing and regeneration of an injured nerve, e.g. scarring of the affected area, which interferes with the tissue healing process. If the injury is prolonged in regeneration of injured nerve fibers (axons), the recovery of the affected nerve and its muscle function will also be delayed. There are several factors to consider regarding the prognosis of nerve injuries, and advice from medical specialists and EMG examinations provides valuable information.

Peripheral nerve injuries primarily affect the upper limbs. They occur in contact sports and throwing sports such as wrestling, basketball, volleyball and hockey, when the shoulder suddenly is pressed down. Injury can also occur in the thoracic longus and suprascapular nerves, which are important for the function of the scapula and shoulder in throwing actions. In dislocation of the shoulder joint in 9–18% of the cases an injury occurs to the axillar nerve in the shoulder region. Compression of the median nerve will cause carpal tunnel syndrome; pressure can also be exerted on the ulnar and radial nerves. In the lower extremities the most important nerve the sciatic nerve, is rarely injured in sport except for in relation to low back problems. The fibular nerve, which is an extension of the sciatic nerve is sometimes injured where it passes the back of the fibula, which results in radiating pain, numbness, pain and weakness over the lateral aspect of the lower leg and foot and weakness in dorsiflexion of the ankle. Radiating pain can occur over the outer, lower part of the lower leg at entrapment of the outer superficial branch of the fibular nerve (peroneus superficial nerve). In tarsal tunnel syndrome the posterior tibial nerve is entrapped or pinched in the so-called tarsal tunnel on the medial malleolus, running to the foot sole causing numbness and pain. Nerve entrapments can also occur in the groin of the cutaneus femoris lateralis, ilioinguinal, anterior cutaneus femoral, genitofemoralis and obturator nerves with groin pain as a result.

It is essential that the injury is detected early so that the biomechanical injury causes are eliminated and nerve function is restored in time avoiding the condition becoming permanent. Motoric peripheral nerve injuries after trauma can be especially serious.

Other injuries

Lacerations

Lacerations are common among athletes, primarily among those who engage in contact sports such as soccer, ice hockey and bandy. Even horse riders, runners and cyclists encounter lacerations in falling against a hard surface. How a laceration occurs is critical to how extensive it is. Different types of lacerations are cutting, crushing, tearing, slashing, puncture, shooting and abrasions. Lacerations may affect the superficial layers of the skin but also go deeper and involve tendons, muscles, blood vessels and nerves.

The healing of a laceration is complicated by movements in the area around it, of contaminants and infection, bleeding (hemorrhage) and the defects between the laceration edges. Treatment therefore focuses on these factors.

Treatment

To stop bleeding (hemorrhage) the athlete can:

- Raise the injured limb. When the injury is located in the arms or legs if possible the person should be laid on the back or side and the affected limb held up. This measure is in most cases sufficient to stop the bleeding.
- Close the wound if the bleeding is severe and does not cease. With a hand on each side of the wound, press the edges of the wound together while the injured limb is still held in a high position, preferably with the help of another person. The risk of infections is reduced if the fingers are not in contact with the laceration. In exceptional cases, where the injured does not have any help the bleeding can be stopped by pressing directly on the laceration with the hands.
- Apply a compression bandage as soon as dressings have been acquired. The laceration edges, the walls of the entire laceration, should be pressed against each other. A folded dressing or a clean handkerchief can be pressed against the soft tissue near the laceration edges to improve the pressure on the area (Fig. 8.38). The dressing or handkerchief can be held in place with an elastic bandage or gauze. A blood pressure cuff should never be used; even a compression bandage should not be left in place longer than 10–20 minutes. If a compression bandage is needed to stop the hemorrhage, the injured person needs to be transported urgently to the physician.

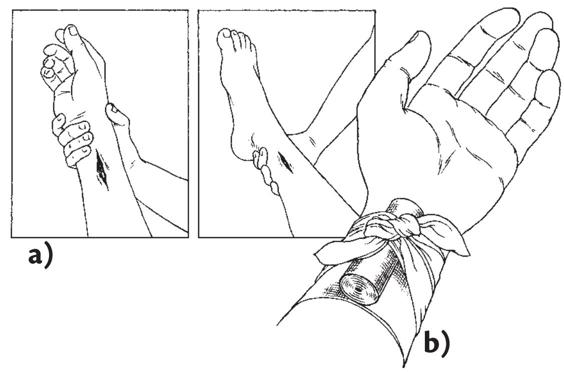


Figure 8.38 Management of an open wound. **a)** The arm or extremity should be kept elevated; **b)** Example of a compression bandage.

Cleaning

Superficial lacerations or abrasions that have been contaminated must be thoroughly cleaned within 6 hours. Otherwise, the laceration will get infected, since after this time bacteria will grow and begin to penetrate the tissues. It is essential that all the dirt is removed, especially from abrasions to the face, because unsightly scars may occur. Abrasions that are heavily soiled may be cleaned with soap and water and a soft brush for several minutes. After general cleaning, the laceration should be washed thoroughly with clean water or saline and covered with a sterile dressing, held in place with a gauze. If the laceration is exuding, the dressing needs to be changed daily. Healing is facilitated if the laceration is treated with vaseline dressings. Small, superficial abrasions heal best if left alone after a thorough cleaning.

Deep lacerations include the skin layer and underlying connective tissue and possibly tendons, muscles, blood vessels and nerves. The laceration edges are often gaping, and hemorrhage may be significant. Puncture lacerations caused by studs or spikes shoes can be treacherous and should be treated by a physician. For injuries to the sole of the foot a foam dressing with gaping may be required, which equalizes the load on the foot when walking. Deep lacerations should be cleaned thoroughly. Physicians may

Tip

The basic rule is that if the lacerations are not treated within 6 hours after they occurred, they should be regarded as infected.

sometimes remove some dead tissue from the laceration (debridement).

Lacerations that need stitches are deep lacerations, lacerations that are associated with massive bleeding and are gaping, i.e. laceration edges are not in contact with each other.

When a laceration needs stitches a physician should be contacted, preferably within 6 hours after the injury occurred.

Infected lacerations are characterized by pain, swelling, redness, and local tenderness. The bacteria in an infected laceration can be spread via the lymphatic system to the lymph nodes. An infection in the leg, for example, spreads to lymph nodes in the groin. The lymphatic vessels may then appear as red streaks in the skin, and the person may experience fever, malaise, and swollen and tender lymph nodes. The condition is called colloquially 'blood poisoning', and lacerations that have caused this have to be treated medically. Common measures are local cleaning antibiotic treatment, cast, etc. If fever and constitutional symptoms are present, the person should lie in bed.

Prophylaxis against lockjaw (tetanus)

All lacerations incurred outdoors are at risk of tetanus. Since 1950 all infants are vaccinated against tetanus in Sweden. The vaccination against tetanus means that 0.5 ml of tetanus vaccine is injected three times, the first two times with at least 4–6 weeks in between, the third at least 6 months after the second. The protection against tetanus remains for many years. Those who have received one or two doses of vaccine are not fully protected, but three doses within a period of 10 years is considered to be a full vaccination schedule. For lacerations that require medical treatment a booster dose of tetanus vaccine is usually given.

Tip

At signs of laceration infection with bacterial proliferation the athlete should always rest.

Blisters

The scourge above all others for athletes are blisters on the feet. Blisters on the hands troubles skiers, basketball players, rowers, tennis, badminton, squash and handball players, etc. When the blister pops it opens up a laceration that can result in intense pain.

Wheelchair athletes often have trouble with pressure sores and blisters, which can be difficult to treat because of impaired sensation and poor circulation (Fig. 8.39).

Treatment

Blisters are treated as follows:

- At the slightest sense of blisters the activity should stop to prevent further irritation. The irritated area can be protected with adhesive plasters. Kinks in the plaster should be avoided, as this can cause larger blisters.

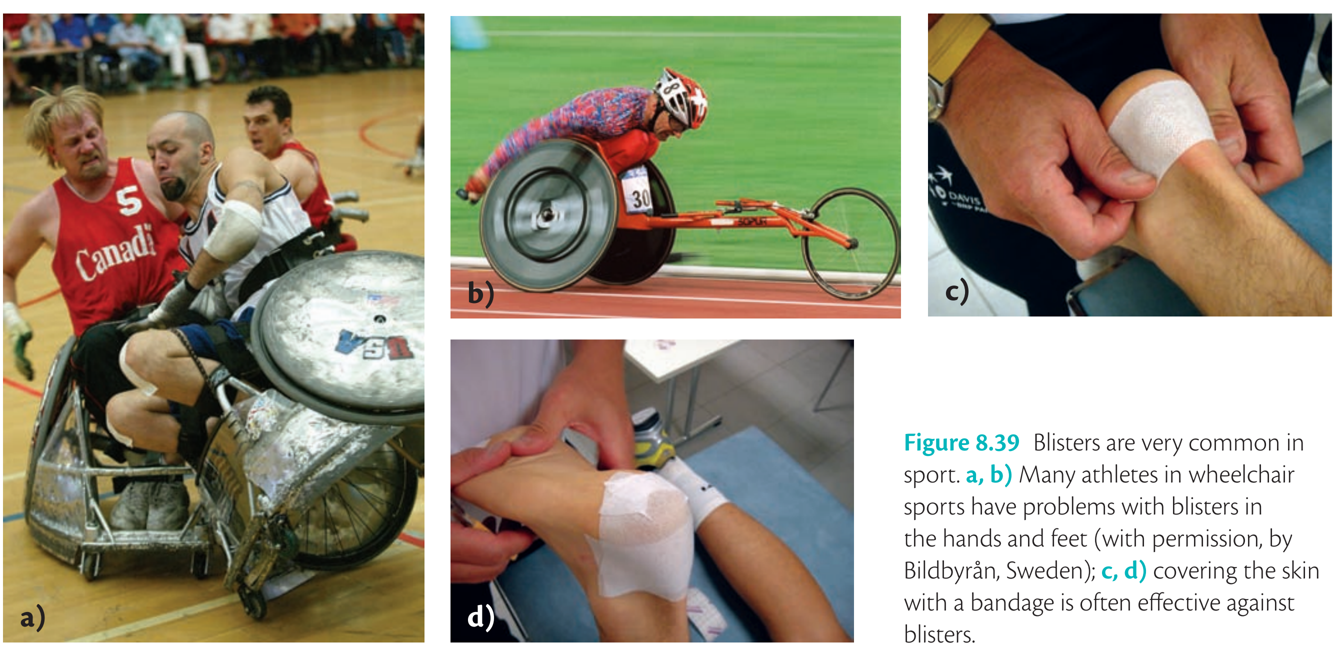


Figure 8.39 Blisters are very common in sport. **a, b)** Many athletes in wheelchair sports have problems with blisters in the hands and feet (with permission, by Bildbyrån, Sweden); **c, d)** covering the skin with a bandage is often effective against blisters.

- If a blister has occurred it is important to try to keep it intact, as it provides good protection against bacteria. It should not be punctured. If the blister is large, it may be possible to puncture the edge with a sterile needle. The blister can be protected against pressure by a piece of foam, which is clipped to a ring corresponding to the blister size placed over it.
- If the blister breaks by itself, it is important to clean the wound thoroughly with soap and water or an antiseptic solution. As protection, a sterile non-adhesive dressing or a vaseline bandage should be used, held in place with gauze, elastic bandages or similar.

Prevention

- All equipment at training and competition must be appropriate. Shoes should be well used. Gloves should be used in sports where that is possible.
- Socks should be well kept, dry, clean and of the right size, so they are not kinked.
- Socks should be changed often.
- The hygiene should be handled carefully. The feet should be washed daily and can be lubricated with salicylic ointment, which softens calluses and makes the skin smooth.
- Sensitive skin areas can be protected with adhesive plaster before training.

When it comes to blisters, it cannot be stressed enough that prevention is most important. It is possible to avoid getting blisters. Even a seemingly minor blister can become infected and it can cause major problems involving a long break from training.

Friction burn

Training and competing on synthetic surfaces and synthetic treated floor surfaces affords risk of getting friction burns when falling (Fig. 8.40). Abrasions arise if the body is in contact with the surface in a dynamic way. Burns generally cover only the outer layer of skin and in its mildest form only results in redness and need not be treated. If blisters in the skin occur, these should be covered with a clean bandage. When the outer skin layer is scraped it creates an exuding laceration surface that needs to be cleaned and wrapped as soon as described above in order to prevent infection.

Treatment and prevention

The athlete can:

- Prevent friction burns through ensuring that the right equipment and clothing is used as protection for vulnerable parts of the body.

Figure 8.40 When playing on synthetic turf, friction injuries can occur during falls. (With permission, by Bildbyrån, Sweden.)

- Reduce friction in any case, by lubricating the exposed body parts with oily ointment.
- Treat friction burns by cleaning the laceration thoroughly with soap and water and put on vaseline bandages, fixed with tape.

Stitch (splenic stitch) – exercise-related transient abdominal pain (ETAP)

It is not unusual that runners that are poorly warmed up feel pain (a stitch) in the upper part of the abdomen a few minutes after they have started to run. Pain can occur in both the right and left side of the abdomen and occurs more often in people who begin to play sports right after a meal. The pain may worsen with deep breathing but can also be alleviated by deep breathing. In a recent study approximately 70% of runners reported experiencing the pain in the past year and in a single running event approximately one in five participants can be expected to suffer the condition.[4]

The actual causes of the stitch are essentially unknown. There are studies that suggest that a purely mechanical effect may be the triggering cause. The connective tissue that anchors the abdominal organ structures can be loaded additionally after a meal. Physical activity after a large meal can cause some tears and hemorrhages in the connective tissue structures. Stitch can occur because the blood does not have time to carry oxygen in sufficient quantity to the respiratory muscles of the diaphragm, and this lack of oxygen can cause pain in the area. Possibly, the pain may also be triggered in the internal abdominal organs like the spleen and liver associated with redistribution of blood flow during physical exertion. Irritation of the parietal peritoneum, which is the part of the lining of the abdominal wall, is now discussed as a likely cause as it explains the features well.

Characteristic is that the pain is a localized pain, that is most common in the lateral aspects of the mid abdomen along the costal border, although it may occur in any region of the abdomen. The pain can be sharp or stabbing when severe, and cramping, aching, or pulling when less intense.

Treatment

The athlete should:

- Avoid training and competition during the first 2–3 hours after a large meal.
- Run forward bent or stop, so that the pain can disappear before training resumes.
- Squeeze a hard object, such as a stone in a hand. Many athletes feel that the pain disappears, but the mechanism behind this 'phenomenon' is unknown.
- Lie on the back on a flat surface and stretch the stomach by pushing it upward.

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9 Rehabilitation Principles

The rehabilitation team surrounding an athlete including physician, physical therapist, athletic trainer and strength trainer, has an important part in both injury prevention and rehabilitation in Sports Medicine. As far as prevention is concerned each sport has its own pattern of movements, which subjects various muscle groups to different types of load. A knowledge of these patterns is vital to the physical therapists and athletic trainers, whose tasks are to emphasize the importance of warm up, make appropriate suggestions for strength and flexibility training with regard to the requirements of the sport in question, and recommend specific training based upon the needs of each individual athlete in order to improve function and thus likely performance and injury prevention.

Movement therapy and physical therapy

When an injury has healed, the aim is to restore original function to the affected part. The physical therapist's instructions are of the utmost importance in ensuring that the correct muscle groups are trained with the appropriate movements and with a well-balanced load.

If surgery is contemplated, physical therapy is valuable both before and afterwards. Prior to a meniscus operation, for example, it is essential for the patient to exercise the thigh muscles as they are responsible for stabilizing the knee, and if they are well trained before the operation, rehabilitation is facilitated. Assessing an individual's functional state is part of the athletic trainer's and physical therapist's work (see, among others, the section on Motion analysis). Analyzing the causes and consequences of a functional impairment enables a program to be drawn up for the treatment of muscles, joints and ligaments. The treatment methods used are flexibility, strength and coordination training in prescribed proportions, together with encouragement, rest and use of modalities to reduce pain and swelling.

The treatment of functional disorders, e.g. joint immobility caused by muscle damage, is based on neuromuscular stimulation, that improves the interaction between nerves and muscles. This interaction is disordered when joints are immobilized, and there is increased tone (hypertonia) in the muscles surrounding the joint. Treatment aims to relax the muscles to improve the range of movement. Stretching should be carried out slowly and smoothly, in order to prevent a rapid reflex muscle contraction (stretching exercises are described on p. 197).

In all strength training it is essential that the correct load is used (Fig. 9.1). After an injury, training should be appropriate to the type and extent of the damage and to the stage of the healing process reached.

No strength training should exceed the pain threshold. The first stage is usually isometric training without external load, after which the training frequency and subsequently the load can be increased gradually. When isometric training can be carried out without pain, dynamic training can be started. Hydrotherapy allows earlier and more aggressive intervention to help physiologic recovery. Muscle training may be supported with electrical muscle stimulation when conventional exercises cannot be carried out (neuromuscular electrical stimulation, NMES is described on p. 208).

Pool training allows for the affected joint (body parts) to work under reduced load, but for the cardiovascular system to be loaded, conditions which can be positive for the physiologic recovery (Fig. 9.2).

Isolated or specific training of an injured area should be avoided, and a comprehensive training program

Figure 9.1 Strength training with different degrees of load. **a)** Lifting of the pelvis on a ball (moving surface); **b)** lunge with a ball; **c)** lunge with weights. (Photos, Heijne/Frohm.)

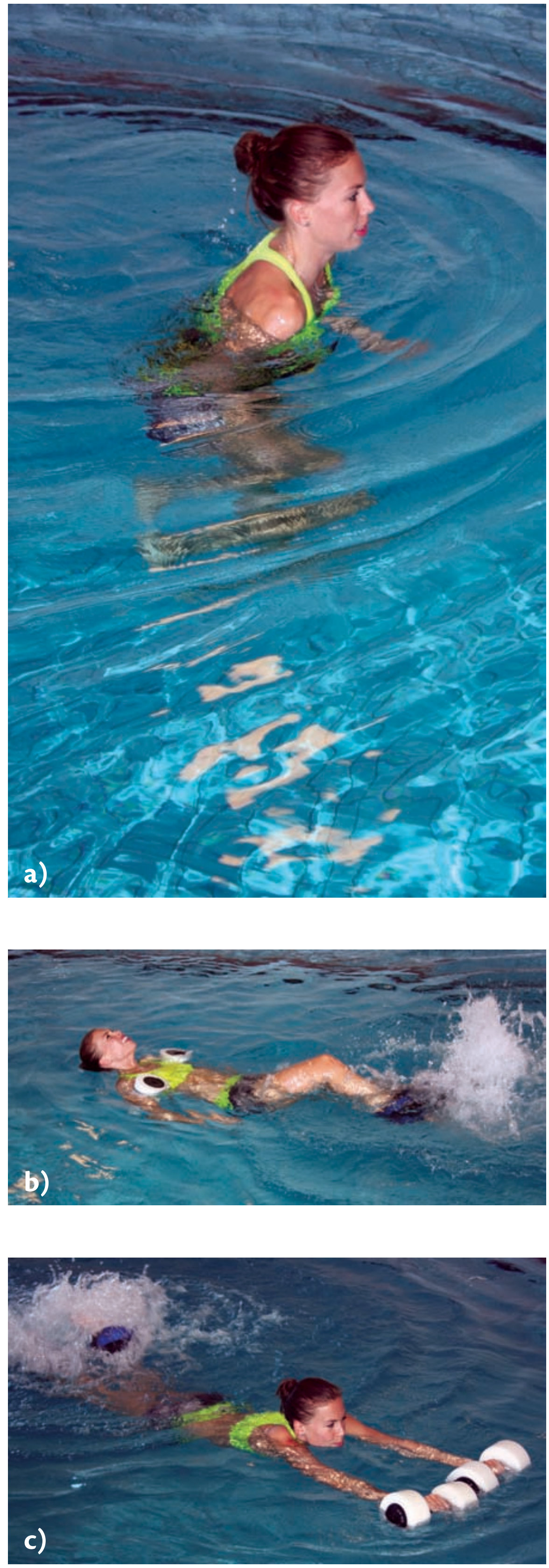

Figure 9.2 a–c) Pool training can be done in different ways. (Photos, Heijne/Frohm.)

should be drawn up to include all the training elements relevant to the athletic activity concerned.

It is important to monitor the healing process so that the injured area is not overused and healing delayed. Athletes do not always have the patience to wait for an injury to heal, and it is common for intensive training to be started too early. Additionally, many athletes experience high pressure from the sporting environment, such as coaches, parents, teammates, and in some cases sponsors and managers, to return quickly to sports.

Tip

This emphasizes the important role of the physical therapist and athletic trainer in the rehabilitation team, to oversee the training program to ensure that it is appropriate in both type and intensity.

Physical therapists and athletic trainers should be involved in the management of sports injuries to a far greater extent than is the case at present (Fig. 9.3). This should include not only the rehabilitation but also the functional and sports-specific training and tests needed before the athlete returns to sports.

Figure 9.3 Physiotherapist gives instruction on the competition field. (Courtesy of Tommy Eriksson, Swedish Athletic Association.)

Psychological aspects of injury and rehabilitation

How an injured individual reacts to injury emotionally is not clear. However, there is research that shows that the athlete can react with a combination of shock, grief and anger with feelings of guilt. Several environmental factors such as teammates, caregivers, coaches and parents but also internal factors, i.e. personal beliefs, have been shown to affect how well an injured athlete adheres to their rehabilitation and their probability to return to sports.

Self-efficacy, i.e. the athlete's confidence in their own ability to perform a certain task, for example rehabilitation after anterior cruciate ligament (ACL) surgery, proved to be crucial to how or if an athlete returns to sports or not. Confidence in their own ability can be influenced by:

- Gradually setting reasonable goals during rehabilitation.
- The injured individual meeting with other injured athletes, who returned to sports.
- The involvement of the injured individual in team activities that do not involve exercise.

Tip

There is often a fear to return to a sport when an athlete is injured. This is commonly known as 'fear of re-injury'. These feelings are important to consider for caregivers, coaches and teammates.

Rehabilitation principles

The aim of rehabilitation is to limit the amount of scarring, and to preserve strength, elasticity, and contractility of the tissue's components. The objective in training these muscles, tendons and joints after injury is to:

- Regain normal mobility (range of motion) of the joints.
- Stretch connective tissue fibers of the tendons and muscles to an optimal length.
- Increase the strength and endurance of the muscles.
- Increase the strength of muscle, tendon attachments, ligaments, joint capsule and it's attachments and joint cartilage.
- Improve stability, balance, coordination and proprioception.

Biomechanics

Biomechanics can be defined as the study of how organs and cells are affected by external and internal forces. A common focus in biomechanics is musculoskeletal effects of forces (external and internal) (Fig. 9.4). The load can damage joints as well as muscles and tendons – particularly during sports performance without adequate preparation. A force, which is not necessarily too large to cause damage to tissues such as muscles and tendons in the thigh and shoulder, may cause damage if it is repeated over a long period of time or too intensively for a short time. A large force, on the other hand, acting on the whole body for a short time, such as 'the push off' in high jump, or a discus throw usually affect a larger number of tissues such as tendons, bones, cartilage and ligaments of the upper and lower extremities.

The body can be regarded as a chain of several 'links'/joints, where a motion or force around a joint is transferred to adjacent joints. A weak or tight 'link' in such a system therefore affects the whole movement design and hence athletic performance.[1]

Tip

Consideration for the biomechanical effects should be included in forming an individual exercise program.

Figure 9.4 Biomechanics of the knee. Measurement of the strain on the anterior cruciate ligament (ACL) during different functions. **a)** Walking up a staircase; **b)** a lunge; **c)** walking down a staircase. (From Anette Heijne's PhD thesis 2007, Karolinska Institutet, Stockholm, Sweden, with permission.)

Range of motion

Joint range of motion (ROM) is limited by the joint surfaces, ligaments, joint capsule and surrounding muscles and tendon length and extensibility. The ligaments and joint capsules are relatively inelastic and contribute to the passive (mechanical) stability, while the muscles and tendons control the active (functional) stability of the joint.

Muscle, tendon and ligament contain fibers with collagen content. A tendon consists of, for example, 90% collagenous fibers and 10% elastic fibers. The collagen fibers run a parallel course in the tendon, the tendon attachment and the transition between the muscle and tendon. At rest there is no tension in these fibers, but during a muscle contraction they are stretched and stressed. Collagen tissue may be elastic (stretchable) or plastic (moldable) and has a high viscosity (inertia). The fact that the collagen tissue is both viscous and elastic means that the speed that the tissue receives a load is substantial. The faster a tendon is loaded, the stiffer and less plastic it gets, while its elastic and plastic properties are enhanced during a slower load.

The collagen fibers in a tendon must be stretched for at least 6 seconds to affect the plasticity. At 36°C or just above normal body temperature the elasticity and plasticity of the collagen fibers are increased. For that reason, it is important that a thorough and gentle warm up is done prior to ROM and flexibility training (Fig. 9.5). Application of heat locally and subsequent slow elongation to pain threshold results in an elongation of collagen fibers of the tendon to the maximum length. Stretching should be performed within 15–20 minutes after the local heat treatment, otherwise the heating effect is lost.

Figure 9.5 Active flexibility exercise of the hamstrings during concurrent static trunk activation. (Photo, Frohm/Heijne.)

Full, pain-free ROM is the goal of all rehabilitation programs. However, this need not be achieved completely before strengthening exercises are initiated as long as the exercises are pain-free. ROM exercises can be facilitated by the use of thermotherapy to limit pain and increase blood flow to the area, resulting in increased tissue extensibility. At the same time the joints are 'lubricated' and the cartilage nutrition exchange is improved.

These exercises may be done passively, actively unloaded or actively. Passive ROM exercises allow for early motion without the use of contractile tissues. Often in the early stages of rehabilitation, passive motion is indicated to allow for adequate tissue healing; active motion may be painful. Active ROM exercises require muscular action for movement to occur. This is the method of choice as rehabilitation progresses and muscle activity is safe.

Tip

The aim of ROM training is primarily to increase mobility in a joint, while stretching is to increase mobility around a joint.

Stretching

The ability to move a joint painlessly through its full ROM, is an important goal of rehabilitation. Flexibility is believed to contribute to fluidity of movement patterns. Most agree that adequate flexibility is necessary for good performance and injury prevention, although this is based primarily on observation rather than research. Modern research suggests that stretching can have a negative impact on running economy in long distance running. Stretching should aim to increase the range of motion of the muscle, tendon, fascia and joint.

Tip

A specific flexibility training should target mainly shortened muscles to maintain or increase joint ROM.

This includes: 1) static stretching; 2) exercises for proprioceptive neuromuscular facilitation techniques (PNF); and 3) ballistic stretching.

Static stretching is an extremely effective and popular technique (Fig. 9.6). This method involves passively stretching a muscle and holding it in its extended position for a period of 10–60 seconds (most often 20 seconds). Passive stretching is a form of static stretching, when an external force is put on the limb to move it into a new position. Passive stretching can be achieved with the help of an assistant (partner), stretch bands or other mechanical devices.

Tip

Stretching with a partner requires that the partner is well educated and is careful with the load he/she puts on the joint.

Static stretching is probably safer than ballistic stretching because the extensibility limits of involved muscles are less likely to be inadvertently exceeded. Training with static stretching should be an integral part of the rehabilitation program following an injury. In most cases, it can begin soon after the injury occurs, although in cases of muscle or tendon rupture, it should be postponed until a physician gives approval.

Generally, static stretching can start when there is no local tenderness in the injured area and when static muscle contractions can be performed without pain. However, static stretching can be used to evaluate the progress of healing in an injured muscle or tendon by using the level of pain as a measure of the state of the healing process. Yoga is a great exercise form to increase the flexibility. In yoga breathing is emphasized to achieve a good effect of stretching.

PNF is a technique for use with flexibility exercises, involving a combination of alternating isometric and isotonic contractions and subsequent relaxation of both the agonist and antagonist muscle groups. The exercises are often performed with a partner, and can consist of 10 seconds of contraction followed by 10 seconds of relaxation and stretching.

Ballistic stretching involves repetitive, small-amplitude bouncing motions. It is generally accepted as less safe because of the quick stretches and somewhat uncontrolled forces within the muscle, which may exceed the limits of the muscle fiber. However, used correctly, it can be effective, for example as a part of the end of a warming-up session in football/soccer to prepare the joint and muscles for fast changes in direction and reduction of antagonistic activation. It is not used much during rehabilitation.

Figure 9.6 Examples of static stretching. (Photo, Frohm/Heijne.)

During any flexibility exercise, the involved muscles should be warm and stretched slowly and controlled to the point of slight resistance or tightness. In order to improve flexibility, each exercise should be performed daily, for five or six repetitions held for a minimum of 20 seconds. Stretching should be included as part of a warm up to prepare muscles for activity. Stretching after activity may prevent some muscle soreness and help increase flexibility by stretching loose, warm muscles.

Tip

Summary of recent findings about stretching:

- During passive static stretching exercises the mechanical properties of muscle and tendons are affected, but these mechanical effects disappear quickly, i.e. within minutes.
- Stretching improves the maximum ROM as it gives a greater tolerance for the stretching exercise in question rather than a change in the mechanical properties of the muscle–tendon unit.
- According to current research stretching before exercise does not significantly reduce the risk of injury.
- Regular stretching can improve muscle strength and jumping ability but does not affect running economy.

Movement analysis

Research has shown that impaired neuromuscular control and strength can increase the risk for acute injuries and it is speculated that a non-functional movement pattern may predispose to injury.

In sports there are both traumatic (acute and chronic) and overuse injury. A number of studies demonstrate that impaired neuromuscular control, such as impaired balance and strength, can increase the risk of acute overuse injury. Reduced mobility, anatomical asymmetry and limited trunk stability may also increase the risk of chronic overuse injury.

Physical therapists who work with athletes often meet athletes with muscle and/or joint dysfunction. Specific functional movement analysis can then be performed, such as the Swedish National Sports Confederation movement analysis 'Bosöns 9+ screening battery' (Fig. 9.7). The purpose of such an analysis is to identify pain and the origin of dysfunction in order to correct and normalize movement impairments with active movement training. The analysis is performed on both the left and right body half.

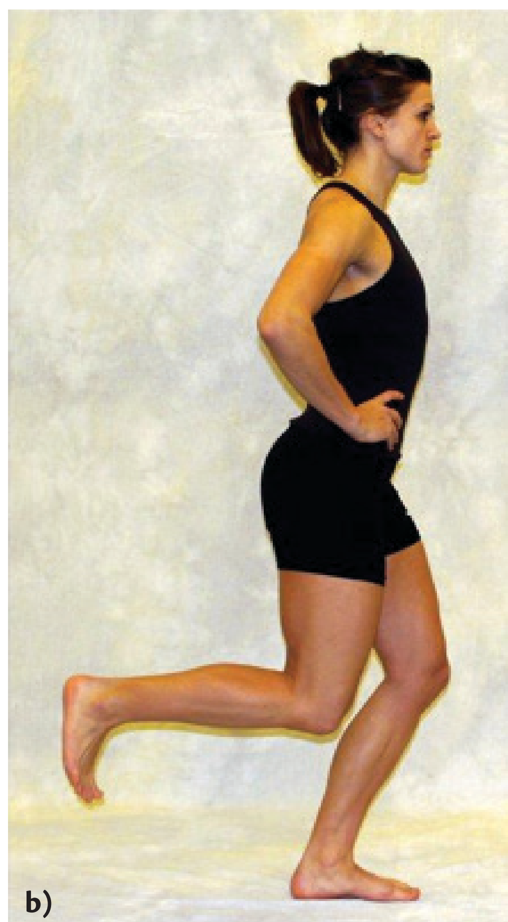

Figure 9.7 a–i) The Swedish National Sports Confederation test battery: 'Bosöns 9+ screening battery'. Deep squats, Single leg squats, lunges, hip flexion, straight leg raises, push-up test, diagonal lift, sitting rotation, shoulder mobility. (With permission, Frohm *et al.*[2])

A test battery like this is easy to use and requires minimal testing equipment. Continued research is however needed to study the significance of the tests for injury incidence prevention, rehabilitation and performance development.

Strength

Strength is the ability of a muscle to generate force against some resistance. The development of muscle strength is an essential component of any rehabilitation program. Muscle weakness or imbalance can result in abnormal movement or impaired performance. Physiologic improvements occur only when an individual physically demands more of their tissues than is normally required – the 'overload principle'. Another principle to consider when weight training is the so-called 'specificity principle', i.e. 'you become better at what you practice'. This applies to the muscle that is activated at the speed and the joint angles that the training is geared to achieving.

The muscles and tendons must be stressed above the normal load in order to effectively increase their performance and strength. Progressive resistive exercise (PRE) is the most common strength training technique used for reconditioning the muscle after injury. It is important to allow the overloaded tissue adequate time to recover.

Muscle contraction is the basis for all movement and exercise. There are three kinds of muscle work:

- Isometric (or static) work involves contraction without a change in the length of the muscle (for example, holding a weight stationary in an outstretched hand).
- Concentric work implies the muscles contract and shorten in length simultaneously so that their attachments are drawn closer together (for example, the contraction of quadriceps muscles when climbing stairs).
- Eccentric work implies that the muscles contract and lengthen simultaneously so their attachments are drawn apart (for example, the action of the quadriceps muscles when walking downstairs).

During activity that involves changes from eccentric to concentric muscular work, or vice versa, there is a risk of tearing a muscle or tendon.

Tip

Concentric work mainly accelerates a moving object, eccentric work decelerates it. Injuries often occur during deceleration.

Muscle training after injury

Muscle strength is proportional to the cross-sectional area of the muscle (i.e. to the diameter and number of muscle fibers). The larger the cross-sectional area, the greater the force that the muscle can generate. The muscle can also develop more power the more synchronized the muscle cells are; this is known as neural adaptation. The degree of force generated varies inversely to the speed at which the muscle contracts. Maximum force is generated by isometric contractions, i.e. contraction without a change in the length of the muscle in which a large number of motor units are used. The faster a muscle contracts, the less force it can generate, as fewer motor units are used.

Strength training increases the strength not only of the muscles but also of their attachments. The strength of tendons, ligaments, and the skeleton does not increase as quickly as that of the muscles since their metabolism is slower, and this fact should be borne in mind when training growing individuals. During rehabilitation after injury, strength training should be carried out to the pain threshold. In order to shorten recovery time, training of muscles in the injured area can begin along the following lines.

Static (isometric) exercise

After many joint and muscle injuries, isometric training can start immediately (Fig. 9.8). For best results the muscle contractions should be as strong as the pain allows. A slow isometric contraction increases the load on the injured tissue gradually, with no movement of the joint or limb where the contraction occurs. It is then easier to avoid exceeding the pain threshold and the strength limit.

The training starts with relatively few muscle contractions per day and increases gradually. Rest should be taken between successive isometric muscle contractions so that the lactic acid formed in the tissue can be dissipated. If possible, a physical therapist should check constantly that no further problems develop as a result of the training. If there are no other medical or structural contraindications, once isometric training can be carried out without pain, supervised dynamic training can start. Training of this type is suitable for the extensors and flexors of the knee joint, for example.

Tip

Increase in number of muscle contractions/repetitions should always precede increases in load.

Dynamic training

After possible bandaging has been removed and medical permission has been given to move the joint, dynamic training can start, at first using only body weight or the weight of the limb as the load. Subsequently the load can be increased gradually by the addition of external resistance such as weights (isotonic training) (Fig. 9.9).

Figure 9.8 a–e) Strength training can be done in different forms, one called 'complex five', meaning a kinetic chain of different functional motions. It should be started without weights, then increased with low weights followed by gradually increasing load. (Photos Frohm/Heijne.)

Muscle activity always causes an increase in joint load. In dynamic training with weights (isotonic training) maximum loading of a joint can only be achieved during part of the ROM. This leads to the risk of overloading the joint at its weaker points. This risk is much reduced in isokinetic training, although this requires the use of special apparatus.

Isokinetic training involves working at a constant speed, usually expressed in degrees/second. The speed is determined by the therapist or trainer. The resistance throughout the ROM is determined by the effort of the person being treated. This makes it possible to train at the maximum level of pain-free resistance at all points in the motion. The risk of overloading injured tissues is limited to the extent that the person training is able to keep their effort level beneath their pain level (Fig. 9.10).

Figure 9.9 Strength training of the muscles of the knee using machines can be effective. **a)** Strength training of the hamstrings; **b)** strength training of the quadriceps. (Photos, Frohm/Heijne.)

Tip

Dynamic training should start with a low load, and in the early stages, the training program should be expanded by increasing the frequency of the exercise rather than the load.

This enables the stamina and the blood flow of the muscle to improve before it is stressed further. When load is increased, it is important to remember that the force to which a joint is subjected can be great. Placing a weight over the ankle joint during training of the knee, for example, increases the load on the knee joint by 10 times.

The overload principle should be, successively, taken into account, i.e. progressively increasing the external load and reduce the number of repetitions.

Dynamic training has a limited effect on the isometric strength of a muscle, except when it is carried out at low speed, in which case it resembles static training. Similarly, static training has only a limited effect on the dynamic strength of a muscle. In other words, all training should be relevant and designed specifically to work on those elements used in the sport in question.

Summary

To sum up, isometric (static) training is used particularly in the early stages of rehabilitation of muscle–tendon injuries or when an injured limb is immobilized. Dynamic isotonic training is used in the later stages of rehabilitation but can also be used to increase and maintain a certain level of strength in preventive training of some risk areas. Dynamic isokinetic training is less arduous since, by choosing a higher speed of motion, provision can be made for reducing resistance at

Figure 9.10 Isokinetic strength test of the quadriceps and hamstring muscle. (Photo, Anna Frohm.)

Figure 9.11 Eccentric high load (eccentric overload) training in a specially designed heavy weight training piece of equipment. (Photo Anna Frohm.)

any points that are painful in one range. In addition, isokinetics induce a marked increase in strength, whether performed at high speed or at low speed with maximum resistance. Training with a variable but not adjustable resistance allows particular muscle groups to be isolated for individual training and facilitates eccentric muscular work and mobility training (Fig. 9.11).

After an initial period of rehabilitation the pain limit can be exceeded during the final few contractions in the exercise program in order to increase the pain threshold.

Tip

It is important to consider the following points before commencing strength training after an injury:

- All strength training should begin with warm-up exercises.
- All training should begin without load and should not exceed the pain threshold.
- There should be a gradual increase in load but it is better to increase the number of repetitions with one load before proceeding to greater loads.
- Asymmetrical exercises should usually be avoided.
- Rest and recovery are important in all types of strength training.
- Strength training should be combined with flexibility training.
- At the end of rehabilitation the strength training should be as sport-specific as possible.

Open and closed kinetic chain exercises

An injury and subsequent disuse has negative effects upon the proprioceptive sense (for a description of proprioception see p. 506) in the joints, tendons and skeletal muscle. Different types of exercise should be used in order to re-establish normal strength and proprioceptive function. Two of these types of exercise are known as open and closed kinetic chain exercises (Fig. 9.12).

Open kinetic chain (OKC) exercises are those involving a fixed proximal body segment and a distal segment that exerts effort through a relatively free ROM. Examples of OKC include overhead pressing or seated throwing exercises for the upper body, and the seated knee extension or cable pulls for the lower extremity. OKC exercises can produce great gains in peak force production, but some of the most commonly used open chain exercises are limited to single joint or single plane motions. This can limit the extent to which they resemble useful, functional activities, and thus reduce their ability to improve proprioceptive ability along with strength.

Closed kinetic chain (CKC) exercises involve a fixed distal segment and a relatively free proximal segment. Examples of CKC exercises include pull-ups and push-ups for the upper body and squats and lunges for the lower body. These exercises commonly use the subject's body weight to create some or all of the resistance, and involve movement of the subject's body in relation to a fixed hand or foot position. Closed chain exercises commonly involve multiple joint segments moving through multiple

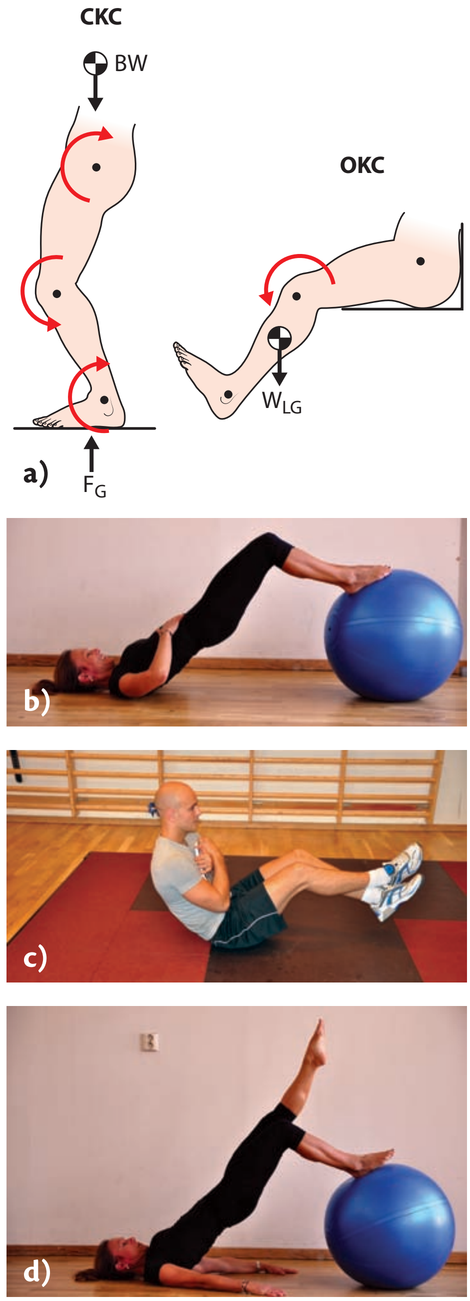

Figure 9.12 Closed and open kinetic chain exercises. **a)** Closed kinetic chain (CKC) and open kinetic chain (OKC); **b)** in CKC the distal segment, e.g. the foot, is fixed with a relatively free proximal segment; **c)** in OKC the distal segment, e.g. the foot, is not fixed but has a relatively free proximal segment; **d)** A closed chain exercise with a movable distal segment. (Photos, Heijne/Frohm.)

simultaneous arcs of motion. Most CKC exercises are weight bearing and stimulate at least some level of agonist/antagonist co-contraction. Both these factors contribute to a reduction in joint shear forces, increased proprioceptive activity in joints and tendons and improved postural and stabilization mechanics.

Tip

In conclusion, CKC exercises are therefore considered to be more gentle and thereby less likely to cause further damage to injured muscles and joints and should be used initially in the rehabilitation. After a period of time they should be combined with OKC exercises.

To reach full effect, however, CKC exercises often need to be combined with OKC exercises.

OKC and CKC exercises can both play an important role in the process of rebuilding strength, proprioception and functional ability.

Stability

Stability training can be defined as training in which the internal, local muscles are trained, i.e. the small muscles surrounding the joints that stabilize the joint and bone (single joint muscle). The intrinsic muscles do not fatigue as quickly and contribute to postural stability. If these muscles are poorly trained or inhibited due to pain, the outer muscles will take over (multi-joint muscle). These muscles are not as durable, which results in a faulty loading of the body and thus fatigue and pain. The superficial muscles contribute substantially to the distal activity (activity in the arms and legs). It is therefore important that the different muscles are trained correctly to get a deep, close to the joint, stability and distal mobility through interaction. Joint stability is provided by the resistance given by the musculoskeletal tissues surrounding a joint. Good stability protects distal joints (Fig. 9.13).

Good stability is characterized by the ability to control the position and activity of the core over the pelvis, which generates optimal power transmission and activity from the vertebral segments in the athletic body. Core muscle activity is the ability to connect single joint muscles with multi-joint muscles to create stability and fluid movement.

Different areas of stabilization

The muscle power is transmitted from the core to the upper and lower extremities. Core muscles are activated before the limbs are initiated. The central nervous system creates a stable base by co-contraction of muscles.

a)

b)

c)

Figure 9.13 Shoulder and core postural stability is important in most sports. **a)** Shoulder stability training with a springing stick; **b)** core stability exercises on an exercise ball (Bobath ball) (photos, Frohm/Heijne); **c)** an effective tennis serve requires good core strength and core stability (with permission, by Bildbyrån, Sweden).

The core muscles

The stabilizing muscles of the core are primarily local, i.e. multifidus, transverse abdominis and the internal oblique muscles. Thoracic longus, rectus abdominis and the external obliques are the global muscles that contribute to core stabilization. Lumbar spine and hip muscles such as the psoas, gluteus medius and maximus muscles also help in stabilizing the core (Figs 9.14–9.16).

Upper extremity

The base for good stability in the body, besides the trunk, is the scapula and the muscles attached to the scapula. Lower, middle and upper trapezius muscles as well as the anterior serratus muscle should be strengthened. The rotator cuff (shoulder blade muscles) is important for the shoulder stability. Mobility and strength of the various muscles are important (Fig. 9.17).

Lower extremity

Foot and knee stability is important to avoid knee injuries such as ACL injuries. Properly performed single leg squats with foot–knee–hip aligned and training on unstable surfaces help to improve the stability of the lower extremity. Strength and mobility in the quadriceps muscles, with its four heads, are important.

Figure 9.14 Core stability training lying on the back. **a–c)** Supine core stability training under simultaneous shift of center of gravity (moving arms and legs); **d)** with an exercise ball. (Photos Frohm/Heijne.)

Figure 9.15 Core stability training lying on the side. **a)** Trunk stability training, step 1. **b)** trunk stability training, step 2; **c)** trunk stability training, with simultaneous shoulder stability training, step 3. (Photos, Frohm/Heijne.)

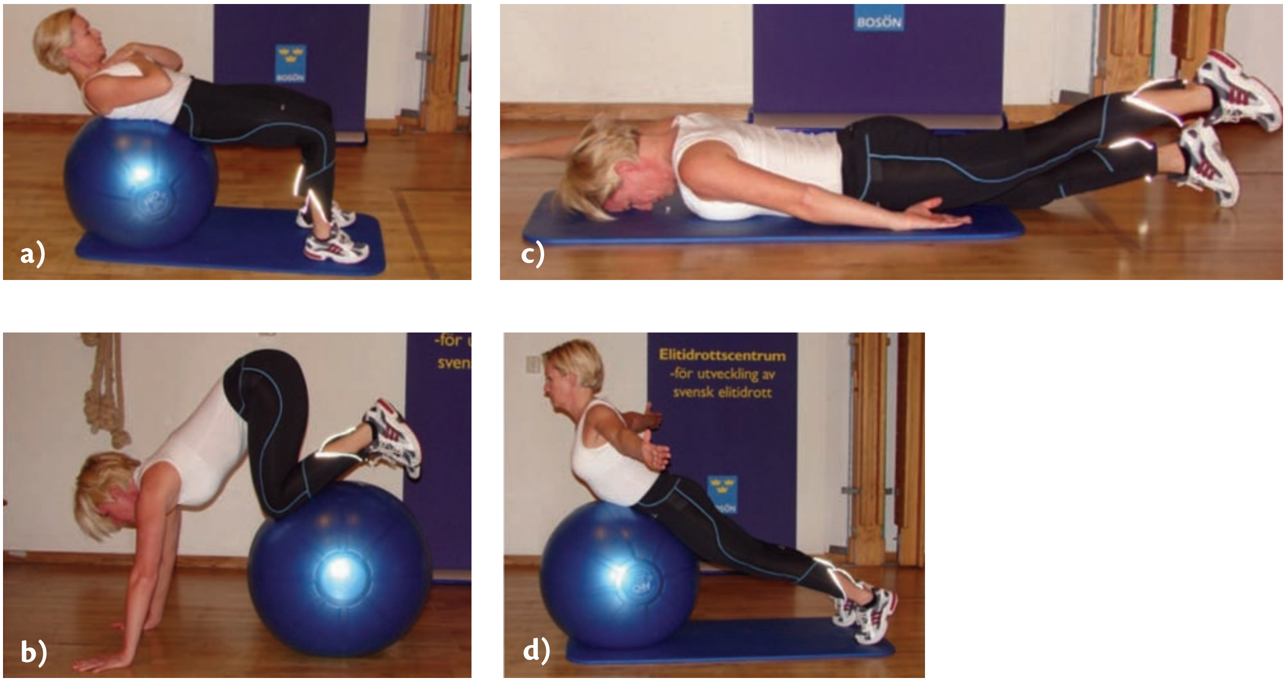

Figure 9.16 Examples of stability training on an exercise ball (Bobath ball, physioball, pilates ball, medical ball). (**a–d**) photos, Frohm/Heijne; **e)** with permission, by Tommy Eriksson, Swedish Athletic Association.)

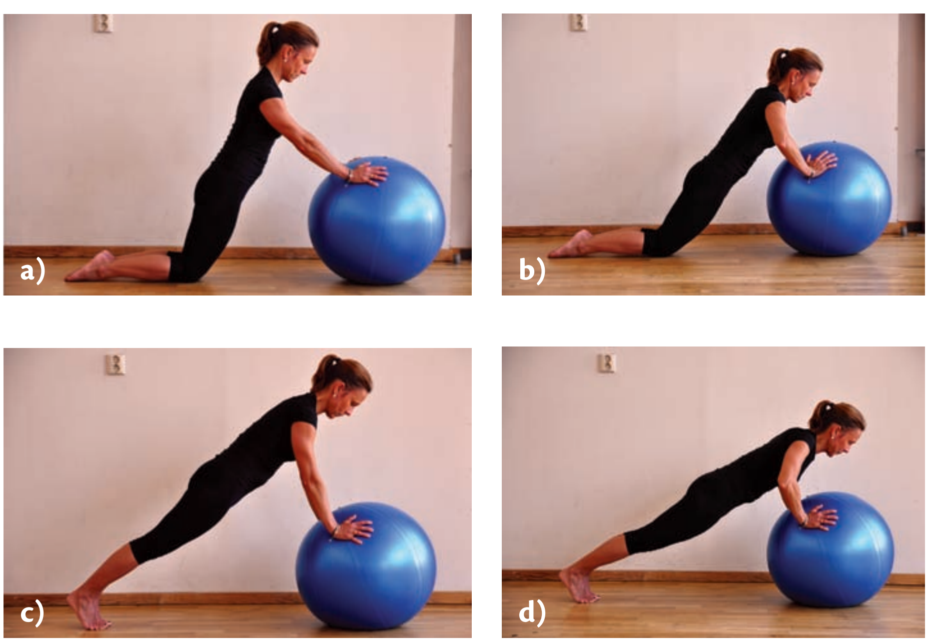

Figure 9.17 **a)** Training of shoulder stability with an exercise ball; **b, c)** training of shoulder stability with push-up; **d)** training of shoulder stability with increased difficulty. (Photos, Frohm/Heijne.)

Tip

The stabilization training should be conducted according to the following recommendations:

- Train in an upright position because stability is usually required in such a position during sports, often while the limbs are moving.
- Strength and stability is required in all directions and should therefore be trained in such a way.
- It is important that deep stability is adequate before the exercises become more complex and heavier.
- The quality of the movement during stability training is essential for this type of exercise/rehabilitation to take full effect.
- Stability training should be initiated in a rehabilitation program at a very early stage.

Power – explosive maximum strength

The ability to develop maximum strength in a short time, i.e. power (explosive maximum strength) is an important characteristic for most athletes. Power training should therefore be included in any rehabilitation program during the final stages of rehabilitation when good strength, stability, flexibility and balance are achieved. An athlete can be very strong without being able to develop power in a short time. There are different weight training methods to achieve maximum power such as heavy weight training, explosive strength training, ballistic training and agility training. Best results are achieved if all methods are used in combination (Fig. 9.18).

Figure 9.18 There are different strength training techniques to improve explosive strength including functional strength training of the lower extremities. **a, b)** lifting weights as training of explosive strength (power) with knee bends; **c)** lunge with a weight on right leg in front; then do 'scissor jumps' (jump switching the position of the legs, moving the front leg to rear and vice versa); when landing adopt the lunge position ; **d)** jumps on one leg with external load; **e)** core and back training (photos, Anna Frohm); **f)** jump rope training is generally effective and develops explosive strength in top athletes (with permission, by Bildbyrån).

Power training should be performed under controlled forms because the tissues are usually subjected to very high loads. The training is carried out usually at loads that are about 20–60% of the maximum weight that the athlete can lift one time (1 repetition maximum) but during high speed. Power training can to some extent be replaced by very heavy weight lifting at slow speeds, which is important to consider in some situations. Power training can, in some cases, be comparable to plyometric training.

Plyometrics

Success in most sports is dependent upon technical skill, speed, muscular strength and power, and a series of coordinated activities that are linked together to make up the sport. While conditioning and weight training can produce gains in strength and endurance, speed and coordinated movements need specialized training techniques. A form of training that attempts to combine speed of movement and neuromuscular coordination with strength is called 'plyometrics' (Fig. 9.19).

Plyometrics heightens the excitability of the nervous system by engaging the inherent stretch–shortening cycle of skeletal muscle. Through a rapid initial eccentric stretch of a muscle, tension is produced prior to initiating an explosive concentric contraction of the same muscle. This mechanism releases the pre-stretch energy in an equal and opposite reaction, producing a powerful response of the contracting muscle.

Picture an athlete about to perform a standing broad jump. As a final step before jumping, the legs are bent at the knees and hips providing an eccentric stretch of the quadriceps. Then as the athlete recoils, a quick concentric contraction occurs in the same group of muscles to provide the power necessary to propel the athlete forward. In contrast, consider the same athlete performing the jump without the initial recoil or stretch of the quadriceps, and note the difference in length of the jump.

After an injury, this neuromuscular pathway is weakened from disuse. Retraining this mechanism is important for safe and successful return to sports. Caution should be used in plyometric programs as they are intense, explosive, and stressful to the tissues involved. It is necessary that the athlete participating in this type of program has normal ROM and flexibility of the affected part, and near-normal strength and be in phase with the healing process. The program should include a progressive approach, beginning with small movements on the spot, working up to jumping and bouncing of high amplitude, including sport-specific drills. Recovery time between sessions of plyometric training should be 3–5 days to allow for muscle recovery.

Tip

It is important to stress that this is an end-stage rehabilitation activity, since it requires good strength and produces high explosive force.

Neuromuscular electrical stimulation

NMES is a well-established clinical physical therapy treatment in Sports Medicine rehabilitation. NMES may be useful early after injury or surgery to limit the

Figure 9.19 Plyometric training in the form of counter movement jump from plinth. **a)** Preparing for landing on the right leg; **b)** landing on the right leg; **c)** landing with both legs. (Photos, Frohm/Heijne.)

inevitable loss of muscle volume (hypotrophy) and to improve muscle function. The method has also been proven to be useful for increasing muscle strength and muscle volume in healthy subjects. After an injury it has been seen that it is primarily the fast-twitch fibers (type II) that loose power and can be helped by using electrical stimulation, compared with exercise without electrical stimulation. A relatively strong stimulation should be used to get maximum effect of NMES, which in some cases can cause pain both during activation and to provide muscle soreness after the first few times. It is therefore important that it is used under the supervision of a physical therapist. The method should be seen as a complement to other physical therapy treatments and should be used at a later stage of rehabilitation combined with active exercise for mobility, strength, coordination and functional training (Fig. 9.20).

Proprioception and coordination

Proprioceptors are specialized sensory receptors located in tendons, joints, muscles and ligaments, which are sensitive to stretch, tension and pressure. These receptors detect changes in position and movement, and send immediate feedback to allow the athlete to modify the movement to prevent injury. Injury and subsequent immobilization or disuse alter the function of these proprioceptors, resulting in decreased reaction time, increased balance deficits, and slower motor control. This cycle may increase the risk of re-injury.

Coordination and proprioception are intricately linked. Movement requires muscular interaction to execute particular tasks utilizing this proprioceptive feedback. Injuries affect this timing, rhythm and judgment for specific skills.

A comprehensive rehabilitation program must include the re-training of these proprioceptors. Activities should begin with balancing on a balance board, e.g. wobble board with a fulcrum of 360° and a bipolar rocker board, or walking heel to toe with eyes closed, progressing to sport-specific tasks such as running in zigzag patterns, backwards, and in figures of eight (Figs 9.21, 9.22). Intensity levels should increase as the athlete is able to complete each skill efficiently and without pain. Additional agility and coordination skills may be added through the use of sports equipment such as a ball – throwing, catching, kicking, etc. Once the athlete can complete these tasks and demonstrate pain-free, smooth, fluid, controlled movements, then a return to sports may be considered.

Figure 9.20 Neuromuscular electrical stimulation of anterior inner thigh muscle (vastus medialis). (Photo, Frohm/Heijne.)

Tip

Proprioceptive training is one of the most important parts of the rehabilitation.

Cardiovascular endurance

Cardiovascular endurance is a necessary component of fitness that must not be ignored during the rehabilitation process. Also commonly referred to as aerobic capacity, cardiovascular endurance is defined as the body's ability to sustain submaximal exercise over an extended period. This capacity depends largely on the efficiency of the pulmonary and cardiovascular systems. Detraining of this system begins quickly, usually within 1–2 weeks of cessation of training.

It is important that during the rehabilitation process aerobic exercise is begun as quickly as is safely possible to prevent detraining. Athletes with upper extremity injuries can often ride a stationary bicycle comfortably in the early stages of recovery. Lower extremity injuries can present a more difficult challenge, but there are many non-weight bearing endurance activities that may be safe early on. Swimming, stationary cycling and even rowing may be included in a program.

Figure 9.21 Balance training carried out in different ways. a, b) Balance training on unstable surface during simultaneous shift of the center of gravity (photos, Frohm/Heijne); c) individually adjusted balance training (with permission, by Tommy Eriksson, Swedish Athletic Association).

Figure 9.22 Running on a thick mat. (Photo, Anette Heijne.)

Tip

In order to maintain cardiovascular fitness it is recommended, that the work-outs be scheduled 3–5 times per week for 20–30 minutes at 70–90% of the athlete's maximum heart rate.

Sport-specific skill conditioning

Sport-specific demands must be incorporated into all rehabilitation programs. Each sport imposes specific requirements on the athlete. A functional progression is a sequence or succession of activities including adaptation of activities and early specific 'cross-over training' simulating actual sports skills, enabling the athlete to re-establish gradually the skills necessary to perform the sport safely and effectively. These functional exercises allow for sequential improvement in strength, endurance, mobility, coordination and agility. This step in the rehabilitation process is essential in easing the athlete's anxiety and apprehension about returning to sports after injury.

Return to sports and then gradual return to competition and full activity

The ultimate decision as to whether an athlete is ready and fit to resume sports activities lies with the caregiver, but is influenced by many people around the athlete such as his/her coach, family and managers. Healing of the injury should, if possible, be verified by objective clinical examination techniques, such as ultrasound, MRI, etc. to secure a safe return and reduce the risk of re-injury.

Tip

Criteria for a safe return include full, pain-free range of motion; normal and equal strength bilaterally; and ability to meet the demands of the sport without intermission, pain, or swelling.

Sports-specific tests should be carried out before a return to sports. These tests should be stable over time, to ensure that the athlete's test results do not depend on chance. Several different tests are described, e.g. by the American College of Sports Medicine (ACSM). Usually, the athlete is allowed to return to sports if his or her physical capacity is 90% or more compared with the healthy side (regarding the extremities). It is under discussion, however, whether for example, strength, should be 100% or more compared with the healthy side, when research has noted that even the healthy half of the body loses both functionality and power after an injury and prolonged rehabilitation. A normal and functional activation pattern is at least as important when returning to sports after injury. Although not all injuries can be prevented, a well-conditioned, fit athlete has less risk of re-injury.

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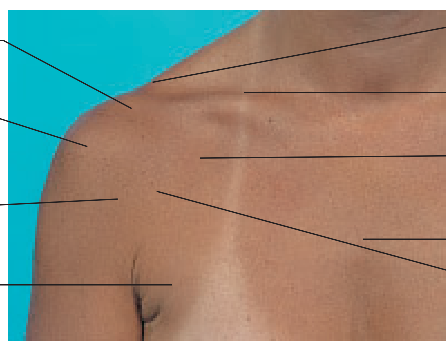
10

Shoulder Injuries in Sports

Shoulder injuries are present in 30% of the athletes during their athletic careers. Subacromial impingement syndrome and rotator cuff tendinopathy were the most common shoulder injuries for the different sports and accounted in one study for 27% and 24% of the total shoulder injuries respectively (Figs 10.1–10.3).[1]

This study furthermore showed that incidence rates for college athletes in baseball was highest for subacromial impingement; in softball subacromial impingement and rotator cuff tendinopathy; in swimmers subacromial impingement, rotator cuff and biceps tendinopathy; and in tennis players subacromial impingement and rotator cuff tendinopathy.

Pain in the shoulders is common, especially in overhead activities, but also in the rest of the population. The prevalence (the proportion of a population that has



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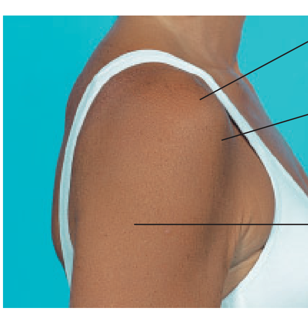

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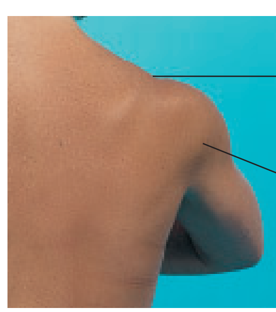


10.3

Figures 10.1–10.3 Overview of injury locations in the shoulder.

the condition at a specific time) of shoulder problems is 15–25% of the 40–60-year-old population in Stockholm, Sweden. The number of shoulder surgeries in Sweden since 1998 has increased annually by 10% to around 6,500 elective procedures in 2004.[2]

Shoulder injuries are common in throwing sports and in sports such as baseball and tennis. Today, about half of all injuries are located to the upper extremities. There are fewer injuries in younger athletes. Most acute injuries still occur in the lower extremities, while the most common serious chronic injuries occur in the upper extremities.

Baseball has been reported to have an injury incidence of 3.61 per 1000 athlete exposures.[3] Muscle and tendon strains were the most common injury type in 30–35% of cases. Pitching in baseball was the most common mechanism in shoulder injuries during training. 10% of these injuries, in particular in pitchers, needed surgery.

The injury incidence in handball is estimated at 2.5 injuries per 1000 playing hours, with a significantly higher incidence during games (14.3 injuries per 1000 playing hours). Upper extremities were injured in 37% of all injuries. One-third of the injuries occurred during an offensive counter attack (Fig. 10.4).

In a study of elite male handball players the average prevalence of shoulder problems throughout the season was 28% and the prevalence of substantial shoulder problems, defined as those leading to moderate or severe reductions in handball participation, performance or to time loss, was 12%.[4] Reduced glenohumeral rotation,

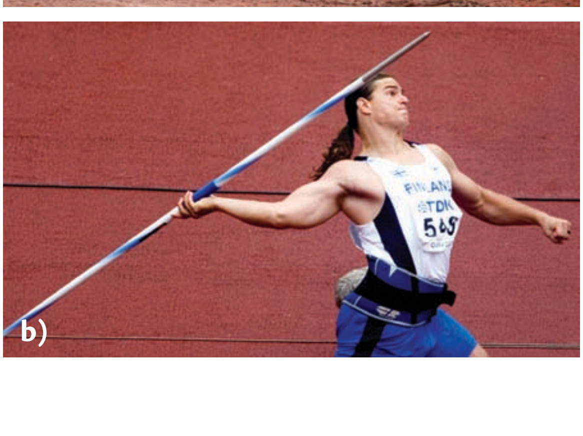


Figure 10.4 a–c) Shoulder problems are common in sports such as baseball, javelin and handball. (With permission, by Bildbyrån, Sweden.)

external rotation weakness and scapular dyskinesis are risk factors for shoulder injuries. In handball partial rotator cuff ruptures and osteo-chondral (bone–cartilage) injuries to the upper arm's (humerus) head were typical injuries. The symptoms correlated quite poorly with findings on magnetic resonance imaging (MRI), which shows that the first priority should be to trust the findings of a good clinical examination, including well-conducted clinical tests.

Maladaptation of the shoulder tissues is found in 60–86% of tennis players. Decreased internal rotation of the shoulder starts a series of biomechanical changes, which leads to injuries of the shoulder and elbow (Fig. 10.5). This reduction of internal rotation of the dominant shoulder in tennis players is combined with an increase in the external rotation of the same side. Limited and reduced internal rotation in the dominant shoulder results in a tight posterior capsule, which causes a forced displacement of the joint head forward in the shoulder joint.

Increased external rotation can cause stretching of the front and the front/lower capsular structures, anterior instability and internal impingement. The shoulder's increased tightness may be a factor for other injuries in the musculoskeletal system.

Tip

A thorough clinical examination, including well-conducted clinical tests, is still the safest way to ensure a correct diagnosis. An MRI examination can verify this.

The shoulder is exposed in the elite tennis player, because today the serve is the dominant type of tennis stroke. 45% of the strokes in the French Open, and 60% in Wimbledon is the serve. 50% of the total energy and power of the serve is developed in the legs, hip and trunk. The shoulder contributes 13% to the total energy and 21% to the total force.

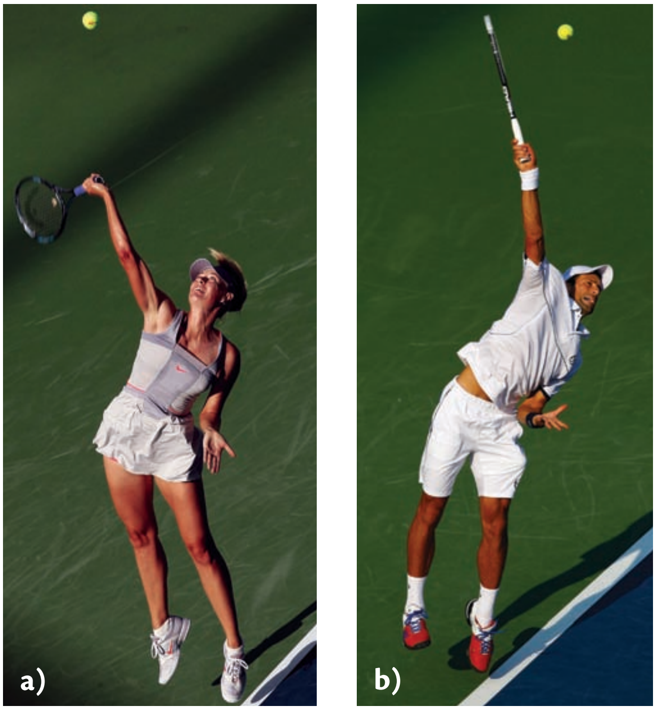


Figure 10.5 a, b) A tennis serve requires the use of the entire kinetic chain to be effective. (With permission, by Bildbyrån, Sweden.)

Functional anatomy of the shoulder region

The range of motion (ROM) in the shoulder region (Fig. 10.6) is determined by the interaction of multiple joints: the shoulder joint (glenohumeral joint), the joint between the sternum and clavicle (sternoclavicular joint), the joint between the acromion on the shoulder blade and clavicle (acromioclavicular joint) and the pseudo-joint between the shoulder blade (scapula) and thorax (scapulothoracic joint).

The glenohumeral joint is the main shoulder joint, comprising the head (ball) of the humerus and the glenoid (socket) of the scapula (shoulder blade). The head is covered with cartilage and is facing laterally and anteriorly. The surrounding capsule is loosely applied and allows a wide range of movements. The articular surface of the socket is enhanced by the glenoid labrum, which is an extension of the joint that increases its stability.

The sternoclavicular joint is the joint between the clavicle (collar bone) and the sternum (breast bone). The joint is surrounded by the joint capsule and strong ligaments.

The acromioclavicular joint is the joint between the clavicle and the scapula. The clavicle is a rather flattened and elongated S-shaped bone and is connected by strong ligaments to the scapula.

The scapulothoracic joint is a pseudojoint (it acts like a joint) where the scapula moves against the thoracic wall rib cage).

The total ROM of the shoulder is extensive because the shoulder joint itself has a shallow socket and a loose capsule. The arm is allowed to move from 0° to 180° of elevation and for approximately 150° of internal and external rotation. Anterior and posterior rotation in the horizontal plane is about 170°. Twenty-six muscles are required to control the various joints for optimal shoulder function.

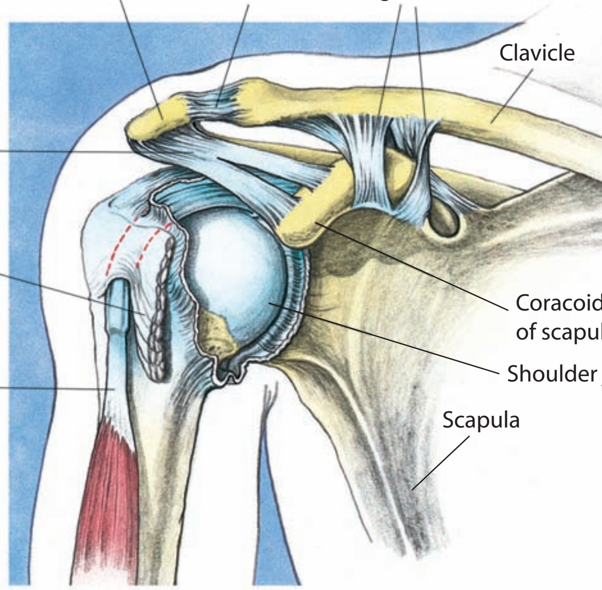


Figure 10.6 Anatomical overview of the shoulder region.

Stability of the shoulder region

The shoulder is a lax joint with great mobility. The ligaments and joint capsule represent the static stability while the four shoulder muscles and tendons in the rotator cuff account for the active dynamic stability.

Static stability

The shoulder does have some static stability from capsular ligaments, the articular components, negative intra-articular pressure and the glenoid labrum.

The capsular ligamentous complex consists of the superior, middle, anterior and posterior inferior glenohumeral ligaments, as well as the coracohumeral ligaments.

- The superior glenohumeral ligament is present in approximately 90% of shoulders. It originates on the glenoid (shoulder socket) anterior to the tendon of the long head of the biceps and courses inferior and lateral to insert on to the lesser tuberosity, which is located on the lateral aspect of the humerus. This ligament resists inferior translation of the humeral head with the humerus at the side of the body.
- The middle glenohumeral ligament is present in 70% of shoulders and courses from the labrum to insert medially to the lesser tuberosity under the subscapularis tendon. This ligament protects against instability by acting as a secondary restraint to anterior translation. The inferior glenohumeral ligament is present in 90% of shoulders, and consists of an anterior and a posterior band. The origin is on the inferior half of the glenoid labrum and the insertion is on the humerus. This ligament provides most of the stability, especially when the shoulder is abducted (moved out from the body) and externally rotated.
- The coracohumeral ligament originates from the coracoid process, blends into the capsule and attaches onto the humerus. This ligament is put in tension in external rotation and resists inferior subluxation to the joint.

The effects of articular geometry are limited. The concavity of the glenoid, however, when combined with a compressive force, does provide significant stability of the humeral head.

The negative intra-articular pressure at rest is –4 mmHg (0.5 kPa). A 52% increase in the humeral head translation (anterior–posterior motion) after incision of the capsule has been documented.

The stability of the glenohumeral joint is enhanced by the glenoid labrum, which is a fibrous structure that forms a ring around the periphery of the glenoid and provides an anchor point on the glenoid for the capsular ligaments (Fig. 10.7). The labrum attaches to the glenoid articular surface. It contributes to glenohumeral stability by increasing the depth of the glenoid socket. Loss of the glenoid labrum decreases the depth of the socket by 50% in either direction. The labrum also contributes to stability by increasing the surface area of the glenoid and acting as a load-bearing structure for the humeral head. The labrum is consistently attached tightly to the glenoid articular cartilage below the equator, and, therefore, detachment in this area is more likely to represent instability.

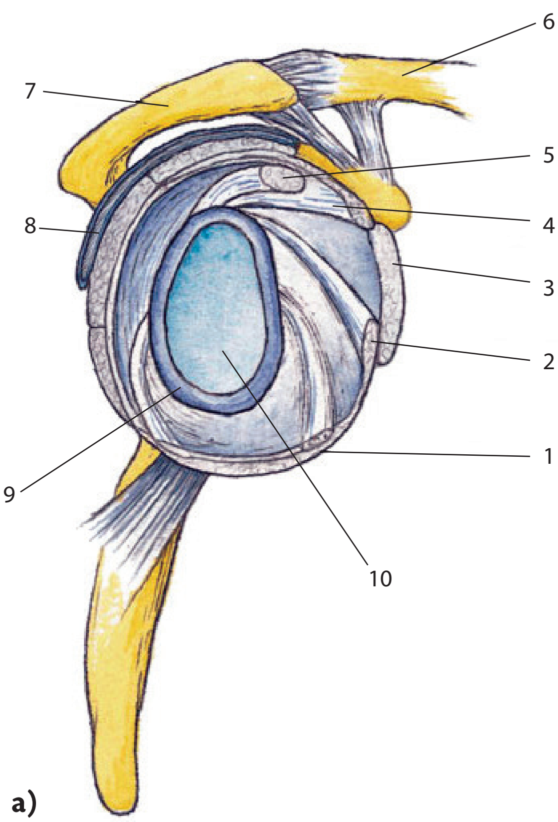


Figure 10.7 The anatomic construction of the shoulder. **a)** The ligament complex of the shoulder. 1. Inferior glenohumeral ligament 2. Middle glenohumeral ligament 3. Subscapularis tendon 4. Superior glenohumeral ligament 5. Biceps tendon 6. Clavicle 7. Acromion 8. Subacromial bursa 9. Labrum 10. Glenoid (shoulder cavity on the scapula/shoulder blade); **b)** good shoulder muscles are important for a gymnast (with permission, by Bildbyrån, Sweden).

The *rotator interval* is the triangular region between the anterior border of the supraspinatus tendon and the upper border of the subscapularis tendon. An injury to the capsular structures in the rotator interval area of shoulder may result in instability.

Dynamic stability

Dynamic stability is provided by the muscles around the shoulders. The rotator cuff is the key to dynamic glenohumeral stability. The supraspinatus muscle tendon plays a major stabilizing role, as exemplified by the throwing movement (p. 97); peak supraspinatus activity occurs during late cocking when the arm is already abducted and is most susceptible to subluxation. The supraspinatus contributes to stability by drawing the humeral head toward the glenoid.

The infraspinatus and teres minor muscles are activated after the supraspinatus and they externally rotate the humerus in addition to stabilizing the shoulder by joint compression. The peak activity is shown to be in late cocking and follow-through phases of the throwing motion.

The subscapularis muscle is active during the late cocking phase of throwing to protect the anterior shoulder structures. Thereafter, it functions as an internal rotator during acceleration and follow-through.

The long head of the biceps tendon is activated during shoulder flexion and abduction. It acts as a humeral head depressor. The pectoralis major and latissimus dorsi muscles are internal rotators of the glenohumeral joint. The trapezius muscles act as an important scapular stabilizer and also decelerate scapular protraction during follow-through.

The deltoid muscle functions in three sections. The middle deltoid participates in all arm activities. The anterior deltoid acts in flexion and is assisted by the pectoralis major and biceps. The posterior deltoid provides extension of the arm.

Investigation of the shoulder

History

Thorough history-taking is the key to correct diagnosis. This involves asking the correct questions and – more importantly – giving the athlete adequate time to answer. The physician must listen carefully to the answers and also watch the patient during the interview to obtain clues through body language. The primary questions should focus on the following areas.

What happened? This is particularly important in acute traumatic injuries. If the athlete can recreate the mechanism of injury, a general biomechanical analysis can indicate which tissues were abnormally stressed. The more detail that the athlete can recall, the better the cause and mechanism of the injury can be recreated to point to the injured structure (Fig. 10.8).

Where does it hurt? The best way to approach this is to have the injured athlete place one finger on the most painful area. Sometimes this can be difficult because the pain may be deep and/or diffuse.

Figure 10.8 a–c) Injury mechanisms. What happened? The physician can generate lots of information from a well-described injury mechanism. (With permission, by Bildbyrån, Sweden.)

What is the nature of the pain? Burning pain that radiates down the extremity can indicate nerve pain. Throbbing pain can indicate pain of vascular origin. Pain of brief duration that disappears quickly can indicate possible mechanical problems from tissues rubbing or locking together. Dull, aching pain is more likely to be caused by chronic overuse problems.

What makes it better or worse? Activities that can change the course of the pain can give clues to the diagnosis. For example, stress fractures will become worse with prolonged activity, and injuries that respond well to anti-inflammatory medications are probably due to inflammatory processes.

Has the athlete been injured before? Often injuries are recurrences of previous problems, or can be related to changes in training habits from previous injury.

What treatments have been used, and did they help? Perhaps the treatment has exacerbated the injury rather than relieved it.

What other health problems are present, and what medications are used? Many musculoskeletal problems are due to disease and not injury. Many times these diseases will have other associated problems that the patient believes are unrelated to the musculoskeletal injury. Finally, all medicines have side-effects, which can sometimes affect the musculoskeletal system.

Physical examination

Tip

The history should direct the physician towards tests that may confirm the diagnosis. A good, accurate history-taking will secure the correct diagnosis in at least 80% of cases.

Both shoulders should be exposed for comparison. Reduced ROM, muscle hypotrophy, bone deformity and shoulder asymmetry should be looked for. A prominent scapular spine suggests rotator cuff hypotrophy, which may indicate a rotator cuff tear or a suprascapular nerve lesion. Deltoid hypotrophy can be noted in association with axillary nerve lesions or fracture.

ROM testing

ROM should be examined in both the upright and the supine positions. The examination includes assessment of total range and rhythm of motion, as well as pain at the limits of motion. To determine total active elevation, the arm is observed from the side, and the angle between the arm and the chest is measured. Evaluation of external and internal rotation is important (Fig. 10.9). It is important when measuring glenohumeral joint internal and external rotation ROM that the examiner stabilizes the scapula to ensure that compensatory motion does not hide true losses in either internal or external rotation. Scapular stabilization can be achieved by simply placing the examiner's hand over the shoulder.

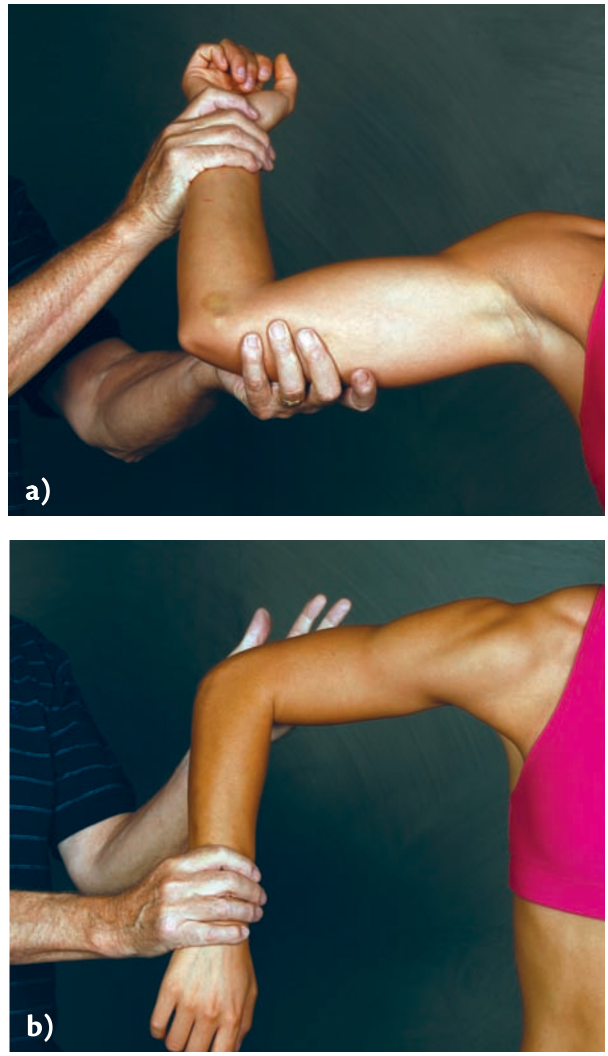


Figure 10.9 The range of motion of the shoulder is tested. **a)** External rotation; **b)** internal rotation.

Abduction (moving the arm from the body) can give useful information relating to impingement and strength. Pain between 80° and 120° of abduction is a reliable indicator of tendinopathy due to impingement. This is called the 'painful arc' (Fig. 10.10).

Strength testing

The strength of forward flexion, abduction, adduction, and external and internal rotation should be documented (Fig. 10.11).

The strength is decreased in abduction and external rotation when there is rotator cuff disease. Specific testing of the supraspinatus is performed by abducting the athlete's arm to 90°, then forward flexing 20°, and maximal rotation of the arm internally into the

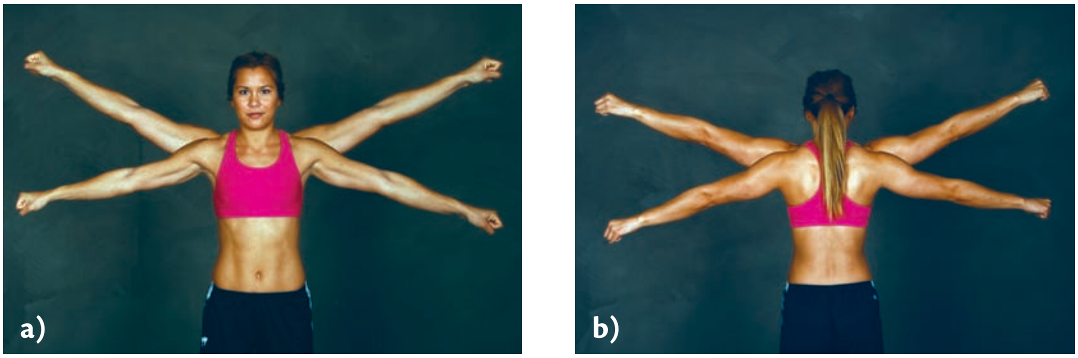


Figure 10.10 The 'painful arc', i.e. painful range of motion from 60° to 120° motion in abduction (outward movement from the body). **a)** Seen from anterior; **b)** seen from posterior.

Figure 10.11 The muscle strength in abduction (the arm is moved externally) can be tested in several situations. **a)** Abduction against resistance with the arm in internal rotation; **b)** abduction with the arm in external rotation.

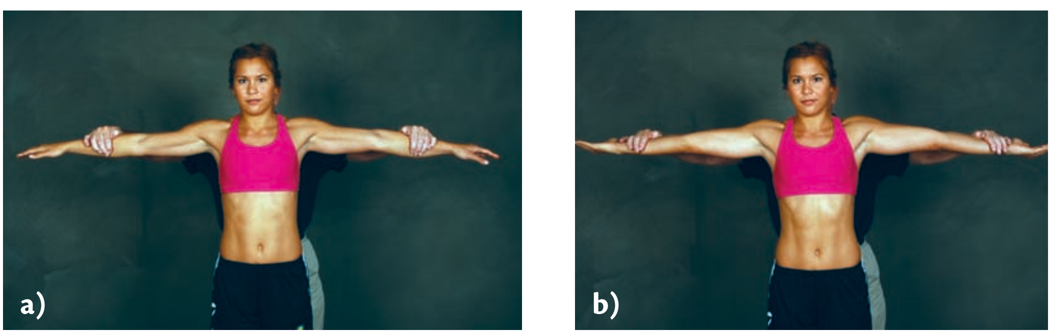


Figure 10.12 Testing of the muscle strength of the supraspinatus muscle and a small part of the middle portion of the deltoid. **a)** With the arm in internal rotation; **b)** with the arm in external rotation.

thumb-down position (Fig. 10.12). Muscle strength in this position is a test of the supraspinatus and a small portion of the central deltoid. This is an important test, since rotator cuff tears usually involve the supraspinatus.

The muscles providing external rotation are the infraspinatus and teres minor. External rotation (strength) is assessed with the arms at the side in a neutral position; resistance is applied and compared with the opposite side. Internal rotation strength is a test of subscapularis strength (Fig. 10.13).

Stability testing

Tip

It is important to distinguish between laxity (hypermobility) and instability.

Shoulder laxity refers to when the humeral head can be displaced relative to the socket (glenoid) without showing any clinical symptoms or cause pathological changes.

Laxity

Laxity is related to the clinical examination. This means that the shoulder joint usually is lax (sagging/hypermobile) without being unstable. Hyperlaxity that gives clinical symptoms and is associated with pathological changes can lead to instability.

Instability

Instability is related to the athlete's subjective symptoms and their experience, or to spontaneous subluxation of the shoulder at specific movements. Instability in the shoulder region is usually a long-lasting and recurring

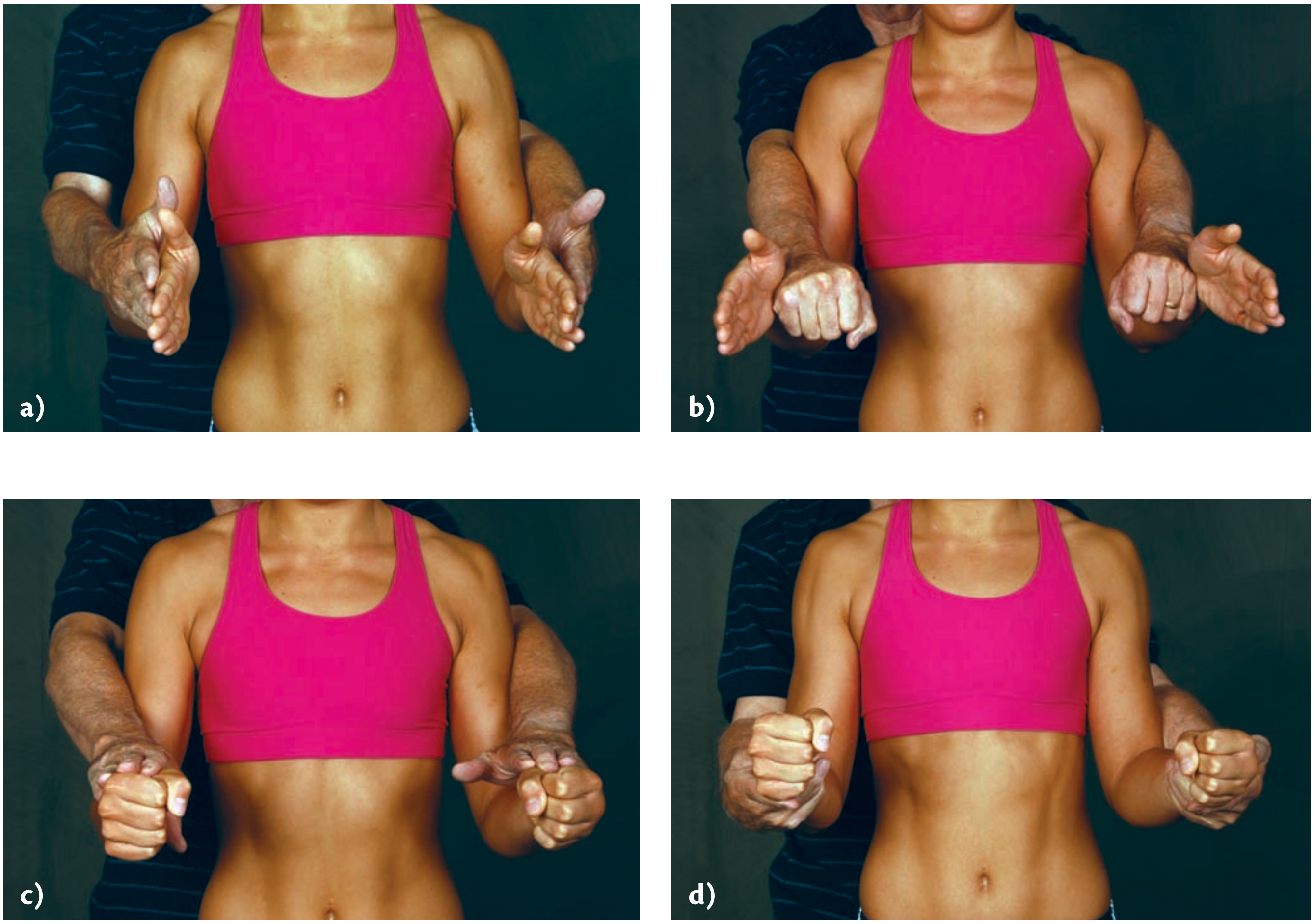


Figure 10.13 Testing muscle strength in the shoulder and elbow. **a)** Testing strength in external rotation; **b)** in internal rotation; **c)** upward flexion in the elbow; **d)** downward flexion–extension of the elbow.

condition. Instability of the shoulder is either forward and downward, backward and downward, backward or in several directions.

The degree of instability may also vary from complete dislocation to partial dislocation (subluxation).

Laxity and instability are diagnosed through various shoulder tests

Drawer test for increased laxity and instability

The *anterior drawer test* is performed with the athlete in a sitting position (Fig. 10.14). The athlete should sit leaning slightly forward with both arms hanging. The examiner holds the athlete's shoulder with one hand while the other hand grasps around the head of the upper arm and pulls it back and forth to detect abnormal movement.

The *posterior drawer test* is performed with the athlete supine (see Fig. 10.14; same technique but the drawer is directed posteriorly). No special degree of translation indicates if it is abnormal, but a difference between the two sides is considered a positive drawer test.

Sulcus sign for general laxity

This test measures the laxity/instability in a downward or inferior direction (Fig. 10.15). The shoulder is held in 0° abduction, neutral rotation and neutral flexion/extension. The examiner pulls the arm down. If a groove in the skin (sulcus) arises between the humeral head and the lateral acromion, the test is positive. Sulcus sign is graded:

- Grade 1: if the distance between the acromion and the upper arm bone (the acromio-humeral range) increases up to 1 cm.
- Grade 2: is an increase of between 1 and 2 cm.
- Grade 3: increase is greater than 2 cm.

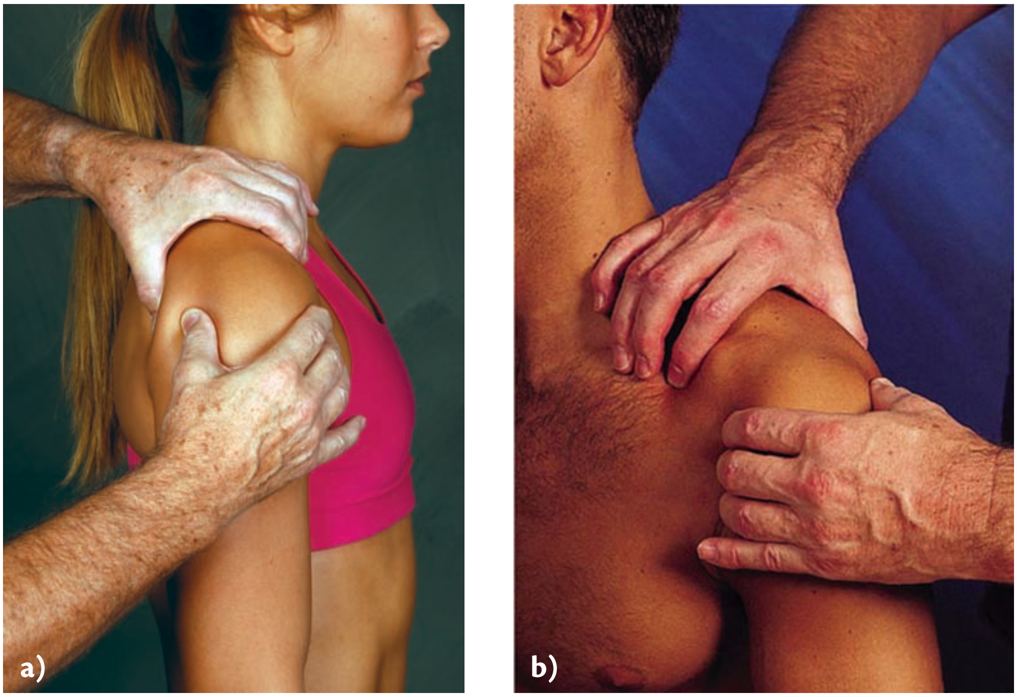


Figure 10.14 Anterior drawer test to test increased laxity and instability. **a)** Seen from the side; **b)** seen from an oblique-anterior view.

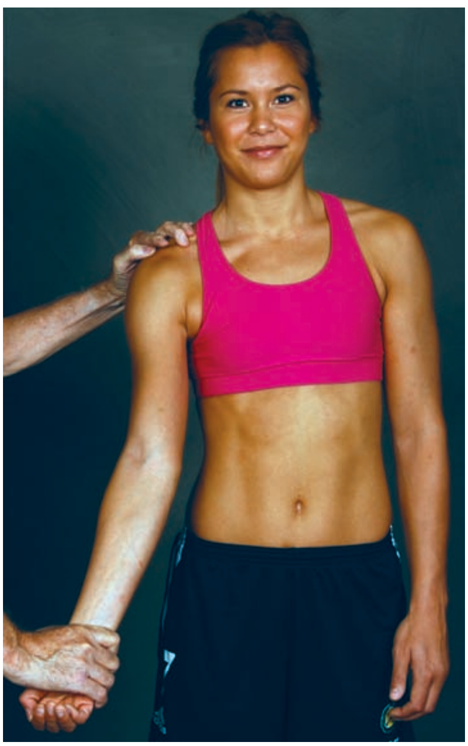


Figure 10.15 Sulcus test is a test for the 'sulcus sign', which can be a sign of general laxity.

The sulcus sign shows pathological deviations if it is more than grade 2. In normal shoulders a normal displacement of 1 cm can occur if the arm is pulled down. The sulcus width may be clinically difficult to assess.

Stability testing under anesthesia

The laxity instability can be evaluated in several directions with the arm in different rotational positions and may facilitate the discovery of abnormal laxity, i.e. instability. Asymmetry in the testing of shoulder laxity need not mean that instability is present.

Diagnosis of shoulder instability

Diagnosis of instability is enhanced by the following shoulder tests:

- Apprehension test of instability: this test examines anterior shoulder instability (Fig. 10.16). The arm is forced in abduction and external rotation. The test can be performed in the upright or the supine position.
- The relocation test combined with the apprehension test (Jobe's test) for anterior instability (Fig. 10.17).

Stability assessments can be carried out with the athlete in the supine or seated position. The shoulder is positioned in the scapular plane with neutral rotation maintained. Anterior and posterior forces are applied to the proximal humerus and the amount of translation is graded (the drawer test) (see Fig. 10.14):

- Grade 1: the examiner can translate the humeral head further in an anterior or posterior direction, compared with the contralateral shoulder.
- Grade 2: the examiner can subluxate the humeral head over the glenoid rim, but the humeral head spontaneously returns to a neutral position when the applied force is withdrawn.
- Grade 3: the examiner can lock the humeral head over the glenoid rim.

For anterior stability, grade 1 or greater is pathological. For posterior instability, only a grade 3 examination is

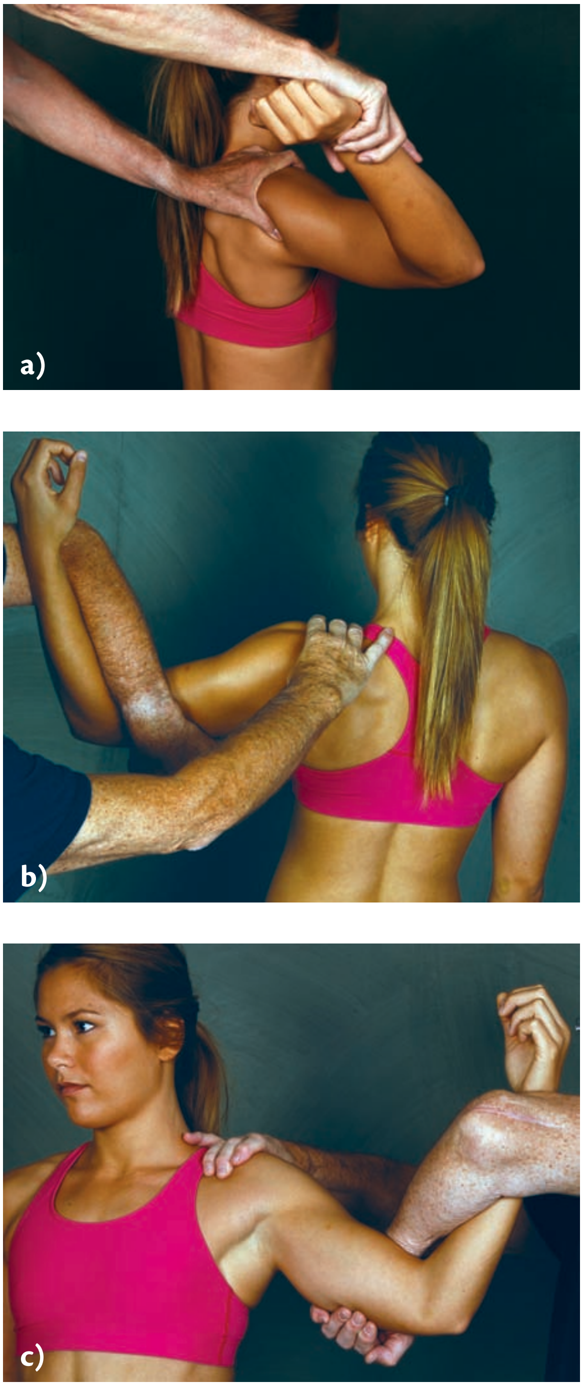


Figure 10.16 Apprehension test examines the instability in the anterior part of the shoulder. This test can be performed in different ways. **a)** Classic way: the examiner raises the arm to 90° of abduction (with the elbow flexed 90°). The right hand of the examiner is placed over the humeral head with the thumb pushing from the posterior aspect of the humeral head for extra leverage. With increasing external rotation and gentle forward pressure against the humeral head, an impending feeling of anterior instability may be produced. Note that if there is a pronounced shoulder instability it can dislocate forward; **b, c)** modification as the external rotation is controlled by the grip around the elbow.

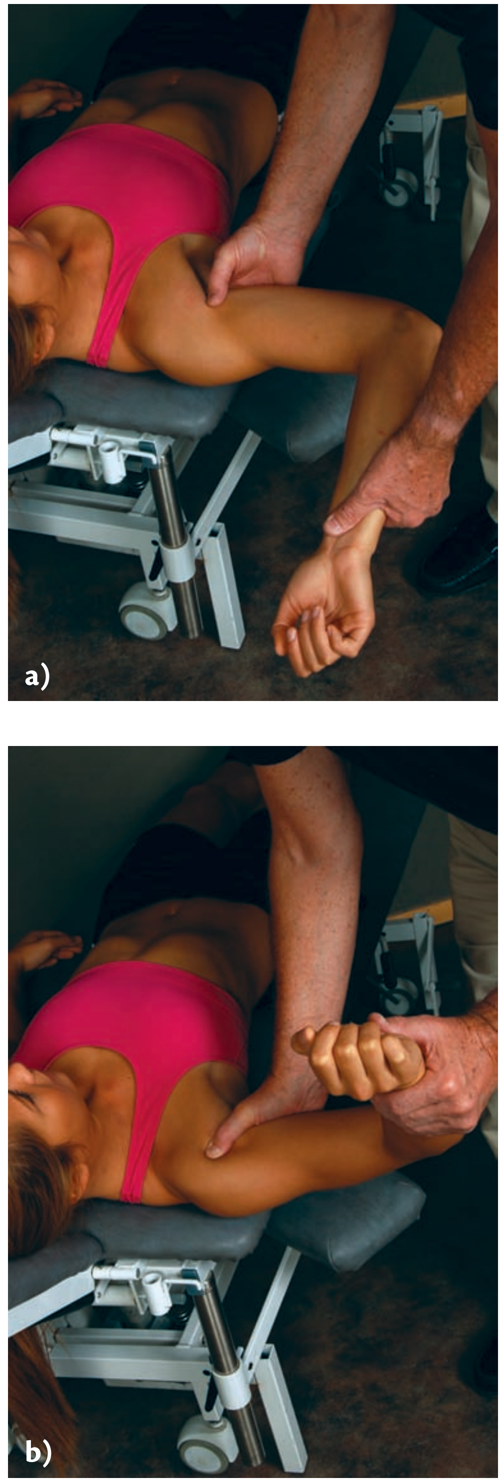


Figure 10.17 Relocation test in combination with the apprehension test ('Jobe's test') is used to test for anterior instability. This test is performed in patients with a positive apprehension sign and suggests the finding of instability. **a)** The examiner places the arm in 90° of abduction and end range external rotation to cause apprehension; **b)** pressure is then placed on the anterior humeral head to push it posteriorly and 'relocate' the glenoid. Immediate relief of pain is considered a positive result.

pathological, as many normal shoulders can be subluxated up to 50% out of the joint posteriorly.

Score system

These are increasingly being used to evaluate athletes with instability. The scoring system is an excellent complement to the objective tests because the injured person can report how they feel after their injury. These provide a good basis for an overall assessment so that the physician can make sound clinical decisions. There are several good scoring systems, but the two now recommended to evaluate shoulder instability are:

- The Western Ontario Shoulder Instability Index (WOSI).[5]
- The Melbourne Instability Shoulder Score (MISS) meets the criteria that it should be simple and effective, completed by the athlete himself, could be used for publication and is weighted towards functional outcome results.[6]

Radiographic evaluation

An *X-ray examination* reveals skeletal changes along the anterior edge of the joint socket and fractures. An MRI (Fig. 10.18) or preferably an MR arthrogram may show a labral tear, intra-articular changes and the redundant capsule. This test is excellent but expensive.

Computed tomography (CT) may be of value to quantify the capsule and bone injuries before possible surgery.

Arthroscopy and examination under anesthesia will confirm the diagnosis.

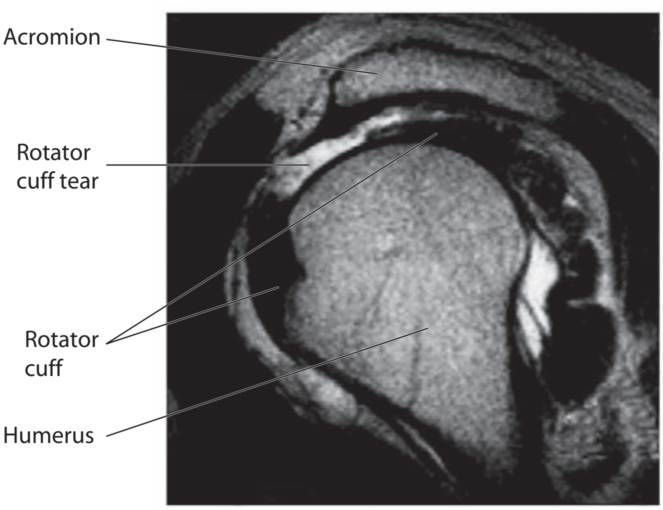


Figure 10.18 Magnetic resonance imaging (MRI) of the shoulder can be of great value to secure the correct diagnoses. MRI with contrast injected into the joint, i.e. MR arthrogram.

Injuries and disorders related to acute and chronic shoulder instability

Dislocation of the shoulder joint

Dislocation of the shoulder joint is a relatively common injury in sports such as ice hockey, team handball, American football, rugby, riding, alpine skiing, skating and wrestling. 8% of the male hockey players active in the Swedish top divisions has had his shoulder dislocated. In Sweden there are more than 3,000 first time shoulder dislocations per year. Shoulder dislocations are three times more common in men 20–30 years old, than in persons aged over 30 years. The male to female ratio for primary dislocation is 9:1.

Injury mechanism

When falling, it is instinctive to lift the arm and turn it outwards to protect the body. Dislocation can occur when the arm, held in this position, receives the impact of the fall. The joint can also be dislocated by falling directly on the lateral aspect of the shoulder or by a violent collision with another player. This injury can also occur when the arm is caught by another player and pulled vigorously outwards and backwards (Fig. 10.19).

Types of dislocation

- Anterior dislocation (diverted forward and downward) is most common and has a tendency to recur in young, active people.
- Posterior dislocation (backward) is unusual; the injury is commonly missed, and needs special attention. It can be difficult to diagnose and treat.

Pathology

Complete dislocations of the shoulder are characterized by lesions of the labrum, capsule, muscles and/or bone (Fig. 10.20). The labrum can be avulsed from the rim; this is called the Bankart lesion and is the most common cause of recurrent dislocation (Fig. 10.20C, D).

A Bankart lesion is today accepted as the typical injury after a shoulder dislocation. This injury is an injury to the anterior (inferior) labrum, which may be avulsed from the bone by its capsular attachment. It is uncertain whether the labral injury itself causes instability.

A dislocation of the shoulder may include varying degrees of rupture or stretching of the capsule off the

Figure 10.19 A fall against the shoulder can result in a shoulder dislocation. **a)** A fall against hard floors, e.g. in indoor volleyball, can cause troublesome shoulder injuries; **b)** a fall against the shoulder in beach volleyball usually has a smaller risk for injury. (With permission, by Bildbyrån, Sweden.)

glenoid. Labral ruptures or ruptures of the capsule off the humeral head occur occasionally. Excessive laxity of the capsule can follow repeated injury. There are no major muscular lesions associated with dislocations.

A bony lesion is produced by the impaction or compression of the posterior humeral head against the anterior rim of the glenoid at the time of the dislocation. This is called the Hill–Sachs (Hermodson) lesion of the humeral head, and is most commonly associated with recurrent dislocation (Fig. 10.21).

Symptoms and diagnosis

- Excruciating pain is felt at the time of injury and as long as the joint is dislocated.
- Lack of mobility; the arm hangs loosely beside the body.
- The upper part of the humerus can be felt as a lump in the armpit, and, where it is normally located, an empty joint socket can be felt.
- The outline (contour) of the injured shoulder looks uneven in comparison with the rounded outline of the undamaged shoulder.
- The diagnosis can be verified by X-ray. A posterior dislocation often requires an X-ray examination using special techniques.

Treatment

The injured athlete should be taken to a physician for immediate treatment. As a rule, the earlier the joint is reduced, the fewer the complications and the shorter the healing period. It is more considerate to manipulate the joint back into position after the patient is anesthetized.

Before the joint is drawn in position, the neurological and vascular function in the arm should be examined and the joint X-rayed, as there can be fractures and vascular and nerve damage present simultaneously. The joint can also sometimes be X-rayed afterwards to check that the joint is securely in the right position. After manipulation, the arm is immobilized against the body in order to reduce pain and to allow the joint capsule and ligaments to heal. The time of immobilization is controversial. A combination of some immobilization and early ROM training can be recommended in most cases. There is no rule on how long the joint should be fixed. For older athletes, it is advisable that the arm is fixed for 1–2 weeks, provided that the bandage is removed at regular intervals so that the ROM can be trained.

The period in a bandage or sling may be extended for the young athlete in whom the danger of redislocation is high, especially if this is a first dislocation. In recurrent dislocations, an early, thorough muscle strength training program can be initiated. After the bandage has been removed, the injured person should train the ROM with, for example, pendulum exercises (see p. 250, p. 255 Table 10.2).

In very active athletes with a first-time dislocation, acute arthroscopy can be of value with debridement and/or stabilization of the labral lesion. This acute treatment is becoming more and more common, as it seems to decrease the recurrence rate in athletes aged 16–25 years, which is currently more than 85%.

Healing and complications

If there are no complications, a dislocated shoulder heals well. Light conditioning and gentle exercise can be resumed after 2–4 weeks.

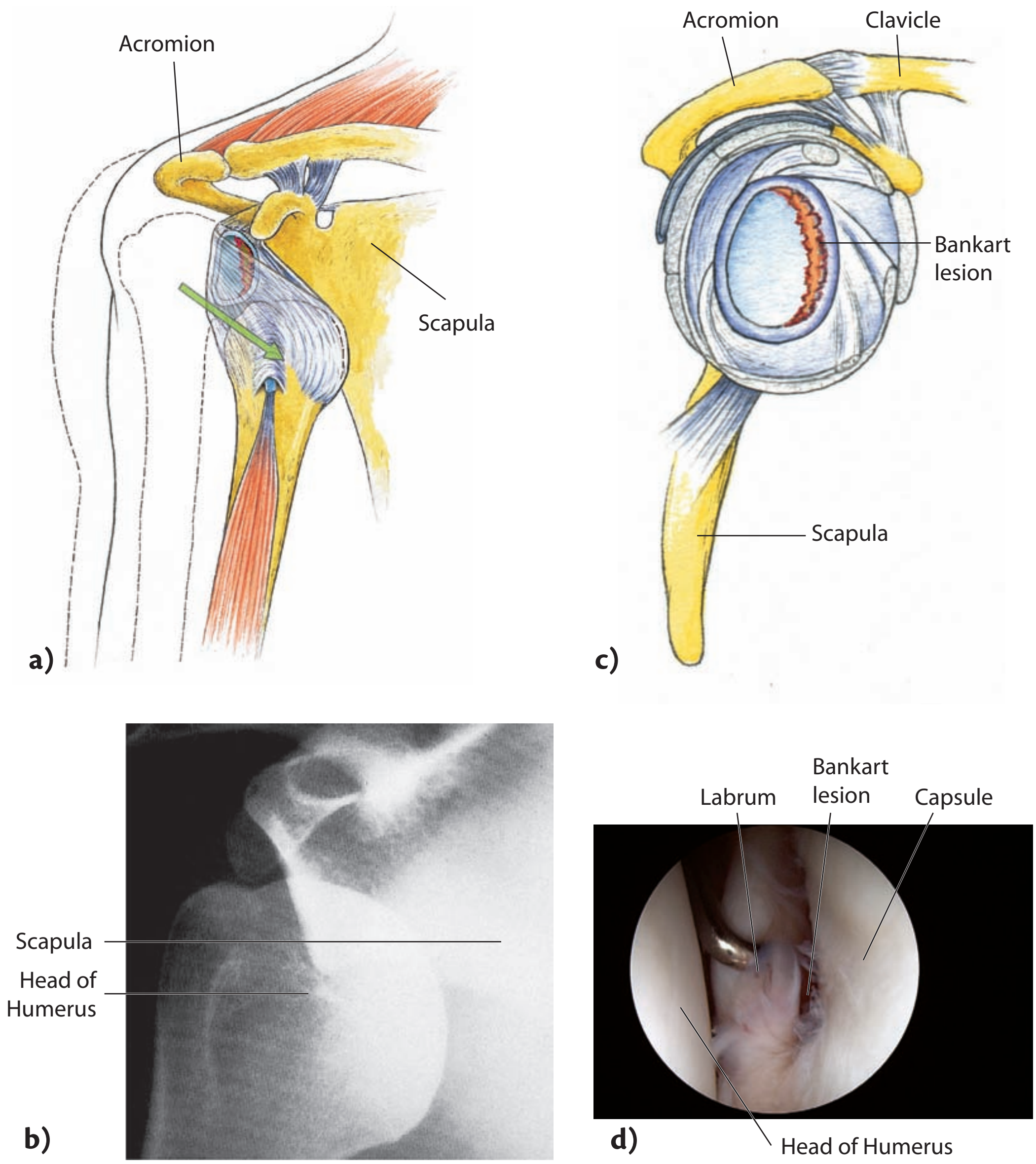


Figure 10.20
a) Dislocation of the shoulder anterior – downward; **b)** X-ray showing anterior – inferior dislocation; **c)** Bankart lesion in the shoulder joint (the labrum is torn from the anterior rim of the joint; **d)** Bankart lesion seen at arthroscopy. Arrows show lesion. (Courtesy of Prof. Marc Safran, Stanford University, California, USA.)

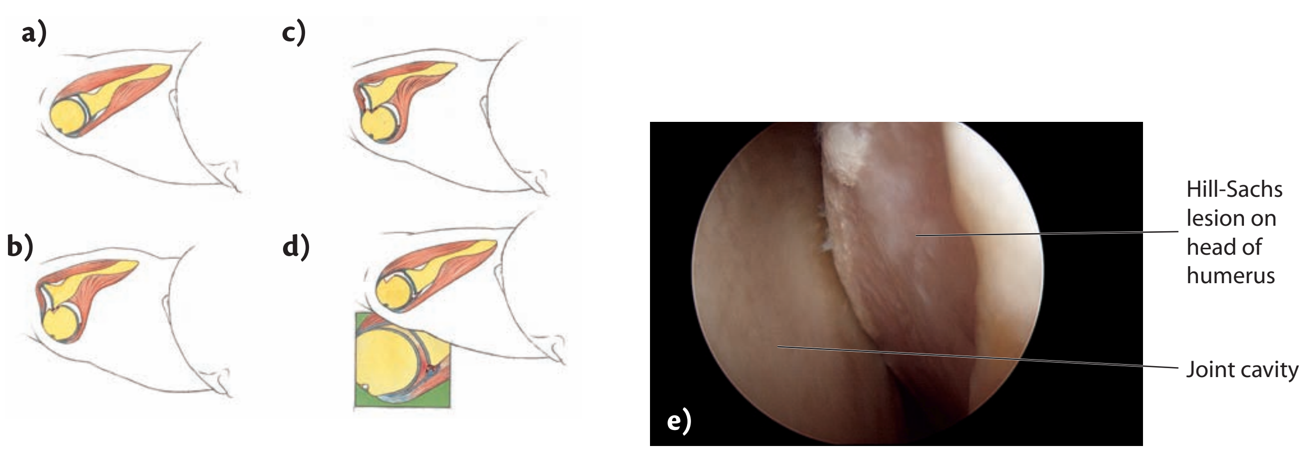


Figure 10.21 Hill–Sachs/Hermodson lesion. **a)** Normal anatomy; **b)** dislocation anterior of the humerus, which can be pressed against the anterior part of the rim. Thereby a fracture can occur and a bony defect in the posterior aspect of caput humeri may result; **c)** anterior dislocation with the capsule torn and stretched both anteriorly and posteriorly; **d)** the shoulder joint is repositioned into the correct position with injuries on the bone and labrum; the enlarged picture shows the posterior capsule overstretched; **e)** injury seen at arthroscopy including an old Hill–Sachs/Hermodson´s lesion.

Figure 10.22 By holding a weight in the arm of the injured shoulder in the prone position as shown here, a dislocation can spontaneously get back into normal position.

Return to sporting activity involving the injured arm should not take place until full mobility and strength are regained, usually 2–3 months after injury. Sometimes a dislocation of the shoulder joint is complicated by a fracture of the upper part of the humerus or the scapula. In rare cases, nerve and blood vessel injuries and muscle ruptures may occur.

Patients who sustain their first dislocation before the age of 25 years are at great risk of recurrent dislocations (Fig. 10.22). If dislocations occur more than three or four times, surgery to stabilize the joint should be considered. The results are good to excellent. With open stabilization, such as the Bankart procedure, the results are excellent in 90–95% of the cases. This procedure is considered as one of the most successful surgeries of the orthopedics. Reconstruction made using arthroscopy is successful in almost equal measure. The arthroscopically assisted technique is developed and improved continuously. Return to sporting activity that requires adequate arm function can generally be between 3 and 6 months.

Chronic instability of the shoulder

Injury mechanisms that develop instability

The significance of throwing injuries is increasing in both professional and amateur sport. They affect both adults and children. The throwing mechanism is described in Chapter 6, p. 97. Sports that are particularly risky for causing throwing-like injuries are tennis and other racquet sports, javelin throwing, handball and sports with other arm movements above the head, such as swimming, baseball and volleyball.

The tennis serve

Tennis puts great physical, mental and emotional demands on its practitioners. We have a good knowledge of the inherent demands of tennis in terms of strength, ROM and the length of the match, etc (Fig. 10.23). We also know a great deal about how muscles and tendons interact. The serve is the dominant type of stroke in tennis and represents 45% of all strokes in the French Open, and 60% in Wimbledon.

Shoulder kinetics

Shoulder kinetics comprise a rotational speed of the world players of approximately 1500°/second, a trunk rotation of about 350°/second and an elbow extension of 1100°/second. This movement pattern gives ball speeds after a serve of 150–170 km/h (95–105 miles/h) for women and 190–220 km/h (120–135 miles/h) for men.

Principles of the tennis serve and throwing (pitching in baseball)

Shoulder injuries can occur in tennis players as the tennis serve is an unnatural and very dynamic movement that often exceeds the physiological constraints of the joint. Some anatomical structures can be overloaded.

Optimal shoulder function requires a well-functioning kinetic chain, good stability and scapula (shoulder blade) coordination at movements above shoulder plane. The rotator cuff should be well balanced to achieve a stable center of rotation. See Chapter 6, p. 97 for further discussion on the mechanisms of throwing and the risks for injury to the shoulder and the upper, elbow and lower arm.

Chronic instability

Instability can generally be divided into anterior, traumatic shoulder instability and multi-directional instability, hyperlaxity, but there is a gray zone in between the categories. According to a previously widely used classification instability can be divided into a:

- TUBS group (traumatic unidirectional dislocations), which often leads to structural capsule and labral injuries, often resulting in surgery.
- AMBRI group (atraumatic multi-directional), which affects both shoulders and is usually treated with rehabilitation.

Instability of the shoulder joint and impingement is a disorder with continuous transitions. There are

Figure 10.23 The tennis serve. (With permission, by Bildbyrån, Sweden.)

many ways to classify shoulder disorders, but in Sports Medicine The following classification is practical:

- Type I: pure impingement.
- Type II: secondary impingement and primary instability due to damage to the joint capsule.
- Type III: secondary impingement with primary instability and hypermobility.
- Type IV: pure instability.

Chronic shoulder instability is most common in athletes participating in sports involving throwing or other overhead activities. Chronic fatigue of the dynamic anterior shoulder stabilizers seems to initiate most problems. As these dynamic stabilizers fatigue, increased and repetitive stress is placed on the static anterior, glenohumeral (shoulder joint) stabilizers, which results in gradual stretching of these stabilizers. A relative imbalance between the anterior and posterior capsule may be the result. This fatigue may result in changes in the throwing or hitting mechanism, which may include scapula lag and/or a dropped elbow. In the early phases there is mostly fatigue or loss of consistency, but no major decrease in performance. At this stage a training program may have good effects with time.

Traumatic anterior instability is the most common type of shoulder instability. The most common complication is recurrent instability. It is difficult to specify how common posterior instability is because of the lack of clear criteria on how this diagnosis should be made. Many consider that posterior instability is present in about 5% of all cases of instability.

Symptoms and diagnosis

- Pain in the shoulder joint occurs during and after exercise and competition.
- 'Dead arm' sign is present. This sudden onset of weakness, numbness and tingling in the arm is provoked by certain actions and can be due to a sudden transient subluxation of the shoulder.
- A feeling of dislocation is experienced when the arm is lifted above the horizontal plane and externally (outwards) rotated.

Treatment

The athlete should:

- Improve the function of the joint with active strength exercises.

The physician may:

- Operate in cases of prolonged problems. It is often enough to stabilize a tear of the labrum (see p. 228), but if there is multi-directional instability, open surgery with a capsular shift procedure may still be needed. Extensive physical therapy led by an experienced physical therapist is also a prerequisite for good results.

Scapular dyskinesis

The shoulder blade (scapula) has many important functions in order to maintain normal shoulder function. When moving the upper arm the scapula is important to secure a well-coordinated scapula rotation. This serves as a stable base for the activation of the rotator cuff and acts as a link in the kinetic chain. These functions are vital for a proper functioning arm and can only occur when the shoulder anatomy generally is unaffected. Tissue damage such as in a muscle/tendon rupture or a nerve injury, e.g. thoracic longus nerve with wing scapula (p. 249 Fig. 10.60b) as well as muscle weakness and stiffness, can affect the scapula's function and change its resting position and/or dynamic movements. This alteration in the normal position or motion of the scapula during coupled scapulohumeral movements is called scapular dyskinesis.

Although this is present in a large number of shoulder injuries it appears that scapular dyskinesis is a non-specific response to a painful condition in the shoulder, rather than a specific response to a specific shoulder joint injury.[7]

An examination includes an inspection of the scapula's position at rest and during dynamic upper arm movements. This along with postural measurements and corrective movements of the scapula indicates the degree to which the scapula is involved in the shoulder injury (Fig. 10.24).

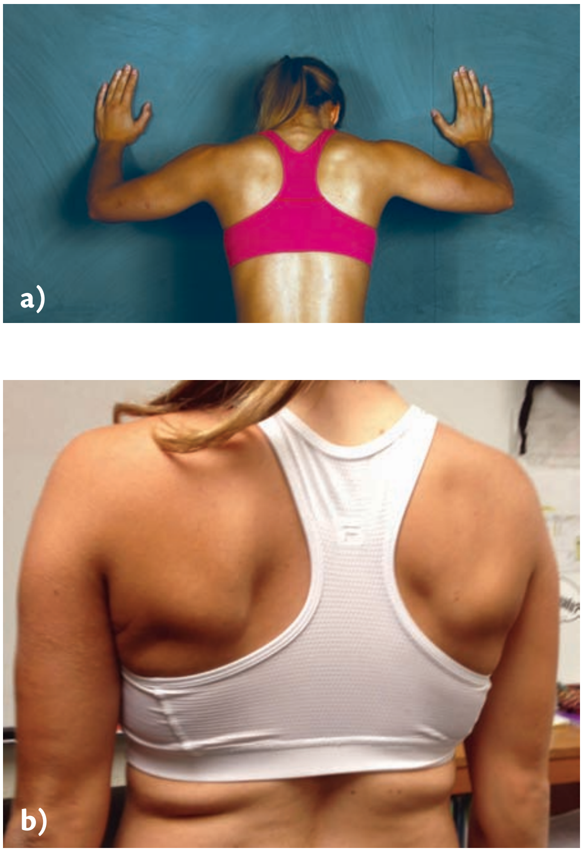


Figure 10.24 Scapular movements are best inspected from behind. **a)** Shoulder with normal motion of the shoulder blades; **b)** shoulder with scapular dyskinesis to the right. (Courtesy of Prof. Marc Safran, Stanford University, California, USA.)

The treatment of scapular dyskinesis starts with ensuring optimal anatomy and then restoring the dynamic scapular stability through strength training of the scapular stabilizers or use of kinetic chain-based rehabilitation.

Maladaption of the shoulder

A shoulder that is used for many years, often started in childhood, for example using a tennis serve or pitching (throwing) in baseball, can get chronic tissue effects.

With time, there is a limitation of the ability to rotate internally fully, which secondarily leads to the posterior shoulder capsule becoming more tense and shortened. Thereby, the humeral head is progressively displaced forward – so-called anterior translation.

This may result in too extensive external rotation as the anterior and lower capsular structures are stretched, creating a risk of anterior instability and a so-called internal impingement. The strength of the internal rotation movement is improved due to the serve movement. In general, there is no difference in strength in external rotation between sides.

Internal impingement

Internal impingement is a growing problem in sports such as tennis. Internal impingement is not a pathological condition but a natural limitation of abnormally increased external rotation. Players can show signs of internal impingement when the arm is abducted and externally rotated.

Injury mechanism

This condition affects tennis players, throwers and volleyball players. Swimmers have similar symptoms. A gradual stretching of the soft tissue in the anterior part of the shoulder causes incomplete dislocation. The shoulder's rotation causes micro-damage of the posterior aspect of the shoulder joint capsule, which is tensed and increasingly changed by micro-tears resulting in scar tissue. This leads to the humeral head, i.e. the upper part, being in a higher position than usual during the cocking phase when the arm is abducted and externally rotated. The situation has resulted in the rotator cuff being pinched in the posterior upper part of the joint socket when the arm is abducted and externally rotated, and it may eventually result in a thickening of the bursa above and wear of the rotator cuff below (Fig. 10.25).

Anterior and upper internal impingement is quite unusual and may be related to instability of the biceps long head. It can also be caused by trauma and degenerative factors in middle-aged athletes and tennis players.

Stress combined with laxity (hypermobility) in the joint increases the risk for internal impingement. The tightness and the increased tension of the posterior capsule, if it lasts a long time, reduce internal rotation in the shoulder. This further increases the risk of developing damage to the underside of the rotator cuff (see p. 236) or upper labrum, called superior labrum from anterior to posterior (SLAP) lesions (see p. 231) through a peel-back mechanism. At external rotation of the shoulder, the base twisting of the biceps tendon becomes a greater rotation load on the labrum and thus releases from its attachment. A peel-back can only be seen by performing an arthroscopic examination.

Movement exercises are important at this stage. If the humeral head translates inside the joint space it

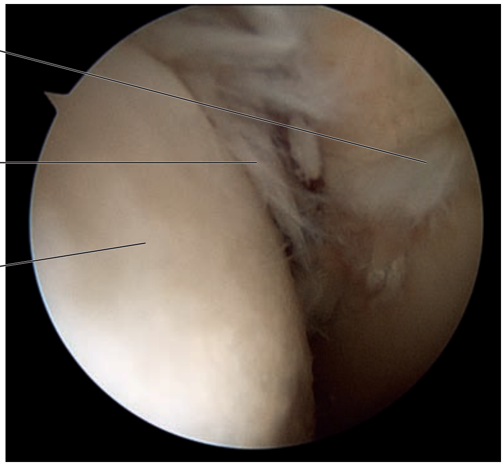


Figure 10.25 Internal impingement seen from the anterior during arthroscopy. The rotator cuff can be impinged in the posterior superior aspect of the joint glenoid fossa when the arm is moved out from the body and externally rotated. By then a thickening of the bursa on the upper side and a wear out of the lower side of the rotator cuff can be seen. (Courtesy of Prof. Marc Safran, Stanford University, California, USA.)

may produce pain during and after physical activity. In connection with activities such as pole vault, hockey, handball, volleyball, basketball, throwing and racquet sports, the athlete may feel as if the humeral head had slipped out of the joint space. For these injuries to be treated successfully, it is important to determine the direction in which instability occurs and how extensive it is.

Glenohumeral internal rotation deficit (GIRD)

Years of repeated throwing creates increased external rotation and decreased internal rotation of the shoulder joint in throwers, pitchers, tennis players, etc., as stated above. The dominant side shows less internal rotation compared with the non-dominant. Tennis players have twice the limitation of internal rotation compared with swimmers.

There is an ongoing debate about how much tissue adaptation, i.e. adaptation in bone and soft tissues, contributes to these changes. The increased external rotation may be due to increased backward rotation (retroversion) of the humerus. The limitation of internal rotation is caused by a soft tissue adaptation. There is a connection between GIRD and an abnormal position of the scapula, especially if there is an increased anterior tilt. The limited internal rotation can be corrected by diligent exercising under a stretching program.

Ruptures in the labrum in the shoulder socket

The glenoid labrum is a fibrocartilage rim surrounding the articular surface of the glenoid fossa (the socket of the shoulder joint) (Fig. 10.26). The labrum contributes to stability by increasing the depth of the glenoid socket. The loss of the glenoid labrum decreases the depth of the socket by 50% in either direction.

Injuries on the labrum are relatively common in middle-aged and older athletes, but does rarely cause any problems. Shoulders become tighter with age and the elderly rarely raise their arms over the shoulder. A glenoid labral tear is commonly associated with anterior dislocation or subluxation of the shoulder or with a degenerative lesion. An isolated glenoid labral tear, without instability, can occur in younger throwing athletes, in wrestlers and boxers, and in racket players. Occupational groups that may have problems include electricians, roofers, painters, etc.

Symptoms

- Good mobility in the shoulder joint, but sometimes it can be easily compromised.
- Pain from inside the anterior part of the shoulder during activity, especially during throwing movements; the pain is most noticeable when the arm is lifted and carried behind the head or backwards in the shoulder's plane. Labrum injuries should be suspected if the athlete complains of pain in the anterior part of the shoulder joint.
- There is a popping, catching or locking sensation.
- Sometimes there can be a feeling of instability.
- During examination the physician can detect a clicking (crepitation) or locking. This is felt during overhead abduction and rotation.
- There is tenderness to palpation over the joint line.

Diagnosis

- Is set after a simple shoulder examination.
- A local anesthetic injection in the shoulder joint usually confirms the diagnosis.
- Kibler's test – anterior slide test for labrum injury (Fig. 10.27).
- O´Driscoll SLAP test – a new test for labrum (SLAP) injury (also known as the Dyanamic Labral Shear test). This test is used with the athlete sitting or standing.

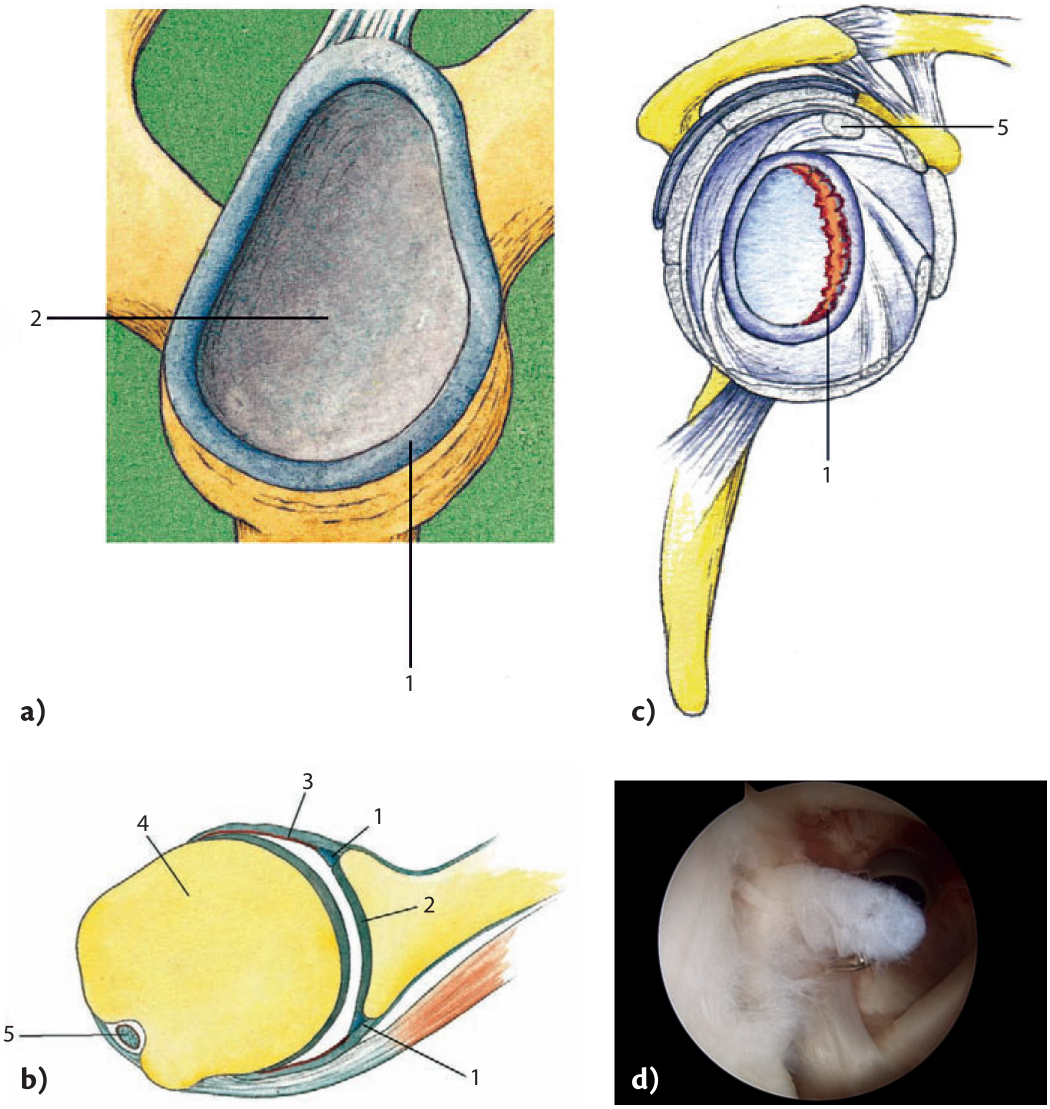


Figure 10.26 The labrum, i.e. the ring of cartilage around the shoulder joint socket (glenoid fossa). **a)** Normal glenoid 1. Normal labrum 2. Glenoid; **b)** a cross-sectional cut through the shoulder and its different structures 1. Labrum anterior and posterior 2. Glenoid 3. Joint capsule 4. Head of humerus 5. biceps tendon; **c)** an injury in the labrum 1. Bankart lesion 5. Biceps tendon; **d)** labrum injury seen during arthroscopy showing a flap tear (courtesy of Prof. Marc Safran, Stanford University, California, USA).

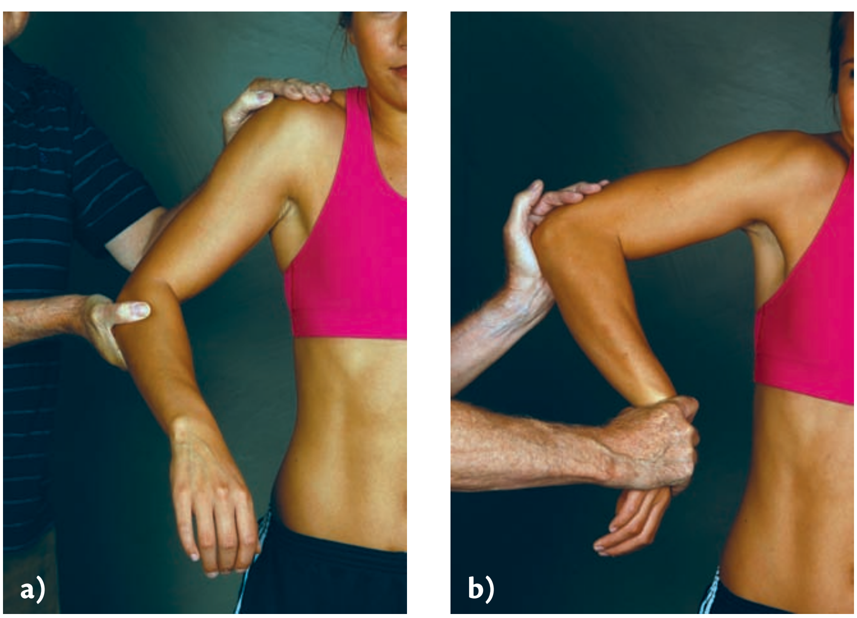


Figure 10.27 Anterior slide test for labrum injury (Kibler's test). The athlete holds the arms to the side while the thumbs are pointing backwards. **a)** The examiner places a hand on the shoulder and the other hand on the elbow. Pain occurs when the arm is pushed upwards; **b)** the examiner places a forward and upward pressure on the elbow while the athlete counteracts this effect. Pain or a click indicates an injury to the labrum.

The examiner moves the arm into the patient's maximum external rotation position with the shoulder in approximately 100° of abduction. The arm is thereafter brought downward into adduction and back upward to 100–120° in the coronal plane, which in a positive test causes discomfort and replicates the patient's. This test is new and has the highest sensitivity of all labrum tests. It has also good specificity. A negative test does not exclude shoulder instability.

- Another good and reliable test is the O'Brien active compression test for SLAP lesion (Fig. 10.28).

If the diagnosis is uncertain, the athlete can be examined with MRI, which with 76–90% accuracy gives the correct diagnosis or MR arthrography i.e. with contrast injected into the joint (Fig. 10.29). It is then an accuracy of above 90%. An arthroscopy can be helpful.

Treatment

The athlete should:

- Rest from painful activities.
- Perform stabilizing exercises, strength training with open and closed kinetic exercises, preferably with physical therapist help.

The physician may:

- Recommend surgery if the patient does not improve by physical therapy. This is performed with the aid of arthroscopy (Fig. 10.30).

Figure 10.28 O'Brien's active compression test (for SLAP lesion and AC joint involvement). **a)** The test starts with the patient in a seated or standing position with the shoulder flexed to 90° in the sagittal plane. The shoulder is then horizontally adducted 10 more degrees (slight cross-am adduction) and fully internally rotated. The examiner then exerts a downward force onto the arm, asking the patient if that replicates either a deep anterior shoulder pain (superior labrum from anterior to posterior: SLAP lesion) or localized AC joint pain (AC joint involvement); **b)** to verify the test, the same position is used once again, this time with the shoulder in external rotation (palm up position) and the pain that was identified in the first part of the examination should be decreased or absent. (Photos, Todd Ellenbecker, ATP vice president, Scottsdale, Arizona, USA.)

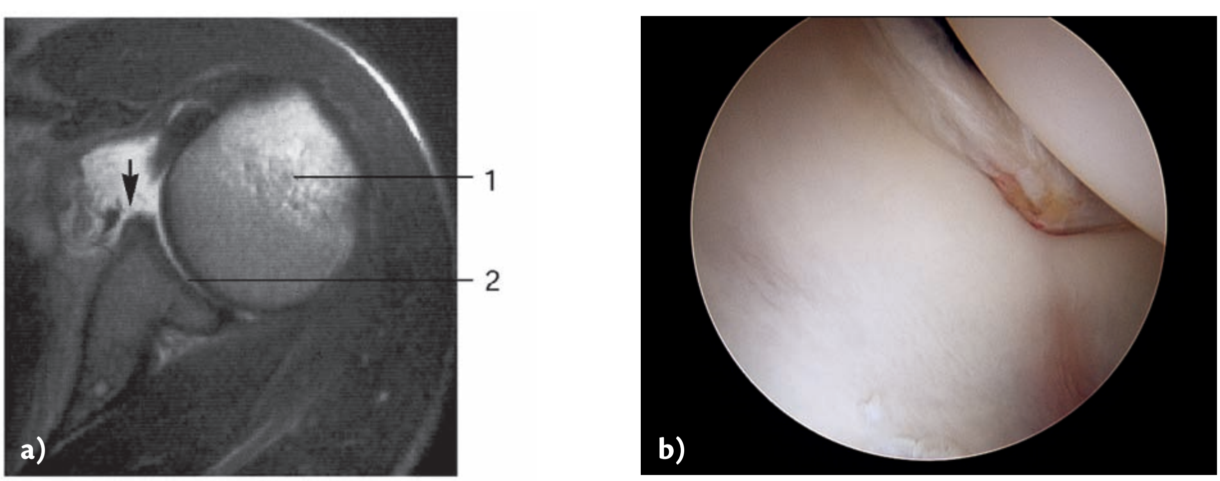


Figure 10.29 Labrum injury. **a)** The labrum injury is seen with magnetic resonance imaging (MRI) examination with contrast, MR arthrography. 1 Humeral head 2. Glenoid. Thick arrow showing labrum avulsion; **b)** labrum injury seen at arthroscopy. Injury seen at arthroscopy between the humeral head and the glenoid. (Courtesy of Prof. Marc Safran, Stanford University, California, USA.)

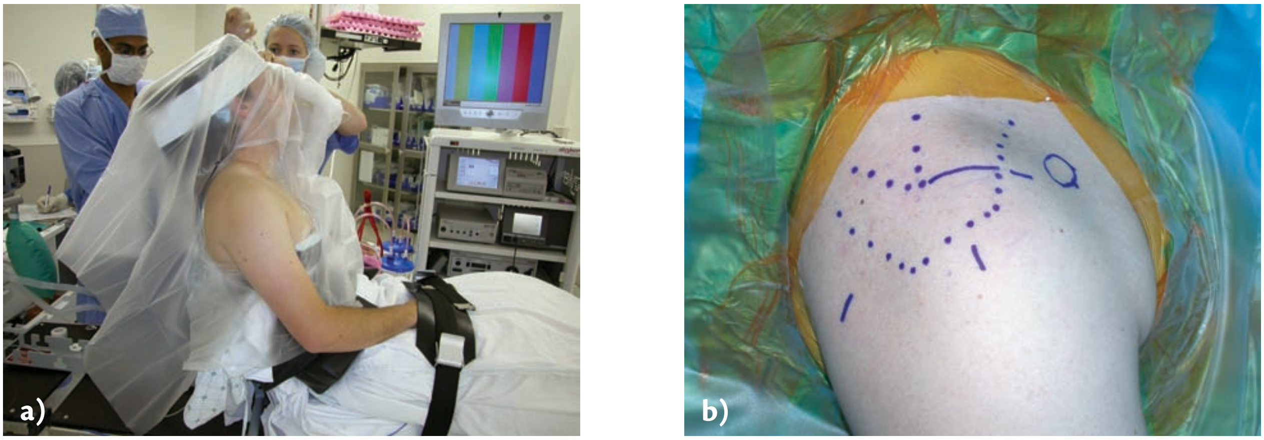


Figure 10.30 a) Set up to perform an arthroscopy of the shoulder. The patient is put in a 'beach chair position'. **b)** some of the most common portals to use for the insertion of the arthroscope. (Courtesy of Prof. Marc Safran, Stanford University, California, USA.)

The labrum is reattached with sutures (Fig. 10.31) or different types of resorbable anchors (can be attached to the bone), e.g. pins (Fig. 10.32).

These anchors are broken down by the body and, in time, they will disappear by themselves. Surgical results are normally good in athletes younger than 30 years, but worse in those who are older than 40–50. A contributing factor to the poorer result may be inadequate diagnostics, when degeneration of the labrum sometimes can be interpreted as a rupture. Healing time is approximately 3–4 months and return to throwing activity takes 3–6 months.

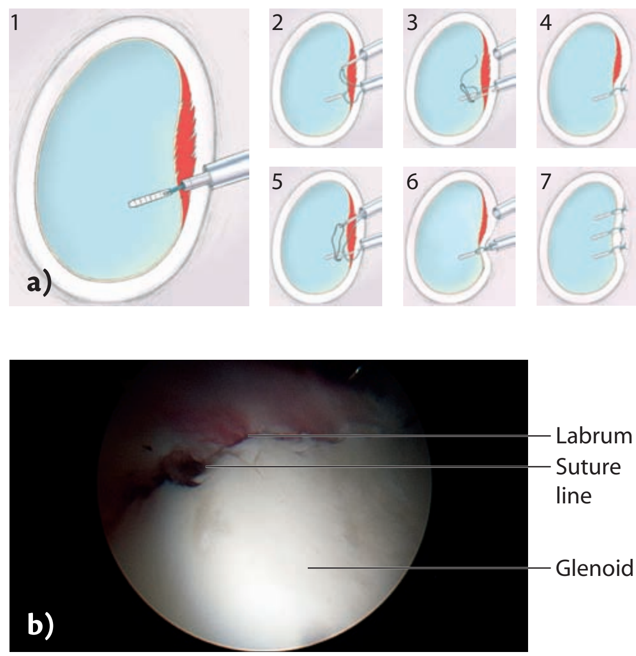


Figure 10.31 A labrum tear can be repaired with sutures. **a)** 1: Anchors with sutures are drilled into the front rim of the joint socket; 2: via a side portal one suture end is grabbed with a hook and pulled out; 3: via the first portal labrum is penetrated from above with a needle; via the other portal a sling finds the end of the suture and it is pulled through the first portal; 4: from the outside both ends are tied and the knot is pressed down against the labrum, which is fixed against the rim of the joint; 5: the ends of the sutures are cut; 6: a fixed labrum with the knots; 7: one or two anchors are required for adequate fixation. **b)** a sutured labrum injury seen during arthroscopy. (Courtesy of Prof. Marc Safran, Stanford University, California, USA.)

Superior labral tear from anterior to posterior (SLAP lesion)

Damage to the labrum in the shoulder joint socket on the shoulder blade (scapula) is usually located in the front part of the socket. However, some types of damage occur in the upper part of the labrum from its anterior to its posterior portion in the tendon attachment of the two-headed muscle (biceps). The damage in SLAP consists of a combination of posterior inferior capsular tightness and scapular dyskinesis, which means a loss of normal scapular function, present in 94% of all who have a labrum injury. This combination results in peeling of the labrum, known as peel back, at the biceps tendons attachment and leads to a SLAP lesion. If this damage causes problems an arthroscopic surgery can done. Four injury types are present (Fig. 10.33):

- Type 1 is characterized by fraying in the superior labrum, but the labrum remains firmly attached to the glenoid. Treatment is by arthroscopic debridement if the injury is causing problems (Fig. 10.33A).
- Type 2 includes an injury where the superior labrum and biceps tendon are stripped off the underlying glenoid. The frayed labral tissue may be debrided or reattached, after which the arm should be immobilized

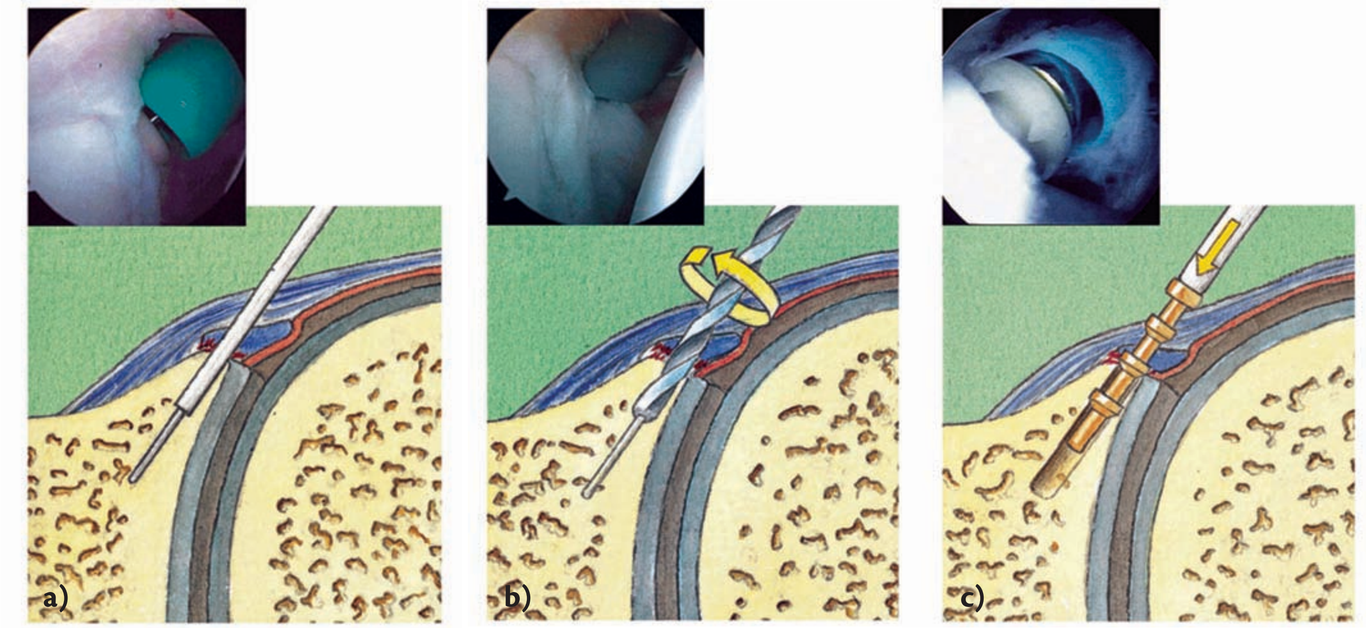


Figure 10.32 A labrum tear can be repaired with the help of resorbable pins (the body will naturally degrade and absorb the pins over time.) **a)** One pin is brought into the joint with the aid of a case and brought through the labrum; **b)** a hole is made around the pin for a screw, which can be anchored directly in the bone; **c)** the screw is anchored in the bone.

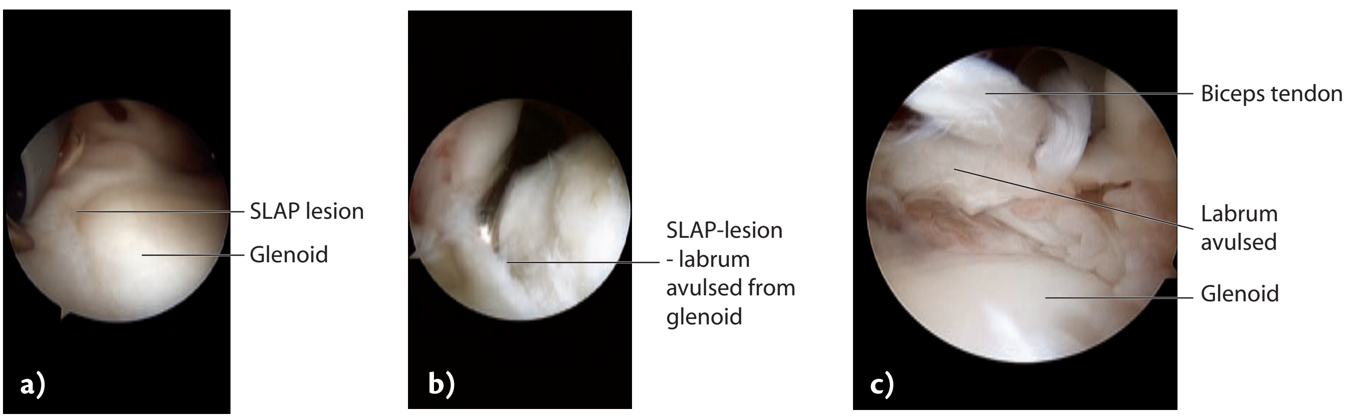


Figure 10.33 Superior labrum from anterior to posterior (SLAP) lesions. **a)** SLAP lesion type 1; **b)** SLAP lesion type 2; **c)** SLAP lesion type 3. (Courtesy of Prof.Marc Safran, Stanford University, California, USA.)

to allow the biceps labral complex to heal. The optimal treatment of this injury is controversial (Fig. 10.33B).

- Type 3 includes fragmentation of the superior labrum with an intact biceps tendon. The treatment is by excision of the labral fragments (Fig.10.33C).
- Type 4 is a labral tear across the superior labrum into the biceps tendon. Treatment usually consists of excision of the labral and biceps fragments.

Impingement syndrome

Impingement can be defined as a trapping of the soft tissues in the subacromial space, between the acromion and the humeral head. The entrapment of the soft tissues when moving the shoulder may lead to a painful reaction. Athletes, including tennis players, swimmers, throwers, and weightlifters, who make repetitive movements of the arms above the horizontal plane, are at risk of developing this painful condition.

The soft tissues can become too large and may be pinched between the head of the humerus, the acromion process of the scapula and the coracoacromial ligament. The soft tissues in the limited subacromial space include the tendons of the long head of the biceps, the supraspinatus, infraspinatus, teres minor and subscapularis muscles, and the bursa overlying the supraspinatus tendon. The subacromial space can also be inadequate. If the ligament is thickened or calcified, or becomes inelastic, or if the anterior–inferior edge of the acromion process over the acromioclavicular joint becomes irregular with bony outgrowths or spurs, the space can be further compromised. This occurs most often in elderly people.

The contour of the anterior–inferior acromial bone is important since it may affect the size of the space below the acromion. The shape of the anterior acromion is studied by plain radiographs (supraspinatus outlet or arch view). The contour of the anterior–inferior acromion is classified according to Bigliani (Fig. 10.34) as follows:

- Type 1: the acromion is flat on the undersurface with the anterior edge extending away from the humeral head.
- Type 2: the acromion is gently curved on the undersurface with the anterior edge extending parallel to the humeral head.
- Type 3: an inferiorly pointing, or hooked, anterior bone spur (osteophyte) narrows the outlet of the supraspinatus muscle and tendon.

When the upper arm is moved forwards and upwards (its usual functional position) to an angle of 90° to the body and the arm is then further internally rotated (inward), the soft tissues are compressed against the sharp edge of the coracoacromial ligament. During movement the tendons and the bursa rub against the ligament, causing mechanical irritation that gives rise to painful inflammation (Fig. 10.35).

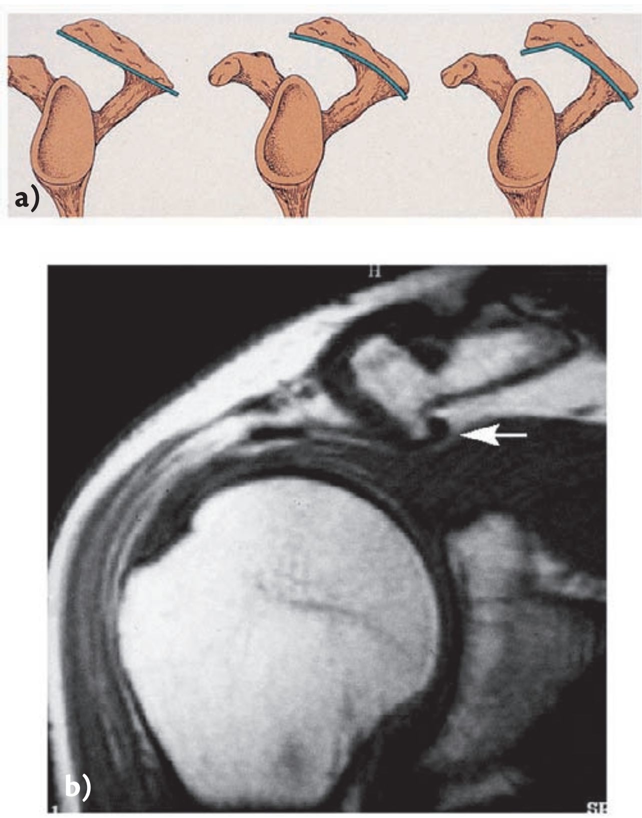


Figure 10.34 Impingement syndrome. **a)** Bony osteophytes under the clavicle after the Bigliani classification; **b)** MRI shows osteophytes as indicated by the arrow.

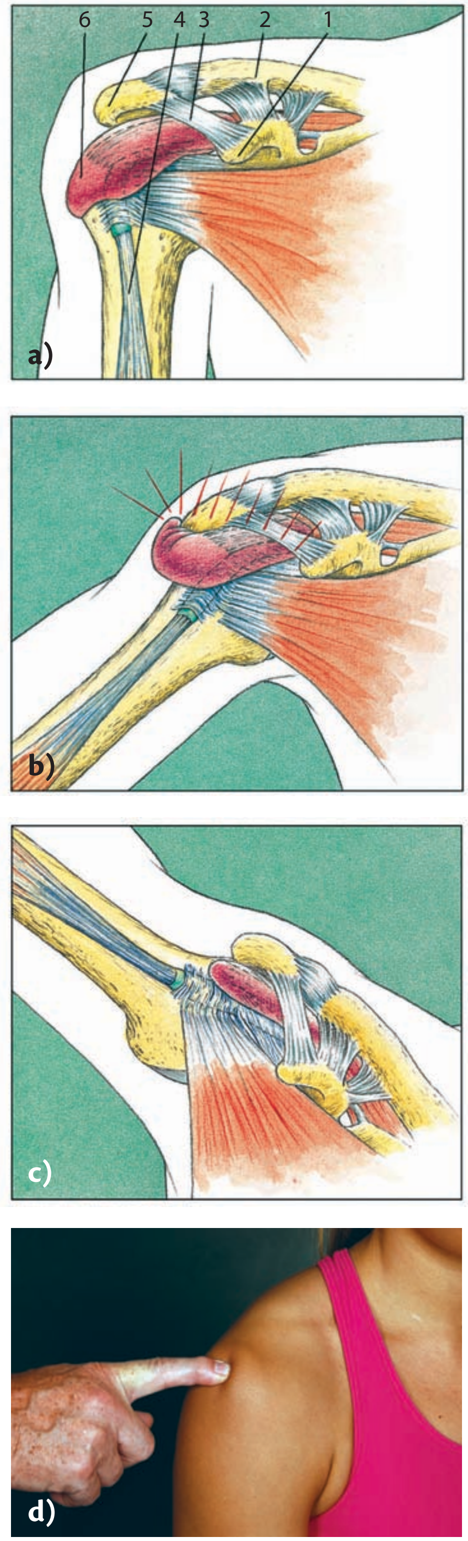


Figure 10.35 Impingement syndrome. **a)** The arm at rest. 1: Coracoid process; 2: clavicle; 3: coraco-acromial ligament; 4: biceps tendon; 5: acromion (shoulder blade); 6: bursa; **b)** the arm is abducted 60–120°. The bursa is compressed between the shoulder blade and the rotator cuff tendons; **c)** the arm is abducted to 120° and the pressure on the bursa decreases; **d)** localization of tenderness and pain caused by this injury.

As inflammation is accompanied by swelling, the space is even further reduced and the condition may become progressively worse. Repeated loading causes thickening of the soft tissues and leads to a chronic inflammatory reaction. The subacromial bursa and the vulnerable areas of the supraspinatus and biceps tendons are most affected by this process.

Etiology

Impingement syndrome may be caused by extrinsic or intrinsic factors.

Extrinsic factors

- Primary extrinsic factors arise from mechanical attrition of the tendon against the undersurface of the anterior part of the acromion. The majority of cases have this etiology.
- Secondary extrinsic factors arise from a relative decrease in the size of the supraspinatus outlet due to instability of the glenohumeral joint. This is more commonly seen in young throwing athletes and swimmers, many of whom have some generalized ligamentous laxity.

Intrinsic factors

Intrinsic factors, such as degenerative changes (pp. 25, 178) within the rotator cuff tendons, are likely to cause problems because of subsequent weakness causing superior migration of the humerus, thus producing a secondary mechanical impingement. Classification entails:

- Grade 1: pretear condition with subacromial bursitis and/or tendinitis.
- Grade 2: impingement with partial rotator cuff tears.
- Grade 3: impingement with complete rotator cuff tears.

Primary impingement or external subacromial impingement

This type is most like Neer's original description of shoulder impingement. The etiology of primary impingement is multi-factorial with a combination of traumatic, mechanical, circulatory and degenerative factors. The source of pathology is outside the shoulder joint and is limited to the subacromial area. The most common area of the rotator cuff that is involved is a rotator cuff tear on the upper portion or the side against the bursa. Patients often experience pain in the anterior part of the shoulder or in front of the shoulder when they perform activities above shoulder level.

As indicated above, the look and shape of the acromion matter. An X-ray examination is of value.

Secondary impingement

This type of impingement is often due to the existence of a problem with keeping the humeral head centered in the shoulder socket (the glenoid fossa) during arm movements. This is often caused by weakness in the rotator cuff muscles, i.e. functional instability combined with a shoulder joint capsule and ligaments that are too loose. This type of impingement occurs in the coracoacromial space secondary to anterior translation of the humeral head, which can be compared with the subacromial space in primary impingement.

Patients are usually younger. The pain is localized to the lateral or anterior–lateral aspect of the shoulder. Symptoms are often triggered by activities above shoulder level. Secondary types of impingement can occur in younger individuals with unstable shoulders, and with calcific tendinitis.

Secondary impingement may cause problems such as scapular dyskinesis, instability, SLAP lesions and GIRD (p. 238). It is essential to treat the underlying instability of patients with secondary impingement.

Symptoms and diagnosis

- When the arm is used for overhead activities and is lifted above the horizontal plane, pain is located at the lateral and upper part of the shoulder.
- When the arm is above 90° of abduction (elevated to the side), the athlete will often substitute scapula-thoracic motion for glenohumeral motion, i.e. will use the shoulder blade more than normally. This can be seen to 'hunch up' the affected shoulder during abduction of the arm. The pain is often worse after the arm is lowered than when it is raised.
- Pain occurs at night, especially if there is involvement of the rotator cuff.
- Tenderness can be felt in the upper aspect of the head of the humerus, and also over the biceps tendon.
- Active ROM can be limited in abduction and forward flexion secondary to pain, especially above shoulder level. There may be a subtle loss of internal rotation.
- Crepitus can be palpable in the subacromial region.
- Hypotrophy of the deltoid and the spine muscles may be present.
- Impingement tests will, if positive, verify the diagnosis.
- Plain X-rays, including an anteroposterior view of the glenohumeral joint (that is, an internal rotation view of the humerus with 20° upward angulation to show the acromioclavicular joint), an axillary lateral view and the supraspinatus outlet or arch view, will show the subacromial morphology well.

Neer's impingement test

Neer's impingement test consists of full forward passive elevation of the humerus in the scapula plane (Fig. 10.36). This causes the critical area of the supraspinatus tendon to impinge against the anterior inferior acromion. If this produces pain, it is a positive impingement sign.

Hawkins's impingement test

Hawkins's test can be performed by elevating the shoulder to 90° in the scapular plane and then forcibly internally rotating the shoulder (Fig. 10.37). This manoever drives the greater tuberosity further under the lateral acromion and coracoacromial ligament, thereby reproducing the pain.

Impingement injection tests

The impingement test compares the athlete's response to impingement testing before and after the injection of an anesthetic agent into the subacromial bursa. Significant reduction of the athlete's pain is a positive sign of impingement.

Prevention

- Proper warm up with flexibility training.
- Exercises that work with the entire kinetic chain including strength training.
- Painful movements should be avoided.

Treatment

The athlete should:

- Carry out active movements of the shoulder and maintain ROM (p. 250).
- Keep up conditioning exercises.
- Apply local heat and use a heat retainer after the acute phase.
- Resume sports training gradually when the pain has resolved.

The physician may:

- Give instructions for specific strengthening and stretching programs. A maintenance program to prevent loss of motion and stiffness is important.
- Prescribe anti-inflammatory medication.
- Use steroid injections selectively (when local steroids are justified, the injection should be followed by a few days of rest).
- Operate if conservative therapy fails.

As long as the patient is making progress and other significant lesions do not exist, conservative treatment should be continued. If a plateau is reached, surgery may be indicated. A subacromial decompression includes removal of the bursa and most often the undersurface of the acromion, which can create more space for the soft tissues. The surgery can be performed with the aid of an arthroscope (Fig. 10.38).

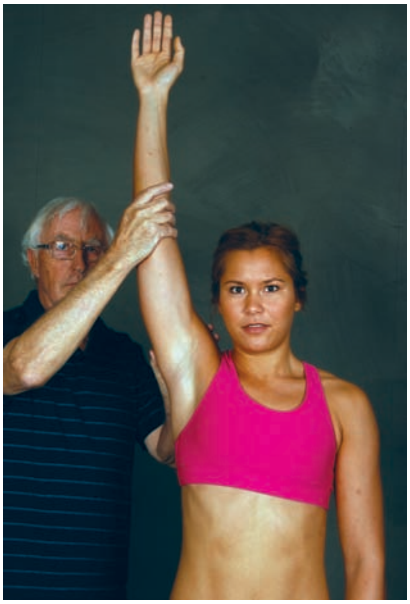


Figure 10.36 Impingement test according to Neer. When doing this test the upper arm is lifted forward and upwards in the shoulder plane with the arm internally rotated. By doing this there is an impingement of the supraspinatus tendon in the critical area towards the anterior edge of acromion. If the motion provokes pain the test is positive ('Neer's sign').

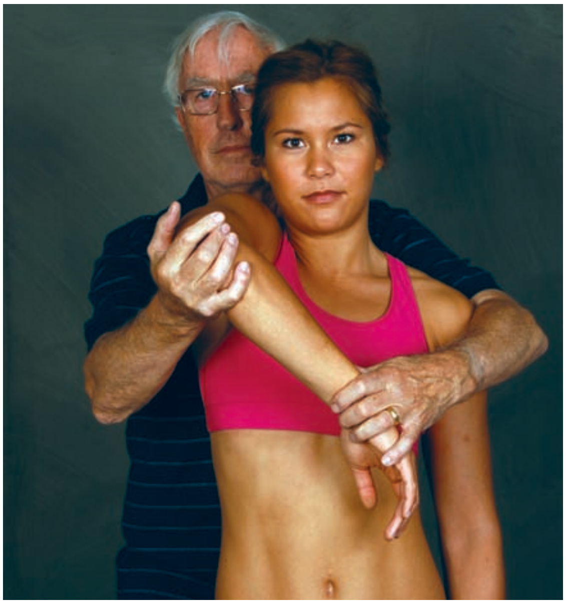


Figure 10.37 Impingement-test according to Hawkins. This test is performed by elevating the shoulder forward 90° in the scapular plane and thereafter forced into internal rotation. Thereby the large bony process (tuberculum majus) is pressed further down under the acromion's lateral part and the coraco-acromial ligament, which may cause pain.

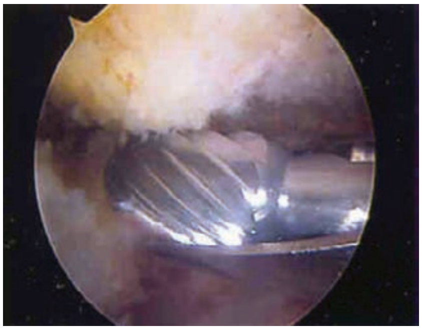


Figure 10.38 Acromioplasty, i.e. surgery through an arthroscope. The bursa is removed and potential osteophytes are taken off using a powered arthroscopic burr.

In the elderly, more extensive measures may be necessary. After surgery, early mobilization with active strength training is recommended. A return to overhead sports is often possible 2–3 months after surgery.

Subacromial bursitis

One large bursa in the shoulder is located between the supraspinatus muscle and the deltoid muscle and acromion process of the scapula. In its inflamed state the bursa is about the size of a golf ball. Inflammation of the bursa (subacromial bursitis) commonly occurs.

Causes

- A fall or blow to the shoulder or a supraspinatus tendon rupture can cause bleeding into the bursa resulting in inflammation.
- Repetitive movements can cause bursitis which, in turn, causes accumulation of fluid in the bursa. The effusion causes tension in the tissues and pain in the anterior (front) and upper part of the shoulder and a thickening of the bursa.
- Inflammation in an adjacent tendon can easily spread to include the bursa.

Symptoms and diagnosis

- Pain occurs in the anterior, upper part of the shoulder.
- Impingement testing is positive (p. 235).
- Tenderness is found on palpation.
- Sometimes the bursa feels 'spongy' on palpation.
- Examination using an MRI, an arthroscopy and/or bursography (contrast is injected into the bursa) can confirm the diagnosis.
- Aspiration of the bursa can also be diagnostic.

Treatment

The athlete should:

- Rest until the pain has resolved, and avoid pain-causing situations.
- Apply local heat and use a heat retainer after the acute phase.

The physician may:

- Aspirate the bursa when bleeding or effusion is accompanied by pain.
- Prescribe analgesic and anti-inflammatory medication.
- Advise mobility exercises (p. 250).
- Administer a steroid injection and advise short-term rest in cases of chronic inflammation.
- Use arthroscopic surgery to remove the bursa in chronic cases.

Healing

When bursitis is treated promptly, symptoms usually resolve in 2–3 weeks, after which sporting activities can be resumed.

Rotator cuff injury

In 75% of cases of shoulder pain, the main source is the supraspinatus tendon of the rotator cuff. The rotator cuff mainly consists of four muscles, derived from different parts of the shoulder blade and attaches to the humeral head. These muscles are: the subscapular, located at the front, the supraspinatus on top and the infraspinatus and the teres minor in the back.

The supraspinatus muscle, together with the deltoid, raises the arm to initiate abduction. If there is a complete tear, the athlete cannot hold the arm elevated in the scapular plane between 60° and 120° and has to drop the shoulder. The arm may swing laterally, at which point the deltoid takes over. The weakest point of the supraspinatus tendon is the part which forms the cuff over the joint in the area that is 1 cm (0.4 in.) from the attachment of the tendon to the humerus. It is at this point that ruptures most often occur. They may be either partial or total. In the vulnerable area there is a network of capillaries. With increasing age or overuse there is decreased blood flow; this causes typical degenerative changes (pp. 25, 178), including reduced elasticity and increasing weakness. These changes are often apparent in elderly athletes, but may start at the age of 30–35 years. When the arm is abducted to an angle of 60–120° to the body, and during static work in this position, the blood vessels are compressed; this further impairs the blood flow and reduces the tissue oxygen supply, increasing the risk of injury.

Etiology

Impingement syndrome (which can be primary or secondary to instability), traction overload tendinitis, and trauma can all cause rotator cuff problems.

Figure 10.39 **a)** Baseball and **b)** tennis are two sports where rotator cuff injuries are not uncommon. (With permission, by Bildbyrån, Sweden.)

- **Impingement syndrome**: primary impingement occurs mostly in persons aged 40 years or more, while secondary impingement is more common in younger athletes.
- **Traction overload tendinitis**: traction overload tendinitis is more common in younger athletes. These patients are less likely to have partial tears of the rotator cuff and are more likely to have asymmetry in shoulder ROM, as well as asymmetry in strength of the periscapular muscles. Posterior capsular tightness and periscapular weakness are common problems, which force the rotator cuff tendons to work harder, thus creating an overload or overuse condition. Symptoms similar to traction overload tendinitis can also be due to subtle shoulder instability.
- **Trauma**: trauma can cause rotator cuff injury by the following mechanisms (Fig. 10.39):
  - ✓ any force that rotates the arm internally against a resistance or that prevents the arm from turning externally, as may occur during team handball, American football or wrestling;
  - ✓ falling directly on the shoulder or on an outstretched arm;
  - ✓ lifting or throwing heavy objects.

Classification

Rotator cuff tears can be of different degrees and distinct types. The location of the tear is important: rotator cuff tears can be located on the bursa surface of the tendon (the bursal side) or on the undersurface of the tendon (the articular side). The tear can also be partial or complete, connecting the articular and bursal sides.

- Primary compressive cuff disease is associated with a type III hooked acromion (contour type 3, see p. 233), degenerative spurs, or a thick coracoacromial ligament. A cuff tear originating on the bursal side of the tendon can be the result.
- Secondary compressive cuff disease is usually due to associated glenohumeral (shoulder joint) instability.
- Tensile lesions occur on the articular side and are believed to occur secondary to cuff resistance to the high deceleration forces that occur during activities such as the later stages of throwing. There is a higher incidence of articular side tears in throwing athletes.

Partial tears

In a cuff with smooth coverings of synovial and bursal tissue, the severity of a partial tear (Fig. 10.40) can be classified as follows:

- Minimal superficial bursal or synovial irritation, or slight capsular fraying with a partial tear less than 1 cm (0.4 in.) in size.
- Actual fraying and failure of some rotator cuff fibers in addition to synovial, bursal, or capsular injury. The tear is usually less than 2 cm (0.8 in.) in size.
- More severe rotator cuff injury, including the fraying and fragmentation of tendon fibers often involving the whole surface of the cuff tendon. The tear is usually less than 3 cm (1.2 in.) in size.
- Very severe partial rotator cuff tear that usually contains, in addition to fraying and fragmentation of the tissue, a tear that often encompasses more than a single tendon.

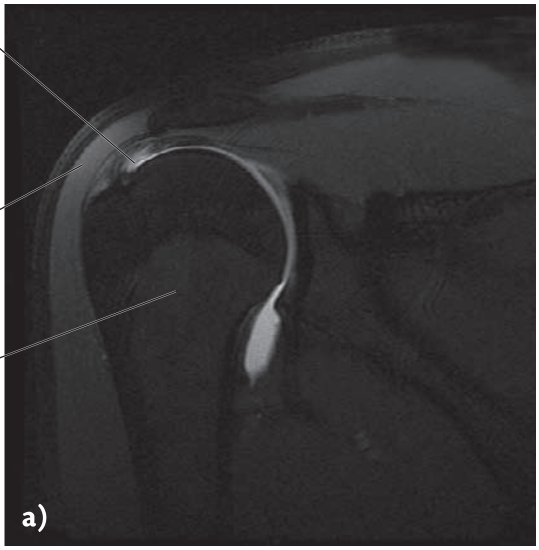
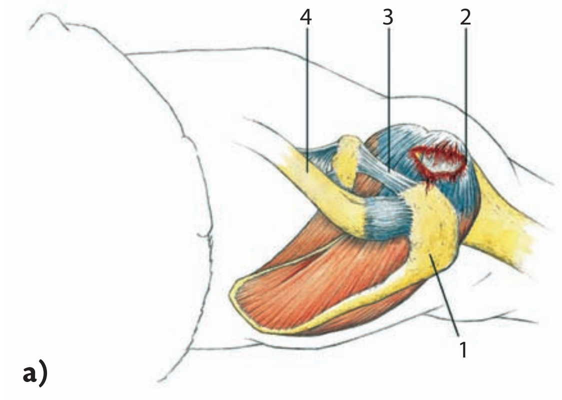


Figure 10.40 Partial tear of the rotator cuff. **a)** MRI with contrast, i.e. MR arthrogram; **b)** tear seen with arthroscopy. (Courtesy of Prof. Marc Safran, Stanford University, California, USA.)



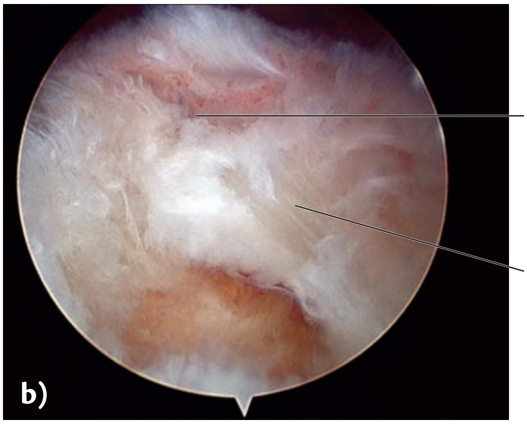


Figure 10.41 Complete rotator cuff tear. **a)** A tear of the supraspinatus including a tear in the nearby part of the infraspinatus, which is a part of the rotator cuff. 1. Acromion 2. Rotator cuff with tear 3. Coracoacromio ligament 4. Clavicle. **b)** an arthroscopic picture of a rotator cuff tear (courtesy of Prof. Marc Safran, Stanford University, California, USA).

Complete tears

Complete rotator cuff tears are classified as follows (Fig. 10.41):

- A small complete tear such as a puncture wound.
- A moderate tear that still encompasses only one of the rotator cuff tendons; the tear is usually less than 2 cm (0.8 in.) in size, with no retraction of the torn ends.
- Large complete tear involving an entire tendon with minimum retraction of the torn edges. The tear is usually 3–4 cm (1.2–1.6 in.) in size.
- A massive rotator cuff tear involving two or more rotator cuff tendons. This is frequently associated with retraction of the remaining tendon ends.

Symptoms and diagnosis

- Intense pain is felt when the injury occurs. The pain returns on exertion, may increase during the next 24 hours and may extend down the upper arm. A diagnosis of a tear of the supraspinatus tendon is suspected if the athlete has fallen on the shoulder, or has lifted or thrown a heavy object.
- Pain is often intense, or increased, at night. The patient often complains of problems with sleeping or lying on the injured side.
- Pain occurs when the arm is externally rotated or is raised upwards and outwards. When the tendon is only partially torn, the arm can be abducted to an angle of 60–80° to the body with little or no pain. The pain increases as the arm is lifted to an angle of 70–120°; it may increase once more when the arm is lowered (Fig. 10.42). Between these angles the arm is also weak. When the tendon has sustained total rupture the arm can be held at an angle of more than 120° to the body, but when it is lowered further it suddenly drops. This is an important diagnostic sign (the 'dropping arm' sign).

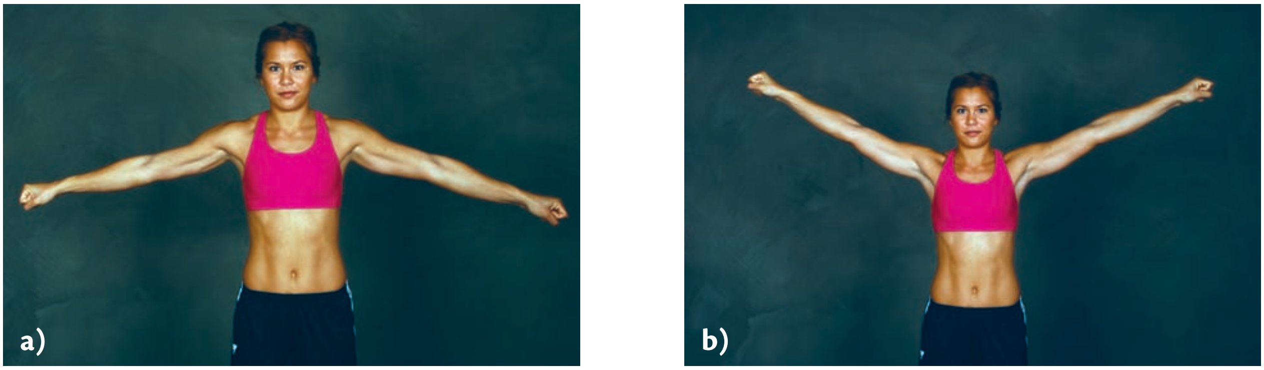


Figure 10.42 Testing the range of motion is an important test with a rotator cuff injury. **a)** An ability to raise the arm in abduction to 60–80° angle from the body without pain indicates no major injury; **b)** when the arm is lifted to 70–120° angle in abduction, pain will occur if injury is present and will decline thereafter.

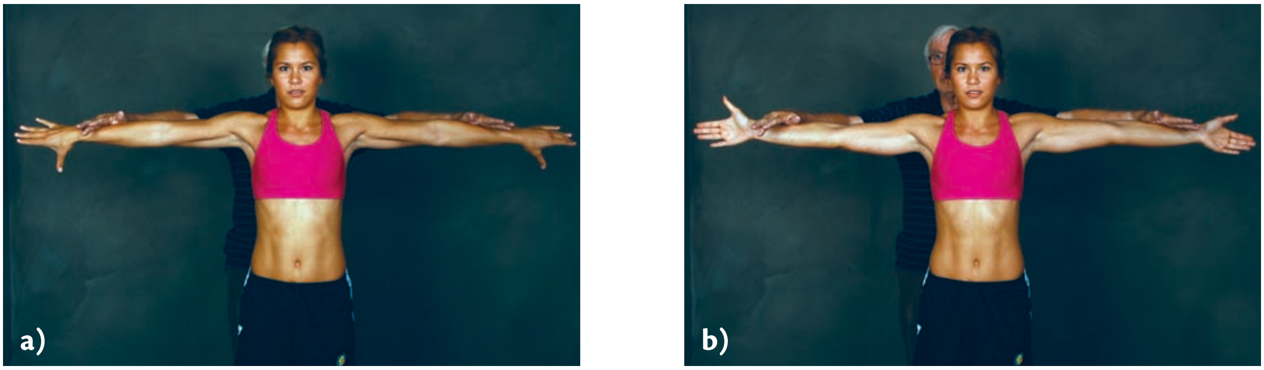


Figure 10.43 Jobe's supraspinatus tests. **a)** The 'Empty Can' test with the arms internally rotated. The test is carried out by lifting the arm externally to a 90° angle towards the body, i.e. until the shoulder is in the same plane as the scapula. The arms are rotated internally so that the thumbs will point downwards, i.e. full internal rotation is present (empty can); **b)** during a 'Full Can' test the arm is held in 45° external rotation. The patient resists when the arm is pressed downwards. The patient may then complain of pain and weakness in the arm.

The rotator cuff test is positive. The 'Empty Can Test' (ECT) was originally described by Jobe and Moynes to test the integrity of the supraspinatus tendon.[8] The 'Full Can' test is not as challenging, but has later been proposed to be a comparable test.

The 'Empty Can' test consists of abducting the arm to a 90° angle, i.e. until the shoulder is level with the scapula. The shoulder is internally rotated so the thumbs are pointing down. (Fig. 10.43). The 'Full Can' test is performed with the shoulders in 45° external rotation. The patient resists as the arm is pressed down, and the patient may complain of pain and weakness in the arm.

- Injection of anesthetic solution into the subacromial space can give relief in 75% of athletes with a partial tear on the bursa side; the relief supports the diagnosis.
- X-ray views, including a supraspinatus outlet view, are helpful in demonstrating acromial morphology and bony spurs that originate from the acromioclavicular joint.
- Ultrasonography can be sensitive and specific in identifying full-thickness rotator cuff tears.
- MRI (Fig. 10.44) is highly sensitive in the diagnosis of rotator cuff tears. It can demonstrate not only the size of the tear, but also the exact location.
- The MRI can be made more accurate when combined with an arthrogram, a MRA.
- Arthroscopy can verify the diagnosis of a tear that can be seen on the bursal or the articular side.

Treatment

The athlete should:

- Treat the shoulder with ice at the scene of the injury.
- Rest.
- Avoid abuse of the arm.
- Consult a physician if the symptoms persist.

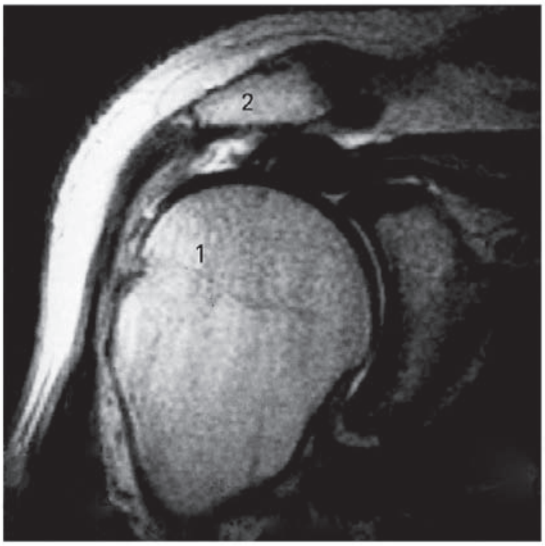


Figure 10.44 Magnetic resonance imaging (MRI) examination showing a complete tear of the rotator cuff seen from anterior. 1: Humerus (upper arm); 2: acromion (shoulder blade).

The physician may:

- Prescribe an exercise program designed to promote dynamic stability of the humeral head (p. 251). Often a physical therapist or athletic trainer is needed to monitor the program. The program should consist of stretching the posterior capsule and maintaining good ROM, as well as shoulder girdle strengthening. The goal of the rehabilitation should be to restore symmetry between the two arms with respect to:
  - ✓ ROM, especially internal rotation which is commonly decreased on the affected side;
  - ✓ quality of motion, with decreased compensatory shoulder blade motion;
  - ✓ strength, with an emphasis on strengthening the rotator cuff muscles to hold the humeral head centered within the glenoid fossa;
  - ✓ strengthening the periscapular muscles to provide a stable base for shoulder motion.
- If pain continues despite physical therapy, give a subacromial injection.
- Surgery in certain circumstances as described below (Fig. 10.46).

Healing and complications

Spontaneous healing of a partial tear appears to be clinically unlikely because of the poor circulation at the site of the tear, the physical separation of the stump ends and the subacromial impingement. Bursal side tears have a poor prognosis, so a more aggressive surgical approach is required.

If there is a partial thickness tear of the rotator cuff, arthroscopic (or, if necessary, open) debridement of the lesion may be performed in the hope that this will reactivate the healing process. This procedure is often combined with an anterior acromioplasty where a part of the acromion is removed. This procedure can be done both open and with the arthroscopic technique (Fig. 10.45). If subtle instability is present, the surgery is focused on this problem. Postoperatively, a gradual progressive strengthening program is begun after full ROM is achieved.

If there is a complete rotator cuff tear (one with full thickness tear), surgery usually gives significant pain relief, but only about 40% of top-level throwers return to their preinjury level of function. A gradually increased

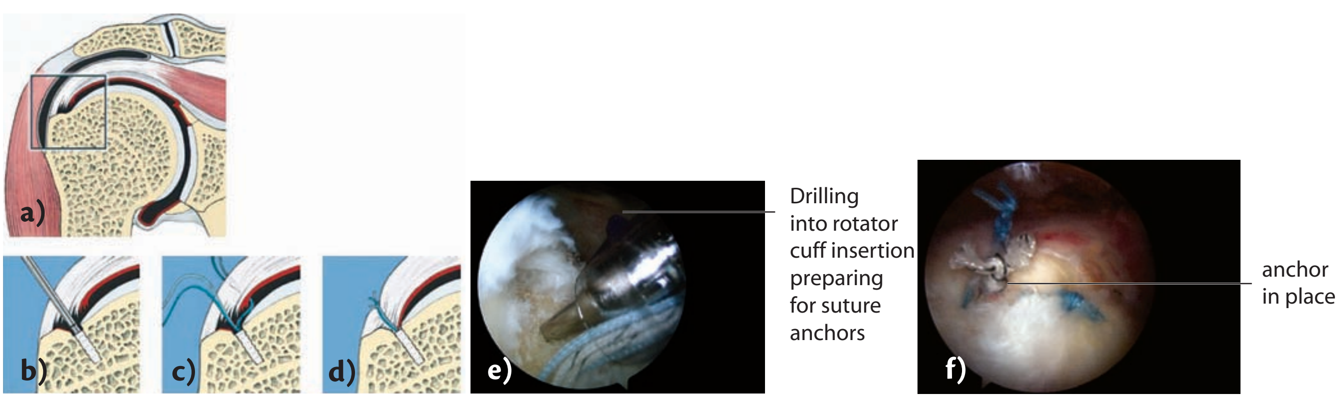


Figure 10.45 Surgery of a partial rotator cuff tear with anchoring the tendon to its insertion on the humerus. This can be done openly or with arthroscopy. **a)** Anatomical picture of a partial tear; **b)** anchor with double sutures are drilled into the insertion on humerus after local debridement; **c)** a couple of sutures are taken out separately through the tendon; **d)** the sutures are knotted and are pulled out lateral of the tendon; **e, f)** repair of a rotator cuff tear with arthroscopy (courtesy of Prof. Marc Safran, Stanford University, California, USA).

rehabilitation program under supervision is important for this injury.

It is important that the rehabilitations program is initiated with an experienced physical therapist and with gradually increasing intensity.

Return to sporting activity

Athletes with conservatively treated traction overload tendinitis may often be able to return to sports 3–4 months after the onset of symptoms. Athletes with partial rotator cuff tears may need 4–6 months before they return to sports after surgical treatment; athletes with complete rotator cuff tears may need even longer. A tennis player can often start playing again 4–6 months after the injury, but has to be careful with the serve for up to 1 year after the injury. ROM and conditioning exercises should start as soon as possible. Lifting and throwing exercises are prescribed individually and should usually be avoided for the first 3–4 months after surgery. A pitcher in baseball may need over 1 year of rehabilitation before he can return to competition.

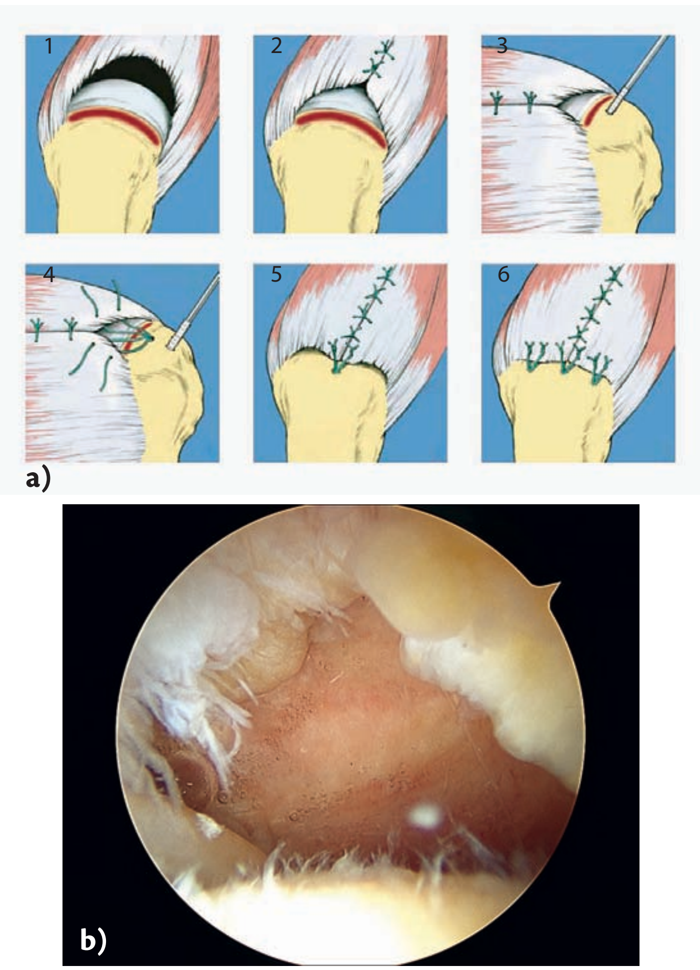


Figure 10.46 Surgical technique open or with arthroscopy for treating chronic complete rotator cuff tear. **a)** 1: Tear of the rotator cuff at the insertion on the humerus. The tendon is retracted and the caput can be seen; 2: the insertion site for the tendon is debrided and the tendon edges are trimmed; thereafter the edges are adapted from side to side; 3: suture anchors are drilled into the humerus; 4: the sutures are placed through the tendon edges from inside and out; 5: the sutures are tied to each other and give a central anchoring of the tendon; 6: another two suture anchors will complete the fixation; **b)** complete rotator cuff tear seen at arthroscopy (courtesy of Prof. Marc Safran, Stanford University, California, USA).

A neglected rotator cuff tendon tear can cause permanent disability due to impaired function. This injury can sometimes be surgically repaired at a later date, but the longer the wait, the lower is the chance of a successful outcome.

Tip

Rotator cuff ruptures always take a long time to treat and heal, so special attention and patience is essential. There is a high risk of re-injury unless good strength training is carried out and these injuries are treated properly.

A stable repair of the rotator cuff results in a more functional shoulder, compared with other surgical techniques.[9]

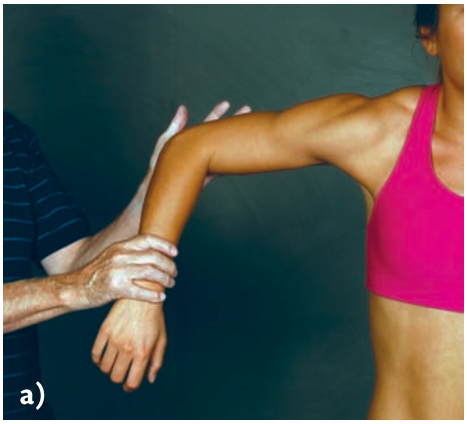
Injury of the subscapularis tendon

The subscapularis muscle (which originates on the inner surface of the scapula, runs anterior to the shoulder joint, and is inserted high into the anterior aspect of the head of the humerus) is the most important internal rotator of the upper arm. Its tendon can be affected by partial or total ruptures. A partial rupture, which is most common, may heal with thickening of the tendon as a result. A complete rupture is uncommon but can occur in conjunction with dislocation of the shoulder joint.

Throwers and athletes whose sports require repetitive overhead activity most commonly suffer from injury and degeneration of the subscapularis tendon. Such sports include baseball, American football (mostly quarterbacks), racquet sports, javelin, team handball, wrestling, weightlifting, and goalkeeping. Tennis players and volleyball players make a similar movement when serving or smashing, but they keep the elbow joint bent until it is extended at the moment of impact.

Symptoms and diagnosis

- Internal rotation is limited (Fig. 10.47).
- Pain is felt on moving the shoulder joint, particularly when the arm is held above the horizontal plane and is turned inwards.
- Pain is initiated by rotating the arm inwards against resistance. Another application is the 'lift-off' test – Gerber´s test for subscapularis injury (Fig. 10.48).
- Tenderness is found when direct pressure is applied against the tendon and the tendon attachment anterior to the shoulder (Fig. 10.49).
- The power of the arm is impaired during movements involving inward rotation.



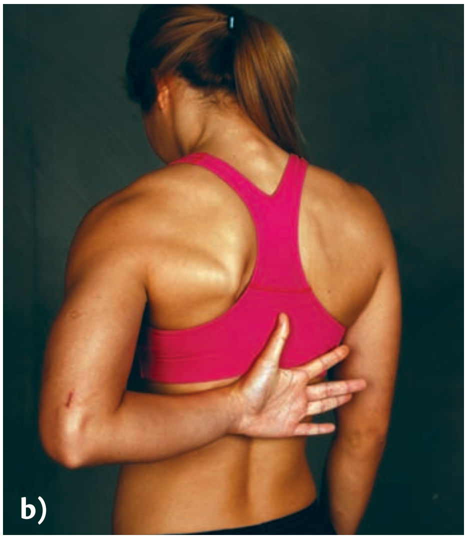


Figure 10.47 Internal rotation can be tested in different ways. **a)** Active; **b)** passive.

Figure 10.48 'Lift-off' test – Gerber's test for subscapularis injury. The arm is rotated internally so that the dorsal aspect of the hand will rest against the lower back. The athlete presses the hand actively away from the back against resistance, thereby testing the integrity of the subscapularis.

Figure 10.49. Injury to the subscapularis can cause tenderness on palpation or pressure directly against the tendon and its insertion.

Treatment

The athlete should:

- Start active mobility training.
- Avoid pain-causing situations.
- Apply local heat and use a heat retainer after the acute phase.
- See a physician if pain is severe.

The physician may:

- Advise active flexibility training (p. 251).
- Prescribe anti-inflammatory medication.
- Arrange physiotherapy with flexibility training and heat treatment.
- When symptoms are chronic, administer a steroid injection around but not in the tendon, followed by a few days of rest.
- Recommend surgery in chronic cases. Sometimes arthroscopy can be of value.
- Surgical treatment can be difficult or impossible to perform on 30% of extensive rotator cuff ruptures. The need to use other tendons may exist. Artificial biodegradable mesh is used as reinforcement of the weakened tissues by suturing it to the repair area. In the elderly, a prosthesis is sometimes used.

Healing and complications

With appropriate treatment, the injured athlete can, in most cases, resume training after 1–3 weeks. If signs of injury in the subscapularis tendon reappear, the athlete should rest from sporting activity until symptoms resolve and consult a physician. Otherwise, the injury may become chronic and force the athlete to interrupt training for several months or even give up the sport completely.

Thickened subacromial bursa

A previously unrecognized form of rotator cuff injury can occur in contact sports. After an acute traumatic injury to the shoulder, the athlete may develop weakness on elevation and external rotation. The clinical symptoms are the same as for a torn rotator cuff (p. 236). An MRI reveals only hypertrophic changes (enlargement and thickening) on the bursal side of the cuff. Symptoms may persist despite rehabilitation.

These patients can be treated arthroscopically. Diffuse proliferation of the subacromial bursa may be noted. After resection of the hypertrophic bursa the athlete tends to improve rapidly. This syndrome should be considered in an athlete with persistent cuff pain and weakness who participates in contact sports.

Calcific tendinitis

The degenerative changes that occur in the supraspinatus tendons as part of the aging process can, in combination with exertion, cause chronic inflammation with deposits of calcium (Fig. 10.50). This can occur in athletes as young as 30–35 years.

The calcium deposits can rupture into the bursa overlying the supraspinatus tendon; this brings about a temporary improvement of the condition but may then cause bursitis. Alternatively, the deposits can disappear spontaneously 2–3 weeks after formation, or simply remain without causing any symptoms. However, there is increased risk of relapse.

Symptoms and diagnosis

- Intense pain can begin suddenly in the anterior upper part of the shoulder. It can be so severe that it prevents sleep. It can at least partially be relieved by holding the arm still against the body.
- Because of the intense pain, a physician is often consulted early. The physician will detect a distinct tenderness over the anterior upper part of the shoulder, and X-rays will confirm the diagnosis.

Treatment

The athlete should:

- Maintain ROM after the acute phase to avoid stiffness.
- Take a pain-relieving preparation.

The physician may:

- Puncture and aspirate the calcium deposit.
- Administer a local anesthetic and steroid injection.
- Prescribe an analgesic preparation.
- Advise flexibility exercises (p. 251).
- If the pain is persistent, operate in order to remove the calcium deposit.

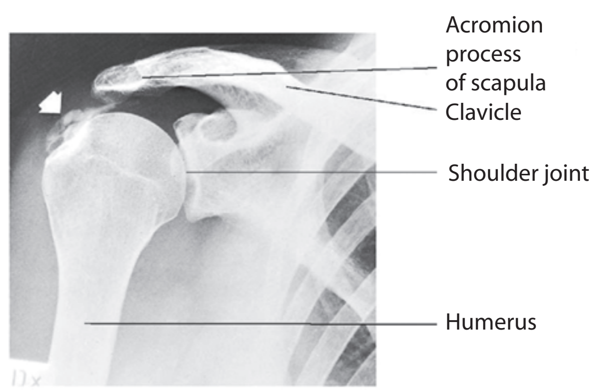


Figure 10.50 Calcific tendinitis.

Coracoid impingement syndrome

Coracoid impingement syndrome is an unusual syndrome that causes anterior shoulder pain. The space between the coracoid process and the anterior part of the humerus can be reduced by changes in the structures around the process. This can be seen as a result of fractures of the arm, calcification within the subscapularis tendon, abnormal orientation of the shoulder joint or simple prominence of the coracoid process itself. It is also seen as a complication of previous surgery for impingement, biceps tendon lesions or instability.

Symptoms and diagnosis

- The patient has anterior shoulder pain localized to the coracoid process.
- The patient has tenderness over the anteromedial shoulder at the location of the coracoid process.
- The pain is made worse by forward flexion and medial rotation combined with adduction (the arm is moved forward against the chest). This manoever can produce a painful click. This is called the coracoid impingement sign (Fig. 10.51).
- An injection of local anesthetic solution between the humeral head and coracoid process can give relief.
- A CT scan can assist with the diagnosis, showing a lengthening of the coracoid process and/or a decrease in the distance between the coracoid process and the humeral head.

Figure 10.51 Test for coracohumeral impingement including anterior internal rotation when the arm is brought in adduction against the chest.

Treatment

The treatment in chronic cases is the surgical removal or shortening of the outermost anterior part of the tip of the coracoid process. Active exercises are started 2–3 weeks after surgery, but heavy loading is avoided for 6 weeks to allow the tendons to heal back to the coracoid process. Return to sports is possible after 3–6 months.

Clavicular injuries

Fractures of the clavicle

Fractures of the clavicle occur as a result of a tackle or falling on the shoulder or the outstretched hand (Fig. 10.52). Clavicle fractures commonly occur during skiing, cycling, riding, and contact sports. The fracture is often located in the middle third or towards the outer third of the bone.

Symptoms

The area over the fracture is mostly very tender and swollen. Pain is felt when moving the shoulder. Crepitus, which is a crackling sensation, can be felt between the

Figure 10.52 a, b) Falls from cycling, speedway and similar sports can cause fractures.

bone ends when movement is attempted. The physician should listen to the lungs to exclude air in the pleura.

Treatment

Sometimes the arm is fixed to the body for a few days. Then, gradually ROM training of the shoulder and arm is introduced. A fracture of the clavicle can also be treated with a sling or figure-of-eight bandage to immobilize both shoulders (Fig. 10.53).

With the bandage in place, the arms can still be moved freely below the horizontal plane. This treatment is usually sufficient, but surgery may be necessary in certain cases, for example, if the fracture is situated at the lateral end of the bone and the fracture ends threaten to penetrate the skin (Fig. 10.54).

Healing

Fractures of the clavicle generally heal well. Conditioning exercises such as running should not be resumed until the fracture has healed or does not cause pain (about 3–8 weeks after the injury). Cycling and non-pounding activities can often be continued during the recovery period.

Separation of the acromioclavicular joint

Separation of the acromioclavicular joint is a relatively common injury in contact sports, riding, cycling, skiing, and wrestling. The joint is surrounded by ligaments running between the clavicle and the acromion process of the scapula (the acromioclavicular ligament), and is further stabilized by other ligaments running between the clavicle and the coracoid process of the scapula (the coracoclavicular ligaments). The joint sometimes contains a cartilaginous meniscus or disk.

The vast majority of acromioclavicular injuries are due to direct force produced by the athlete falling on the point of the shoulder with the arm in the adducted position (close to the body) or when an ice hockey player is tackled against the board. Force is transferred up the arm through the humeral head and the acromion process. Acromioclavicular joint injuries occur less commonly as a result of indirect force, for instance when the athlete falls on an outstretched arm.

Classification

These injuries may be classified according to the extent of ligamentous disruption to the acromioclavicular joint and coracoclavicular ligaments. The most common injury types in athletes are grades I–III; grades IV–VI are very rare (Fig. 10.55). They can be characterized as shown in Fig. 10.55.

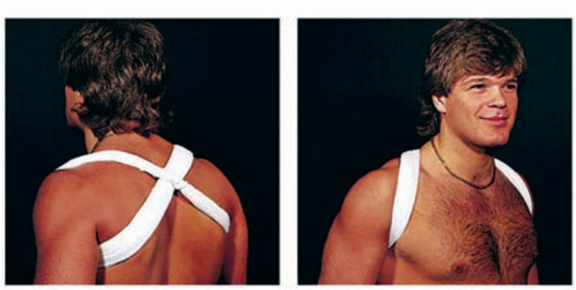


Figure 10.53 The clavicle fracture can be treated with a so called 'sling of eight'.

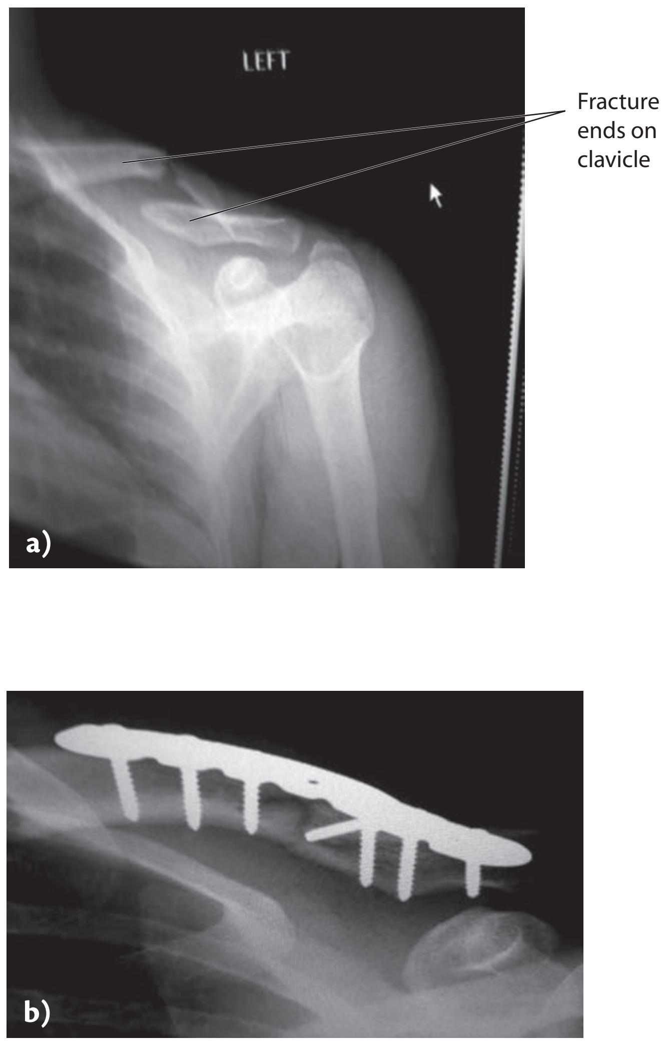


Figure 10.54 Fracture of the clavicle may occur after falls in cycling. **a)** Fracture of the clavicle; **b)** plate with screws is put in during surgery and thereby the fragments are brought and held in place. (Courtesy of Clay Sniteman, RPT, ATP World Tour.)

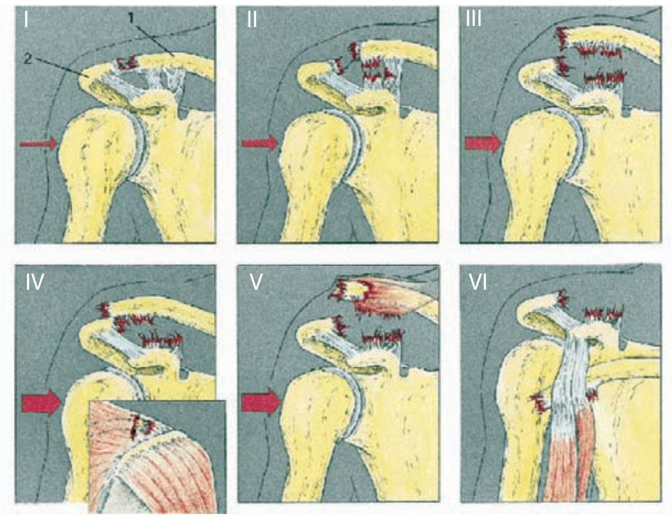


Figure 10.55 Schematic grading of injurires of the acromioclavicular joint. Grade I: a sprain of the acromioclavicular ligament, causing pain over the acromioclavicular joint and minimal pain with shoulder motion. There is mild tenderness; Grade II: disruption and widening of the acromioclavicular joint with some elevation of the distal end of the clavicle. There is moderate to severe pain near the acromioclavicular joint and shoulder motion is restricted. The athlete will usually withdraw from competition; Grade III: disruption and dislocation of the acromioclavicular joint with superior displacement of the clavicle. The coracoclavicular ligaments are disrupted and the coracoclavicular space is greater than in the normal shoulder. The upper extremity is seen to be depressed and the clavicle can be free-floating, possibly lifting the skin. Moderate to severe pain is present. There is tenderness over the joint. The athlete is usually unable to continue sports. The lateral end of the clavicle is reducible; Grade IV: the acromioclavicular joint is dislocated, with the clavicle displacing posteriorly into or through the trapezius muscle. The coracoclavicular ligaments are completely disrupted. The clinical findings are similar to type III injury, except that more pain is usually present and the clavicle is dislocated posteriorly and not reducible; Grade V: disruption of the acromioclavicular ligament as well as the coracoclavicular ligaments. The acromioclavicular joint is displaced with gross disparity between the clavicle and the scapula. The clinical findings are similar to type III, but there is more pain and displacement between the distal clavicle and acromion. The skin may be tented so much that there is a threat it will be penetrated. This injury is rarely seen in athletes; Grade VI: the acromioclavicular and coracoclavicular ligaments are disrupted and the joint is dislocated with the clavicle being displaced inferior to the acromion or the coracoid. The shoulder has a flatter appearance superiorly. This injury is rare in athletes owing to the great trauma necessary to produce the subcoracoid dislocation. There is a high incidence of associated fractures (see Fig. 10.54).

Symptoms and diagnosis

- A complete history will often secure the diagnosis.
- Pain is localized to the anterior superior aspect of the shoulder (Fig. 10.56A). The pain does not radiate and the severity is often proportionate to the degree of injury.

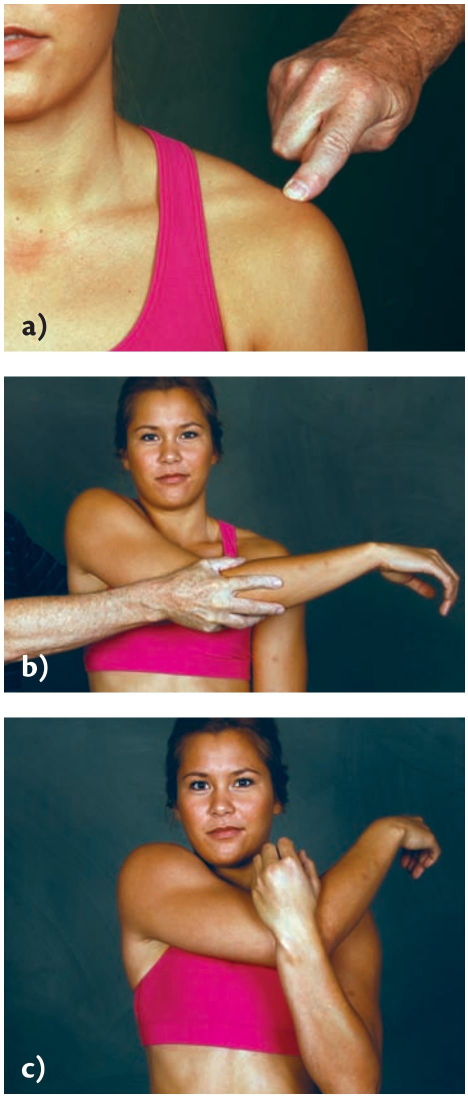


Figure 10.56 Acromioclavicular injuries often cause pain. **a)** Location for pain on palpation at the anterior aspect of the shoulder; **b, c)** pain may be experienced when the arm is passively or actively moved towards the shoulder.

- Physical examination shows swelling, abrasion, skin color changes (ecchymoses), and sometimes deformity of the joint. The involved arm is usually held at the side and all shoulder motions are restricted because of pain.
- There is localized tenderness over the joint.
- Clinical tests for acromioclavicular joint injuries: pain often occurs when the arm is passively adducted (passive adduction, Fig. 10.56B, C). In this test, the patient is seated. The arm is elevated to 90°, i.e. the shoulder plane. The arm is then brought over the chest in a passive adduction. If there is pain the examiner should suspect damage to the joint.
- Injection of local anesthetic solution may relieve pain.
- Depending on the degree of separation, the lateral end of the distal clavicle may be displaced upward. A partial separation (grade I and II) involves tearing

of the acromioclavicular capsule and ligaments, and a complete separation (grade III) will also have a complete tear of the coracoclavicular ligament.
- The diagnosis is confirmed by X-ray, which is more likely to reveal the abnormality if it is carried out with the joint loaded. In grade III separation, there is no contact between the articular surface.

Treatment

The physician may:

- Prescribe early mobility exercises, especially in grade I–III injuries.
- Use a bandage to reduce the clavicle back into position. The results of this technique are limited.
- Recommend surgery in grade IV–VI lesions. The treatment of grade III injuries remains controversial, but there is a definite trend toward nonoperative management with early mobilization. A surgical approach should be considered in young athletes (15–25 years) in sports with overhead activities. With nonoperative management the athlete may have a residual displacement but the end result and function are largely the same. In most cases, therefore, early symptomatic treatment is recommended with progression to resistance exercises as soon as tolerated. The athlete can return to sports when there is pain-ROM, which usually occurs in 4–8 weeks.

Healing and complications

In grade I and II injuries degenerative changes and arthritis occur in the joint in 8–9% of cases. If this injury continues to cause pain, an excision of 1 cm (0.4 in.) of the distal end of the clavicle is indicated. This usually results in early pain-free return to sports. If there is residual pain or disability interfering with performance after a grade III injury, an excision of the distal clavicle may be indicated, with restoration of the coracoclavicular ligaments. Return to sports is usually possible within 2–3 months.

Chronic acromioclavicular joint injury

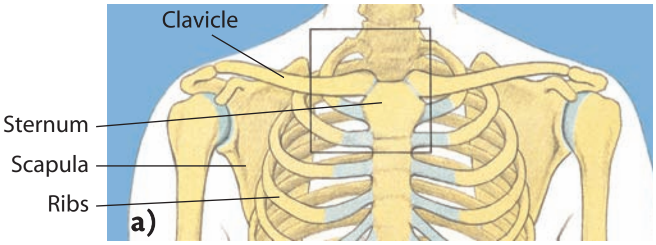
Persistent pain after acromioclavicular joint injury may necessitate surgery, which includes removal of the lateral end of the clavicular bone.

Separation of the sternoclavicular joint

The sternoclavicular joint is seldom separated, but it is an important injury to recognize (Fig. 10.57). The medial end of the clavicle, and hence the shoulder, is anchored to the sternum by the sternoclavicular ligaments. The joint cavity lies obliquely and contains a meniscus (disk). If the shoulder is subjected to a violent impact, the sternoclavicular joint can slip and the ligaments can tear, causing the medial end of the clavicle to move either in an anterior direction making it more prominent, or posterior.

Symptoms and diagnosis

- Pain may be located towards the shoulder region rather than in the sternoclavicular joint itself.
- Tenderness occurs when pressure is applied to the joint (Fig. 10.58).
- The clavicle is usually only partially separated, but its medial end can be completely detached from the sternum.
- An X-ray and CT scan should be obtained.
- If the clavicle is displaced backwards (posteriorly) towards the major blood vessels, life-threatening injury can occur.



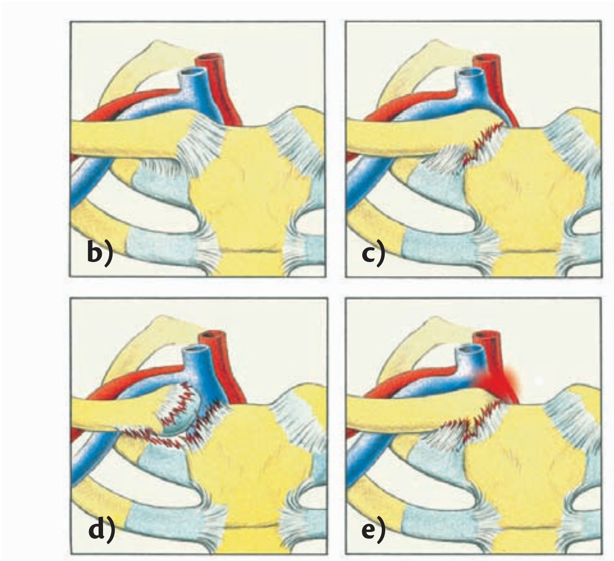


Figure 10.57 Separation of the sternoclavicular joint. **a)** The framed part shows a normal anatomy for the joint between the clavicle and the sternum; **b)** normal joint between the clavicle and the sternum. Notice the closeness to the large vessels going to the head and the arm; **c)** partial separation of the joint between clavicle and the sternum. Ligaments and joint capsule are ruptured; **d)** complete separation between the clavicle and the sternum combined with avulsion of the ligament between the clavicle and the first rib; **e)** the end of the clavicle can penetrate into the large vessels lying just posterior and cause a bleeding and thereby create a life-threatening condition.

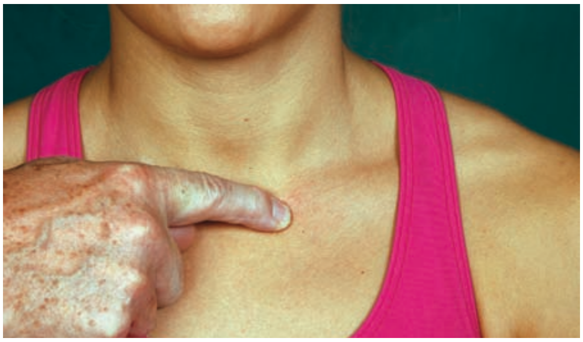


Figure 10.58 Tenderness on palpation over the joint.

Treatment

The physician may:

- In cases of partial separation, suggest that the injured person rest for 1–2 weeks with mobilization of the shoulder as tolerated.
- In cases of posterior separation, make sure that there is no pressure or damage to the underlying vessels. Surgery is indicated in cases of complete posterior dislocation.
- Operate in cases with chronic pain or major discomfort. The surgery usually involves excision of the medial end of the clavicle bone.

Healing

In cases of partial separation of the sternoclavicular joint, the injured athlete can generally resume sporting activity early; however, pain and other symptoms may remain for several months.

Nerve injuries in the shoulder region

Nerve damage in the shoulder region is uncommon but should nevertheless be considered. It occurs mainly after injuries caused by impact and external pressure but it can also occur as a result of overuse.

Injuries to the suprascapular nerve

The suprascapular nerve supplies the supraspinatus and infraspinatus muscles. It runs in a groove on the upper edge of the scapula, and is held in the groove by a ligament. The suprascapular nerve can be damaged at the time of forward or backward dislocation of the shoulder joint, with the dislocation stretching the nerve over the edge of the scapula (Fig. 10.59). In addition, the nerve can be damaged by a direct blow to the scapula, by external pressure (e.g. from a backpack) or by repetitive, one-sided overhead motions of the shoulder, which cause tension in the nerve. Damage can also be caused by a local cyst.

Symptoms and diagnosis

- Pain radiates out toward the upper posterior part of the shoulder.
- Weakness in the supraspinatus and infraspinatus muscles is manifested by impaired abduction of the shoulder joint to an angle of 80–120°.
- Decreased volume (hypotrophy) of the supraspinatus and (especially) infraspinatus muscles can be pronounced and readily noticeable.

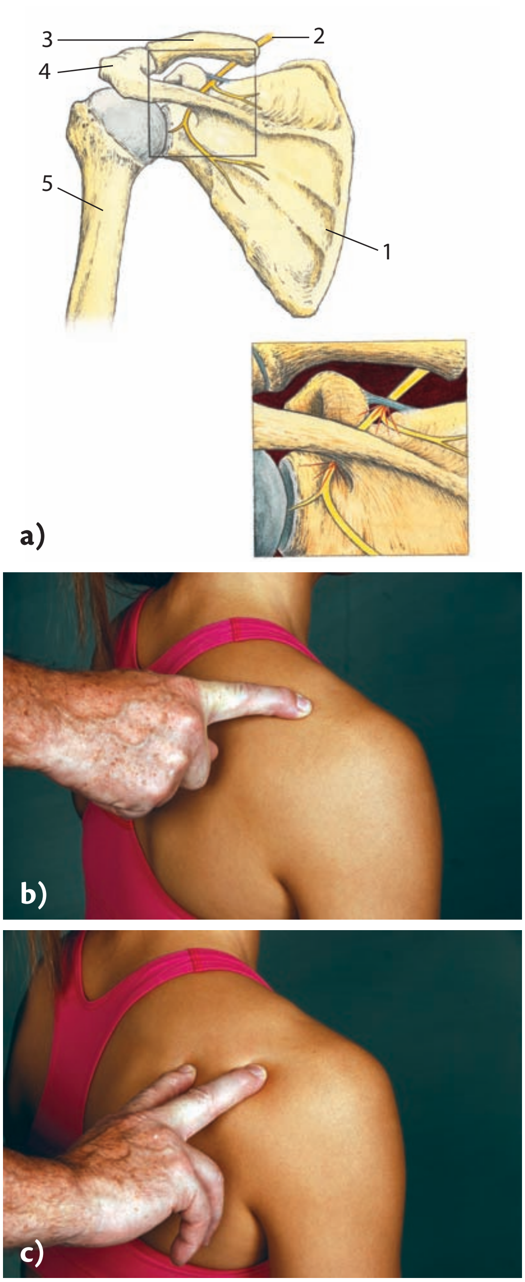


Figure 10.59 a) The passage of the suprascapular nerve over the upper edge of spina scapulae. 1. Scapula 2. Suprascapular nerve 3. Clavicle 4. Acromion 5. Humerus; b) the point where the suprascapular nerve passes the spina scapulae; c) localisation of the passage of the nerve.

- Electromyographic examination will confirm the diagnosis.
- If only the infraspinatus is involved, compression of the nerve passing the spina scapulae should be suspected.

Treatment

- Avoiding use if there is pain.
- Flexibility training and, if there is no pain, strength training.
- Local steroid injection.
- If the complaints persist, surgery to free the nerve by cutting the overlying ligament.
- Neurolysis (release of the nerve), which should be performed distal to the spine.

Injuries to the axillary nerve

The axillary nerve supplies the deltoid and teres minor muscles and runs close to the shoulder joint. Damage to this nerve usually occurs as a complication of dislocation or fracture of the upper part of the humerus. The symptoms include radiating pain and impaired sensation over the lateral aspect of the upper arm, along with weakness (due to paralysis of the deltoid muscle) when the arm is abducted.

Since the course of the axillary nerve wraps around the upper part of the humerus close to the bone, a hard blow to this area can sometimes injure it. However, the symptoms are usually transitory.

Injuries to the long thoracic nerve

The long thoracic nerve supplies the serratus anterior and latissimus dorsi muscles which holds the scapula in position. An isolated injury to this nerve can occur during violent shoulder movements, e.g. during weightlifting. Backstroke swimmers may also sustain similar damage as their arm is moved through a combination of external rotation and forwards and upwards lifting.

When the long thoracic nerve is damaged, there is usually a dull ache which disappears spontaneously. The ability to lift the arm is impaired and, at the same time, 'winging' of the scapula is seen (Fig. 10.60B), i.e. the medial side of the scapula protrudes backwards on the damaged side.

One way of revealing the injury is to ask the athlete to perform press-ups (push-ups) against a wall (Fig. 10.60A); the medial side of the scapula will protrude posteriorly. The treatment consists of anti-inflammatory medication and gradually increasing strength training.

Brachial plexus injuries (Burner syndrome)

Burner syndrome is not uncommon in contact sports such as American football. Following trauma to the head and shoulders, the athlete complains of a burning pain and numbness extending down the upper extremity. The cause of this pain may be a traction injury to the brachial plexus (nerve bundle between the shoulder and the neck) and/or cervical nerve roots (typically the C5 and C6 roots). The extremity can feel weak and heavy for a short time, but these problems usually resolve within several minutes.

If there are prolonged motor and sensory deficits, these may represent a more severe injury. The athlete should not return to contact sports until a clinical examination, including electromyography (EMG) and strength evaluation, has been carried out, and strength has returned to normal. It is important to differentiate a brachial plexus injury from a serious neck or spine injury. If there is any neck pain or tenderness, the athlete's neck should be immobilized and an emergency evaluation performed.

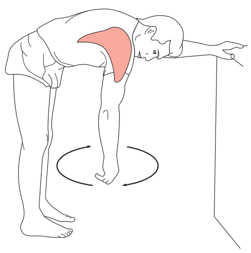
Injury to the brachial plexus can also occur without an inciting traumatic event and is characterized by acute onset of persistent severe pain. There may be a motor loss, but sensory loss is usually minimal. Treatment includes rest followed by rehabilitation. Weakness may persist for long periods or may be permanent.

Figure 10.60 Scapula dyskinesis. The position of the scapula can be studied by asking the injured patient to perform push-ups against a wall. **a)** Normal position; **b)** scapula on the left is winging, i.e. moving asymmetrically. (Courtesy of Prof. Marc Safran, Stanford University, California, USA.)

Rehabilitation of the shoulder and upper limb

There are several common issues to be remembered when dealing with shoulder rehabilitation, despite the wide variety of injuries that may be sustained by the shoulder complex.

- The shoulder girdle is a series of complex joints and articulations that function together to provide smooth, rhythmic, and coordinated movement. The complexity of this combination of joints and its heavy reliance on soft tissues to provide both dynamic and static stability often make the shoulder a difficult rehabilitation challenge.
- The rotator cuff and the periscapular muscles must be rehabilitated together to maintain the dynamic stability of the shoulder girdle.
- Weakness in the stabilizers of the scapula changes the biomechanics of the shoulder girdle: there is abnormal stress in the anterior capsule, greater compression of the rotator cuff and decreased activity of the rotator muscles.
- Normal ROM of the shoulder girdle must be achieved to maintain rhythmic scapulothoracic and glenohumeral motion. This should include both capsular motions and muscular soft tissue flexibility. Increased thoracic curvature (kyphosis) results in decreased glenohumeral mobility.
- An understanding of the biomechanics and joint kinematics of the shoulder movements and the demands of various sports and activities is necessary to provide important information about the injury and the rehabilitation needs.



Shoulder ROM exercises

Pendulum exercises

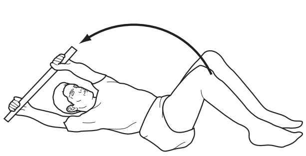
The goals of pendulum exercises are threefold: to improve muscular relaxation; to establish a limited arc of pain-free, relaxed motion; and to prepare the shoulder complex for additional activity.

- Stand, holding on to a stable object with the uninvolved arm.
- Bend over slightly at the waist and let the involved arm hang straight down, relaxing all the shoulder muscles.
- Swing the arm gently (a) forward and back, (b) side to side, and (c) in circles, first clockwise and then counterclockwise, increasing the diameter of the circle.
- Using the momentum of the swing, keep the muscles as relaxed as possible.
- Repeat 10–15 times each way.

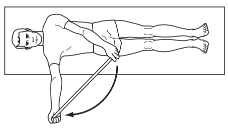
Their pain-relieving and relaxation-enhancing qualities make pendulum exercises a good choice also for 'cooling down' exercises.

Cane-assisted exercises

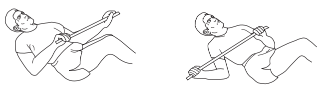
Using a cane, a stick or a broom handle, the uninvolved arm is used to assist the involved arm in increasing the ROM.



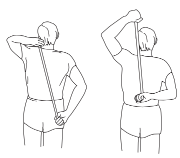
- **Forward flexion:** lying on your back, grasp the cane with both hands, shoulder width apart, palms down. Start with the cane resting across the hips. Lift the cane with straight arms out in front of you, as high as you can until a stretch is felt (assisting the involved arm with the uninvolved arm). Pause at the top for 5 seconds, then return to the starting position. Repeat 10 times.



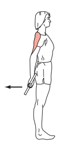
- **Abduction:** lying on your back, grasp the cane with both hands, palms down, shoulder-width apart. Start with the cane resting across the hips. Using the cane, push your involved arm out to the side, as high as you can. Pause at the top for 5 seconds, then return to the starting position. Repeat 10 times.



- **Internal/external rotation:** lying on your back, grasp the cane with both hands, elbows bent to 90°, hands shoulder-width apart. Using the cane, keep your elbows tucked in to your waist, and rotate the involved arm out to the side as far as you can. Hold for 5 seconds, then return to the starting position. Repeat 10 times. Repeat the exercise, rotating your arm across your body in the other direction.

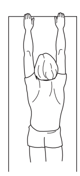


- **Internal rotation behind back:** hold the cane behind your back, with the uninvolved arm at the top. Use this arm to pull the involved arm up your back as far as you can. Hold for 5 seconds, then return to the starting position. Repeat 10 times.

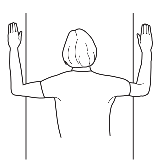


- **Extension:** stand with your arms at your side, elbows straight. Hold the cane behind your back with both hands, palms facing away from you. Slowly push the cane away from your body. Hold for 5 seconds, then return to the starting position. Repeat 10 times.

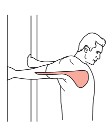
Upper extremity stretching



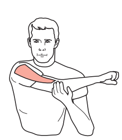
- **Latissimus and teres major stretch:** facing a doorway, hook the fingertips of the involved arm over the top of the door molding. Lean forward through the doorway. Feel the stretch along the underside of the arms. Hold 20 seconds, repeat 5 or 6 times.
- Lay supine on the ground, extend your arm overhead. Turn your palms towards the ceiling and press chest onto the thighs.



- **Pectoralis stretch:** stand in a doorway with elbows bent 90° and upper arms held parallel to the floor. Hold the elbows against the door jamb and lean forward. The arms stretch backwards as the body pushes forwards. The stretch should be felt across the front of your shoulders. Hold 20 seconds, repeat 5 or 6 times.

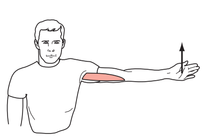


- **Pectoralis, biceps, deltoid stretch:** stand in a doorway with your hands behind you at shoulder level. Grab the door jamb with thumbs pointed upwards. Lean forward through the doorway keeping your elbows straight. The stretch should be felt across the front of your chest. Hold 20 seconds, repeat 5 or 6 times.

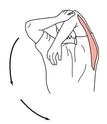


- **Deltoid/rhomboid stretch (posterior capsule):** grasp the elbow of the involved arm with the uninvolved arm. Pull the involved arm across the chest at shoulder level. The stretch should be felt behind the involved shoulder and across the back of the upper arm. Hold 20 seconds, repeat 5 or 6 times.

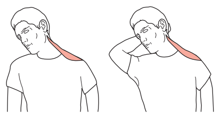
- **Triceps stretch (inferior capsule):** raise the involved arm overhead. Bend the elbow down behind the head. Using the other arm, gently pull the elbow of the involved arm behind your head. The stretch should be felt along the back of the upper arm. Hold 20 seconds, repeat 5 or 6 times.



- **Biceps stretch:** hold the involved arm straight out to the side at shoulder height. Start with the palm facing up, then turn the palm down toward the floor. Slowly bring the arm back behind you, keeping the elbow straight. Feel the stretch across your upper arm. Hold 20 seconds, repeat 5 or 6 times.

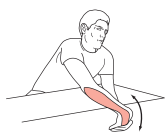


- **Latissimus dorsi:** repeat the triceps stretch and side-bend the trunk to the opposite side. Feel the stretch along the trunk. Hold 20 seconds, repeat 5 or 6 times.

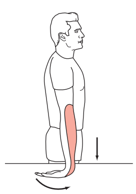


- **Levator stretch:** sitting, lean your head forward on a diagonal, looking toward your right elbow. Feel the stretch down the left side of your neck, shoulder, and upper back. Repeat to the other side. Hold 20 seconds, repeat 5 or 6 times.

- **Wrist flexor stretch:** straighten your elbow completely and, with palm downward, grasp your hand with the other hand. Pull wrist back as far as possible. The stretch should be felt along the bottom of your forearm. Hold for 15–20 seconds, repeat 5–6 times.



- **Wrist extensor stretch:** straighten your elbow completely and, with palm downward, grasp your hand with the other hand. Push wrist down as far as possible. The stretch should be felt across the top of your forearm. Hold for 15–20 seconds, repeat 5–6 times.
- **Infraspinatus stretch:** lay on you back with one of the arms extended towards the side. Flex the elbow to 90°. Use the other arm to press the hand down towards the ground as far as possible.

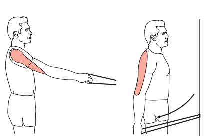


- **'Tennis elbow' stretch (wrist extension/pronation stretch):** stand with the back of the involved hand resting on a table, while keeping the elbow straight. Exert a downward force toward the table. Grasp the involved hand with the other hand and rotate the wrist and hand of the involved side to the outside, while maintaining a bent wrist. The stretch should be felt across the top of the forearm and top of the wrist. Hold for 15–20 seconds, repeat 5–6 times.

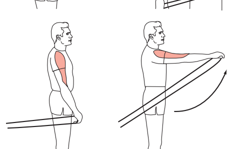
Shoulder strengthening

Rubber tubing exercises

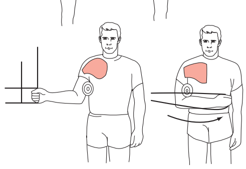
Fasten a piece of rubber tubing to a stable object such as a door or heavy piece of equipment or furniture. Tie a knot in the other end, to hold. Each exercise should be performed in a slow, controlled manner to minimize momentum. Perform 2 or 3 sets of 10–15 repetitions. The trunk must be kept stable throughout exercises.



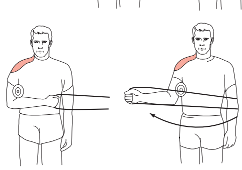
- **Shoulder extension (latissimus dorsi, triceps, teres major):** stand facing the tubing, with the involved arm fully extended. Pull the tubing straight back, keeping the arm straight. Slowly return to the starting position. Repeat.



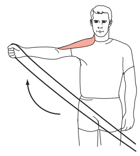
- **Forward flexion (anterior deltoid, biceps, infraspinatus):** stand facing away from the tubing, involved arm extended and down by your side. Keeping the arm straight, lift it forward to shoulder height. Slowly return to the starting position. Repeat.



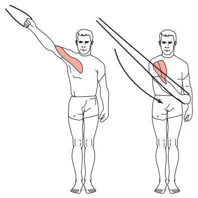
- **Internal rotation (subscapularis, pectoralis):** stand sideways with the involved shoulder closest to the tubing, elbow bent to 90°. Squeeze a rolled-up towel between your side and elbow. Grasp the tubing in your involved hand, and by rotating your arm from the shoulder, pull the band across the front of your body, keeping your elbow tucked into your side. Slowly return to the starting position. Repeat.

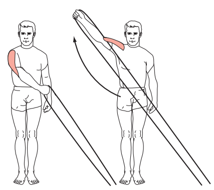


- **External rotation (teres minor, infraspinatus):** stand sideways with the uninvolved shoulder closest to the tubing, elbow bent to 90°. Squeeze a rolled-up towel between your side and your elbow. Grasp the tubing with your involved hand, and by rotating your arm from the shoulder, pull the tubing away from your body, keeping your elbow tucked into your side. Do not pull far enough to create pain in the shoulder. Slowly return to the starting position. Repeat.



- **Abduction (deltoid, supraspinatus):** stand sideways with the uninvolved shoulder closest to the tubing, arm straight at your side. Lift the tubing away from your body to shoulder height while turning your thumb up. Slowly return to the starting position. Repeat.

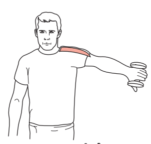




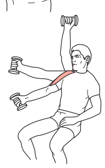
- **Diagonal patterns:** (1) stand sideways with the involved shoulder closest to the tubing and the arm out straight with palm facing forward. Pull the arm down and across your body towards opposite hip. Slowly return to the starting position. Repeat; (2) stand sideways with the involved shoulder away from the tubing. Position your arm diagonally across your body with the palm facing backwards. Pull the arm up and across your body as shown. Slowly return to the starting position. Repeat.

Isolated shoulder exercises

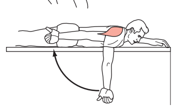
Exercises of the shoulder should train for both acceleration and deceleration. The following exercises isolate specific musculature surrounding the shoulder. They are vital to the proper functioning of the rhythmic movement of the shoulder complex. They should be performed precisely and with small weights (0.5–1.5 kg, 1–3 lb) held in the hand. The weights should be light enough that the motion can be completed without any pain. Perform 2 or 3 sets of 10–15 repetitions (depending upon the sport).



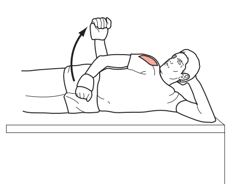
- **'Empty can' exercise (supraspinatus):** stand with the elbow straight and thumb rotated inwards. Raise your arm diagonally out to the side to 45° from the body, keeping your thumb pointing downwards. Stop at shoulder height. Hold for 3 seconds and slowly lower. Repeat.



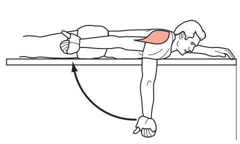
- **Elevation in the scapular plane (scapular stabilizers):** standing with elbow straight and thumb rotated upwards, raise your arm overhead diagonally away from your body to 45°. Hold for 3 seconds and slowly lower. Repeat.



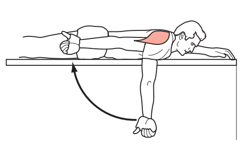
- **Prone shoulder extension (rhomboid, latissimus, teres major):** lay face down on a table or the edge of a bed, with your involved arm hanging straight down. Keeping the elbow straight, with the thumb rotated inwards, raise your arm backwards to the level of the table. Hold for 3 seconds and slowly lower. Repeat.



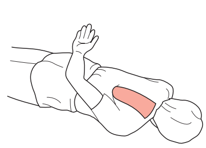
- **Side-lying external rotation (teres minor, infraspinatus):** lay on your uninvolved side with the involved arm resting on your body, elbow bent to 90°. Keeping the elbow of the involved arm fixed to your side, rotate your arm, from the shoulder, outwards. Hold for 3 seconds and slowly lower. Repeat. This exercise should not be taken to the point of pain, and in certain cases should be limited in range.



- **Prone internal/external rotation (infraspinatus, subscapularis, scapular stabilization):** lay face down on a table with your shoulder out to the side at 90°, your elbow bent to 90°, and your palm facing the floor. Keeping your upper arm supported by the table, slowly rotate your shoulder outwards and then inwards as far as possible. Hold for 3 seconds at each position and slowly lower. Repeat.

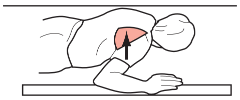


- **Prone rowing (scapula stabilizers, triceps, posterior deltoid, teres major):** lay face down on a table, arm hanging straight down. Lift your arm, leading with your elbow towards the ceiling, pinching your shoulder blades together as you lift. Hold for 3 seconds and slowly lower. Repeat.

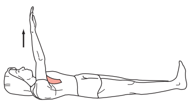


- **Hands off back (rhomboids, suprascapularis):** lay face down, place your involved arm behind your back on your buttocks, elbow slightly bent. Lift your arm towards the ceiling, trying not to straighten your elbow. Make sure to lift from the shoulder as you lift your whole arm towards the ceiling. Hold for 3 seconds and slowly lower. Repeat.

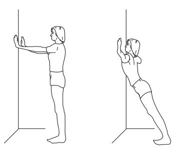
- **Lift over head (lower trapezius):** lay face down, arms straight out overhead, elbows straight. Raise your arms up off the floor as far as possible. Be sure to keep your head and scapulae down. Hold for 3 seconds and slowly lower. Repeat. Alternatively, use diagonal movements of the arms (one up, one down) and alternate.



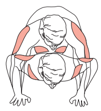
- **Lift off arm (middle trapezius):** lay face down with your arm out to the side at 90°, your elbow bent to 90°, and your palm facing the floor. Lift your entire arm as one unit towards the ceiling, pinching your shoulder blades together as you lift. Be sure to keep your head down. Hold for 3 seconds and slowly lower. Repeat.



- **Scapular protraction (serratus anterior):** lying on your back, raise your involved arm straight toward the ceiling keeping the shoulder at 90° to the floor, elbow straight. Lift your arm towards the ceiling as one unit (your shoulder blade should lift off the floor). Hold for 3 seconds and slowly lower. Repeat.



- **Wall push-ups (scapula stabilizers):** stand in a corner, with your feet about one pace back from the wall. Place your hands on the wall(s) at shoulder height. Slowly lean into the corner, then push back out. Repeat. Alternatively, fall forward into the corner with raised hands.



- **Push-ups with a plus (scapula stabilizers):** perform a standard push-up. Once elbows are straight, try to 'push-up' further by rounding your shoulders. Hold for 3 seconds and slowly lower. Repeat.

Shoulder stability training

Shoulder stability training is of great importance for the shoulder joint's anatomical structure, i.e. to create a large range of motion at the expense of stability. Stability training is intended to counter a sway in one or more joints in a static position or in a specific motion and it includes strength, coordination, balance and body awareness.

It is important to improve the 'muscular timing', i.e. the muscles are working at the right moment, with the right effort and with the right speed. In rehabilitation, stability is initially trained on a stable surface and progresses to an unstable surface.

Rehabilitation program

Rehabilitation programs for specific injuries are presented in Table 10.1 Impingement syndrome, and Table 10.2 Forward dislocation of the shoulder joint.

Table 10.1 Rehabilitation protocol for impingement syndrome

	Early phase	Intermediate phase	Late phase	Return to activity
Goal	Decrease pain and inflammation Restore joint and capsular motion	Develop strength of rotator cuff and periscapular muscles Full pain-free AROM	Refine strength imbalances Increase muscular endurance	Functional progression into activity
Manual therapy	Posterior capsular stretching	Continue capsular stretching	Continue capsular stretching	
ROM	Cane-assisted exercises: – IR/ER – IR behind back – Extension – Forward flexion	Continue if deficits remain	Continue if deficits remain	

Table 10.1 Rehabilitation protocol for impingement syndrome

	Early phase	Intermediate phase	Late phase	Return to activity
Strengthening	Isometrics: IR, ER, abduction, extension, flexion Isolated shoulder exercises: – prone extension – prone rowing – serratus anterior – side-lying ER	Continue previous program Add isolated shoulder exercises: – 'empty can', 'filled can' – lower trapezius – middle trapezius – rhomboid – prone IR/ER	Continue previous program Add: – rubber tubing exercises – diagonal rubber tubing exercises – push-ups with a plus – wall push-ups Isotonic upper extremity strength training machines	Continue isotonic upper extremity strength training machines Continue comprehensive strengthening program focusing on periscapular and rotator cuff muscles Include eccentric exercises
Stretching	Deltoid/rhomboid stretch Pectoralis stretch	Abduction, flexion in doorway Biceps stretch	Continue stretching Pectoralis stretch	Continue upper extremity stretching
Functional/ Proprioceptive	Neuromuscular firing patterns	Light sports activity below the horizontal plane if painless (exercises with physical therapy balls)	Simulated sport activity with rubber tubing, weighted balls; deceleration exercises (catching balls)	Return to sport if full pain free motion, full strength

AROM, active range of motion; ER, external rotation; IR, internal rotation; ROM, range of motion.

Table 10.2 Rehabilitation protocol for anterior glenohumeral dislocation

	Immobilization phase (0–3 weeks)	Early phase (3–6 weeks)	Intermediate phase (6 weeks–3 months)	Late phase (over 3 months)	Return to activity
Goal	Heal joint capsule, trauma Reduce/control pain	Initiate and maintain ROM	Normalize ROM Aggressive strength training	Normalize strength Functional progression of activities	Prepare for return to activity
ROM	In sling fulltime Pendulum exercises AROM of elbow, wrist, hand	Pendulum exercises Cane-assisted exercises: flexion, extension, abduction Avoid combined abduction and ER	Continue ROM exercises Avoid combined abduction and ER	Abduction with ER allowed	
Stretching	None	None	None	Upper extremity stretching program	Upper extremity stretching program
Strengthening	Isometric strength training Scapula stabilization	Isolated shoulder exercises: – PNF? – prone shoulder extension – prone rowing – serratus anterior – side-lying ER, limited ROM anterior – rhomboid Rubber tubing exercises: IR/ER, limited ROM, flexion, extension	Continue previous exercises Add isolated shoulder exercises: – lower trapezius – middle trapezius – prone IR/ER – Scaption Push-ups with a plus Isotonic upper extremity strength training machines	Continue previous program Add: – multiplane exercises – diagonal strengthening – push-ups with a plus – wall push-ups	Continue previous program

contd...

Table 10.2 Rehabilitation protocol for anterior glenohumeral dislocation (*contd...*)

	Immobilization phase (0–3 weeks)	Early phase (3–6 weeks)	Intermediate phase (6 weeks–3 months)	Late phase (over 3 months)	Return to activity
Functional/ proprioceptive	None	None	Light sport-specific exercises	Simulated sport activity with rubber tubing, weighted balls	Return to sport when ROM and strength are normal

AROM, active range of motion; ER, external rotation; IR, internal rotation; PNF, proprioceptive neuromuscular facilitation; ROM, range of motion.

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Further reading

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11 Injuries to the Upper Arm

Injuries to the upper arm in association with sports are relatively few. The most common are those involving the biceps muscle and its tendon, that can be damaged both proximally in the shoulder where the tendon is attached, in the groove on the upper arm and in the attachment on the elbow (Fig. 11.1). The major pectoral muscle and its tendon can rupture during wrestling and other power sports. Various kinds of upper arm fractures can occur after falling on it.

Functional anatomy

The upper arm is defined by the shoulder at the top (proximal) and the elbow and forearm at the bottom (distal). The upper arm muscles attach to the humerus (upper arm bone). On the front of the upper arm are the muscles that bend the elbow, e.g. biceps brachii, coracobrachialis and the brachialis muscles and on

Figure 11.1 a–c) Examples of sports that can apply heavy loads to the upper arm tissues. (Courtesy by Bildbyrån, Sweden.)

the back, the extending muscles, e.g. the triceps brachii muscle.

The nerves in the arms come from the spinal nerves of the spinal cord C5–T1. These intertwine in the shoulder in a nerve nodule called the brachial plexus. From there, the nerves continue out in the arm as the musculocutaneus, median, ulnar, axillary and radial nerves.

Overuse injury of the long tendon of the biceps

Overuse injury of the long tendon of the biceps is usually secondary to another shoulder injury such as impingement or instability. The biceps injury is usually of a degenerative nature. Midsubstance degenerative changes in a tendon are referred to as tendinosis (p. 178). This biceps tendon glides over the articular head of the humerus and leaves the joint through a special groove. When degeneration of the tendon occurs, tenderness at the uppermost part of the extremity is very noticeable. This injury occurs most commonly in canoeists, rowers, weightlifters, swimmers, javelin throwers, fencers, wrestlers, golfers and tennis and other racquet sport players.

Symptoms and diagnosis

- Tenderness is felt over the anterior aspect of the upper arm and shoulder, especially when the elbow joint is flexed.
- Yergason's and Speed's tests are positive (Figs 11.2, 11.3).
- In the acute stage tendon crepitus (creaking) can be felt over the anterior aspect of the shoulder during flexion and extension of the elbow.

Treatment

The athlete should:

- Gradually progress through a carefully planned exercise program.
- Apply local heat and use a heat retainer after the acute phase and before activities.

The physician may:

- Prescribe anti-inflammatory medication.

Healing

The injured person can resume sporting activity when symptoms have disappeared.

Figure 11.2 Yergason's test for injuries of the biceps tendon. The elbow is flexed to an angle of 90° and the forearm is pronated (turned inwards). The examiner holds the athlete's wrist to resist active supination by the patient. Pain localized to the bicipital groove area suggests the presence of a lesion in the long head of the biceps.

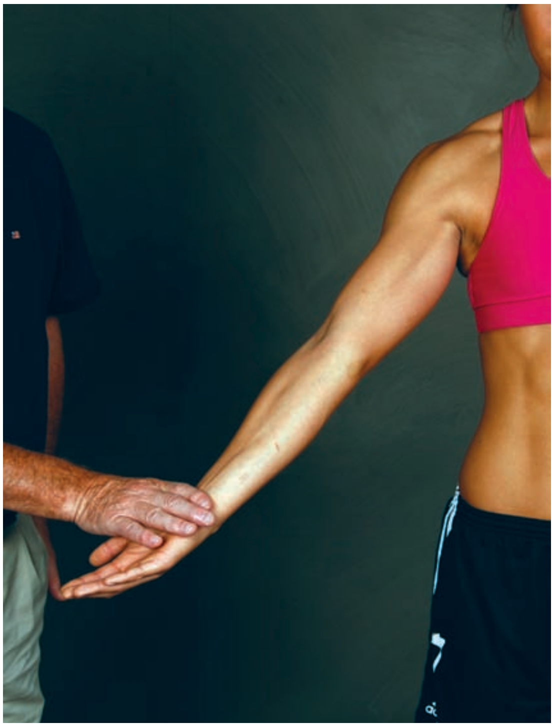

Figure 11.3 Speed's test for biceps tendinopathy. With the elbow extended and the forearm supinated, the arm is forward elevated against resistance to approximately 60°. The test is positive when there is pain localized to the biceps groove area.

Dislocation of the long tendon of the biceps

On the anterior aspect of the humerus, between the attachments of the tendons of the supraspinatus (greater tuberosity) and the subscapularis muscles (lesser tuberosity), is a ligament that holds the long biceps tendon in the groove in which it glides (Figs 11.4, 11.5). If this ligament stretches or tears or if the groove is shallow, the biceps tendon may become partially or totally dislocated. Dislocation most commonly takes place medially, giving the tendon a straighter course during contraction. It can also dislocate laterally with abduction and external rotation.

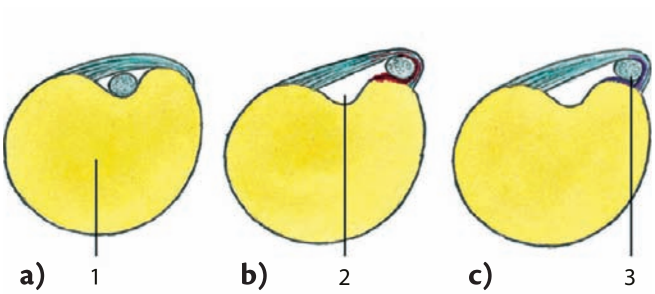

Figure 11.4 Dislocation (luxation) of the tendon to the long head of the biceps muscle. **a)** The biceps tendon in the groove of the humerus (upper arm) seen in cross section; **b, c)** the biceps tendon is dislocated inwards.

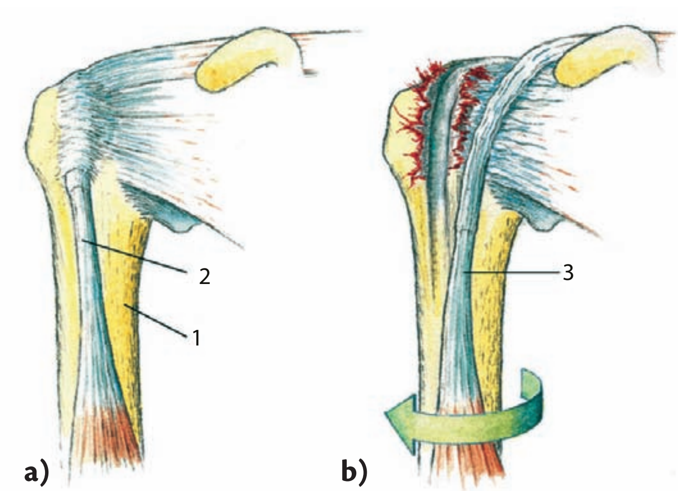

Figure 11.5 The upper arm with the biceps tendon seen from the anterior. **a)** The biceps tendon in place in the groove; 1: humerus (upper arm); 2: biceps tendon; **b)** the biceps tendon dislocated inwards with the anterior capsule damaged; 3: dislocated biceps tendon.

Symptoms and diagnosis

- Bending of the elbow and abduction of the shoulder may cause pain extending up to the shoulder.
- Internal rotation of the humerus can cause pain over the anterior aspect of the shoulder.
- The examiner may feel the biceps tendon slipping in and out of its groove when the arm is externally and internally rotated.
- A magnetic resonance imaging (MRI) scan can assist with the diagnosis (Fig. 11.6).

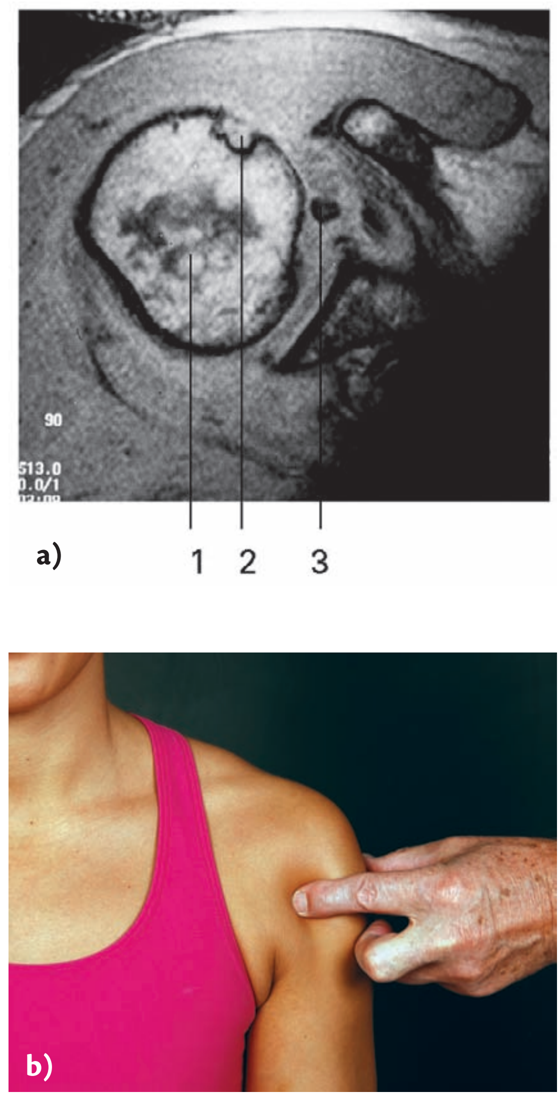

Figure 11.6 Dislocation (luxation) of the long tendon of the biceps muscle. **a)** Magnetic resonance imaging (MRI) of the upper arm (1) will secure the diagnosis. Here is a picture showing an empty groove (sulcus) in cross section (2) and the biceps tendon clearly moved medially inward towards the joint (3); **b)** location of tenderness on palpation.

Treatment

The athlete should:

- Rest.
- Apply local heat and use a heat retainer after the acute phase.

The physician may:

- Prescribe anti-inflammatory medication.
- Immobilize the arm in acute cases.
- Perform an ultrasonography, MRI or MR arthrogram (with contrast medium in the joint) of the shoulder.
- Operate if the tendon is completely dislocated or causes persistent problems. This usually has good results.

Tear of the long tendon of the biceps

Tears of the biceps tendons may occur both proximally and distally. Tears at the elbow are discussed in Chapter 12.

Tears of the long tendon of the biceps muscle mainly occur in 40–60-year-old individuals, who often have a history of shoulder problems. Biceps tears in the younger population may occur after falls and then often proximally in athletes such as snowboarders, gymnasts, tennis players and badminton players, wrestlers, rowers, weightlifters and javelin throwers.

The long biceps tendon is susceptible to degenerative changes, which predispose it to rupture (Fig. 11.7). The tears occur most often in athletes over the age of 40 years; in younger athletes this injury is relatively unusual. The injury mechanism is a sudden eccentric (opposite-directed) resistance during flexion and/or external rotation of the elbow or shoulder.

Symptoms and diagnosis

- Moderate pain occurs over the anterior aspect of the shoulder joint.
- Swelling is visible over the anterior aspect of the upper arm.
- There is inability to contract the muscle against resistance in the acute stage.
- Strength is moderately impaired when the elbow joint is flexed and the forearm is supinated.
- At a later stage slow contraction of the biceps produces a more prominent swelling than that produced by the normal biceps of the healthy arm. The muscle fails to make its full contribution to flexing of the elbow joint.

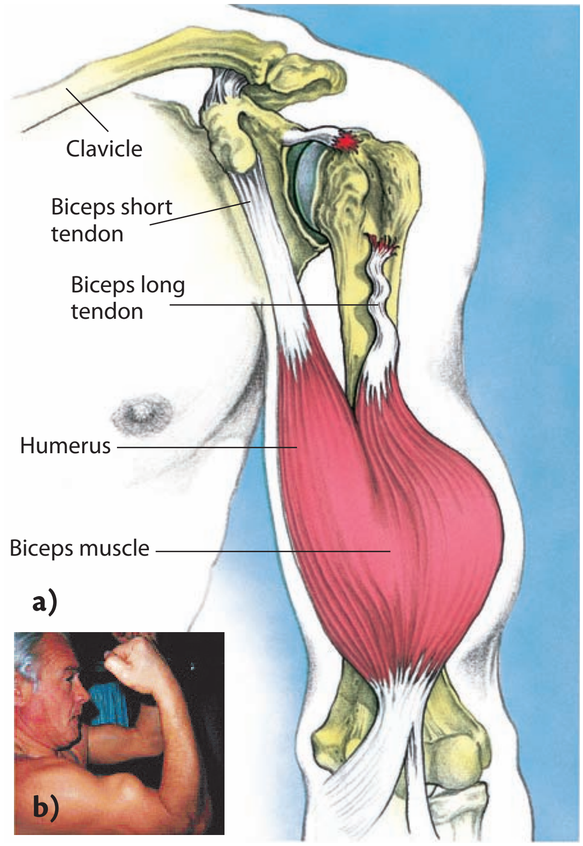

Figure 11.7 a) Complete rupture of the biceps tendon in the upper part of the humerus. The muscle often markedly contracts and forms a well-defined 'tumor' on the front side of the humerus, shown in **(b)**.

Treatment

The athlete should:

- Consult a physician for advice.

The physician may:

- Prescribe physiotherapy and mobility exercises (p. 250).
- Operate when a complete rupture has affected a young athlete active in overhead sports.

Healing

If surgery is not considered necessary, mobility and strength exercises can be started as soon as the pain begins to subside. After conservative treatment there may be some residual weakness.

If surgery is carried out, range of motion (ROM) exercises start within 1–2 weeks. Conditioning exercises not involving the upper extremity can start early. Gradually increased strength training should not be resumed until a few weeks later. Contact sports should be avoided for 2–3 months. In younger athletes surgical treatment may be considered.

Tear of the tendon of the triceps

Falling on the hand when the arm is flexed or forceful throwing can cause a rupture in the tendon of the triceps. Weightlifting with very heavy weights can also cause this injury. Most triceps tears are partial and are most commonly located at the insertion of the olecranon (the tip of the elbow); occasionally, however, the tendon attachment will be completely torn away from the olecranon.

Symptoms and diagnosis

- Pain occurs at the tip of the posterior aspect of the elbow.
- A gap can be felt in the tendon.
- Weakness and impaired ability to straighten the arm at the elbow are present.
- An X-ray should be carried out to exclude bony injury.
- An MRI scan can show the extent of the injury.

Treatment

- In cases of minor or partial tears, gradually increasing exercise is the main treatment.
- Surgery should be carried out when active athletes have suffered a complete tear of the tendon or its attachment. This is rare.

Tear and inflammation of the deltoid muscle

Tears of the deltoid muscle, though infrequent, do occur in team handball and volleyball players, American footballers, weightlifters, wrestlers and other athletes. The muscle is damaged in most cases by direct impact, but it can also be injured by overuse. The tear affects only a small part of the muscle, making it difficult to raise the arm upwards and in abduction. Local tenderness is felt over the region of the tear (Fig. 11.8). The treatment is rest.

Overuse injuries can affect the deltoid attachment to the humerus, particularly in young athletes who repeatedly elevate and abduct the arm under a heavy load. Overuse of the posterior part of the deltoid muscle occurs, for example, in butterfly-stroke swimmers because of their vigorous backward arm movements. Overuse of the anterior part of the muscle is not uncommon in certain contact sports when players use their outstretched arms to push or tackle. The treatment for these overuse injuries is, as a rule, rest and heat.

Figure 11.8 A rupture and an inflammatory condition in the deltoid muscle on the upper lateral part of the arm, where the insertion is located. The finger indicates the area that is most commonly tender.

Rupture of the major pectoral muscle

The pectoral muscle has its origin on the anterior chest wall and its insertion on the anterior surface of the upper part of the humerus (Fig. 11.9). Its function is to draw the upper arm towards the chest and to rotate the arm inwards. When it is subjected to a heavy load, the pectoral muscle can tear. A complete tear can be induced by strength training (especially bench-press training), heavy weightlifting, and other strength sports such as wrestling, shot-putting and discus and javelin throwing. It is usually the tendon close to the insertion of the muscle onto the humerus that is damaged.

Symptoms and diagnosis

- Pain occurs at the insertion of the major pectoral muscle onto the humerus.
- Swelling and bruising (secondary to bleeding) appear over the anterior aspect of the upper arm.
- Tenderness is found over the anterior aspect of the upper arm.
- Impaired strength is noted when the upper arm is adducted (drawn inwards towards the chest) or is internally rotated against resistance.
- The major pectoral muscle fails to contract when the upper arm is pressed inwards against resistance. This can be felt by placing a hand over the muscle so that it covers both the damaged and healthy portions.
- There is visible deformity or loss of definition of the muscle.

Treatment

The athlete should:

- Apply acute treatment (Chapter 7).
- Carry out a gradually increasing strength training program when the tear is partial;
- Consult a physician.

The physician may:

- Operate in cases of complete muscle rupture, especially in weightlifters, wrestlers and throwers, since this muscle has no agonist (muscle with same function).

Healing

Following surgery, early ROM exercises are recommended. A supportive sling should be worn for about 2–4 weeks. Strength training should not be resumed until at least 4–6 weeks after the injury and then only with gradually increasing light loads. Increasing the number of repetitions is preferable to increasing the loads.

Return to sport

In a partial tear, early strength training is initiated and sport is resumed when normal strength and pain-free normal ROM are achieved. After a complete tear, return to sport is possible after 3–5 months.

Overuse injury at the insertion of the pectoral muscle

The insertion of the major pectoral muscle can be the site of local traction injury with inflammation. The injury occurs particularly in gymnasts, tennis players, badminton players, squash players, golfers, rowers, weightlifters, swimmers and throwers. The usual cause is intensive strength training and overuse.

Symptom and diagnosis

- Pain occurs in the region of the insertion of the major pectoral muscle tendon onto the humerus.
- Tenderness is observed at the tendon attachment.
- Pain, and sometimes weakness, are felt when the upper arm is adducted against resistance.

Treatment

The athlete should:

- Rest the damaged area.
- Apply local heat and use a heat retainer before activity and ice after activity.

The physician may:

- Prescribe anti-inflammatory medication.

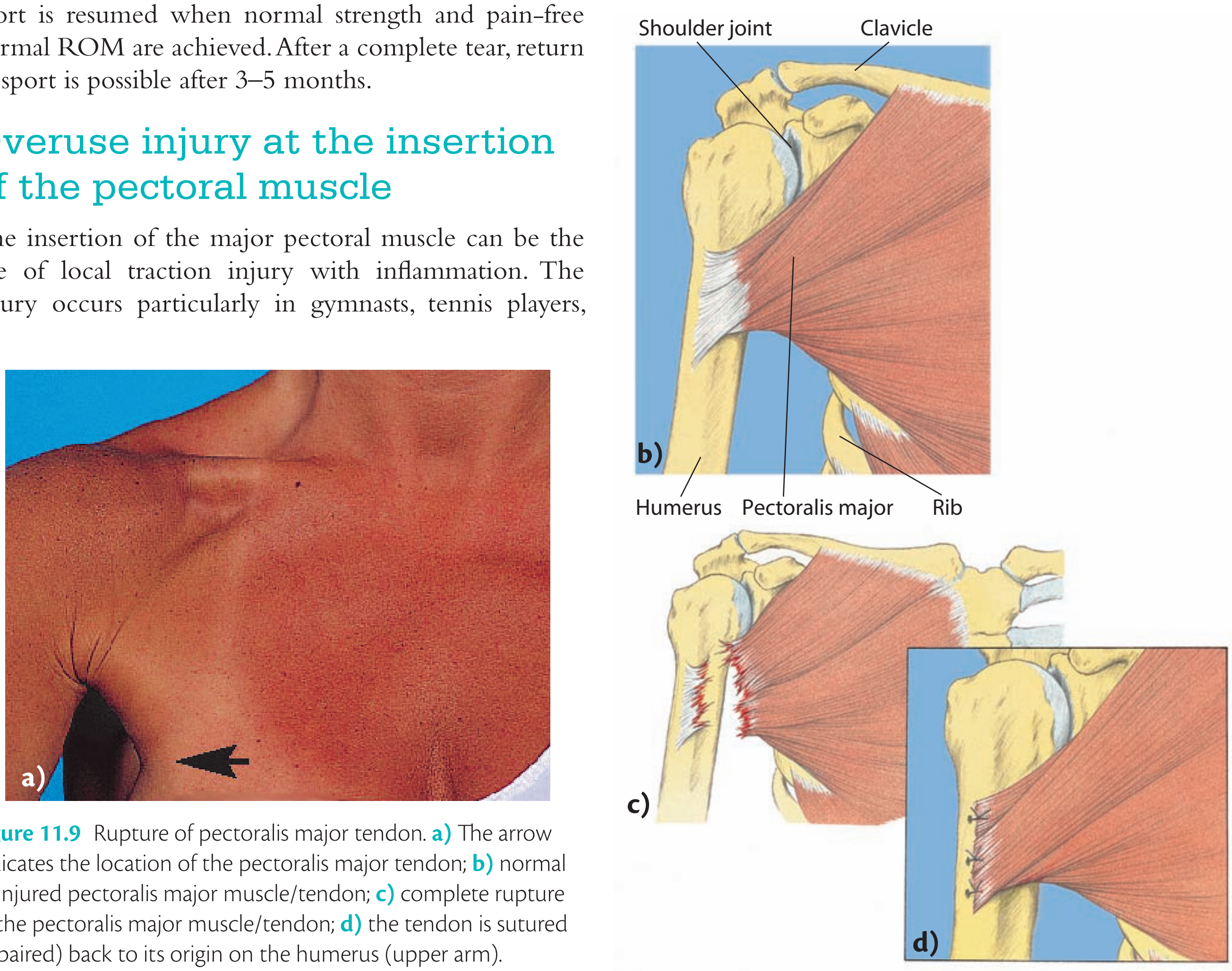

Figure 11.9 Rupture of pectoralis major tendon. **a)** The arrow indicates the location of the pectoralis major tendon; **b)** normal uninjured pectoralis major muscle/tendon; **c)** complete rupture of the pectoralis major muscle/tendon; **d)** the tendon is sutured (repaired) back to its origin on the humerus (upper arm).

- Initiate strength and flexibility training (p. 250–1).
- Give a local steroid injection and prescribe a few days of rest.

Fractures of the humerus

Fractures of the upper part of the humerus occur most frequently as a result of falling on an outstretched arm, but they may also follow a direct fall on the shoulder during contact sports, such as rugby and American football, alpine skiing and riding. Fractures of the upper part of the humerus occur most frequently through the surgical neck of the humerus. Sometimes they are avulsion fractures of the greater tubercle (supraspinatus tendon insertion) or the lesser tubercle (subscapularis tendon insertion).

Symptoms and diagnosis

- Tenderness and swelling occur over the area of the injury, and pain is experienced on attempted movement.

Treatment

- The injured person should be taken to a physician or a hospital for examination and an X-ray (Fig. 11.10).

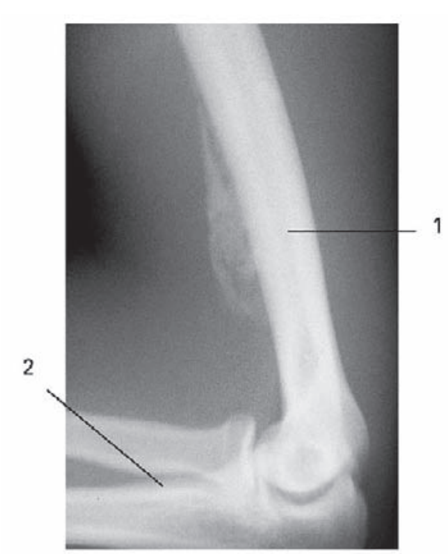

Figure 11.10 Myositis ossificans (bone formation secondary to a hematoma) in the muscles anterior to the humerus is seen using MRI (magnetic resonance imaging). 1: Humerus bone (upper arm); 2: Ulna bone.

- A support bandage is applied and kept in position for a few days, after which mobility training is begun. Mobility training starts with pendulum movements and progresses to the exercises described on p. 250, 283.
- Physical therapy aids the process of rehabilitation. If the displacement of the avulsed tubercle is great or interferes with the ROM, surgery should be considered.

Healing

As a rule, fractures of the upper part of the humerus heal well, and conditioning can be resumed after 4–8 weeks.

Fractures of the midshaft of the humerus can occur in riders, wrestlers, and other athletes. They are usually treated by cast bracing or occasionally by strapping the arm to the body for 3–6 weeks. Surgery may occasionally be necessary. A rehabilitation period of 3–6 months is advisable before resumption of any sporting activity involving the use of the injured arm.

Stress fractures of the humerus can occasionally occur, for example, in javelin throwers. Management is suggested on p. 153.

Myositis ossificans

After a blow to the arm, an intramuscular hematoma can occur. Pain, swelling, and impaired muscle function are common. In spite of early treatment with ice, compression and rest, the injury may be complicated by bone formation within the muscle secondary to the hematoma (p. 175, 395).

Further reading

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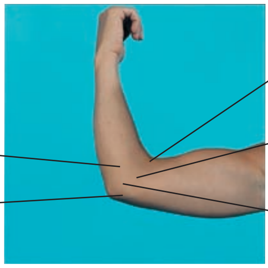
12 Elbow Injuries in Sport

Elbow injuries due to overuse are common in sports such as tennis, badminton, baseball, golf, javelin throwing, handball, etc. These injuries usually occur during throwing movements and they are often more chronic in nature. In falling or body contact in sports such as football/soccer, hockey, etc. the injury becomes more of an acute nature and usually requires emergency treatment. The chronic injuries can often be difficult to deal with and healing can take a long time before the athlete can return to full sporting activity at the same level as before the injury.

The elbow joint not only allows the arm to flex, but also permits the forearm to rotate inwards, so the palm faces down (pronation), or to rotate outwards and so the palm faces up (supination). Good elbow function is essential for everyday activities. In addition to that the elbow joint is provided with muscles and ligaments, there are large blood vessels and nerves passing close to the joint, and thus serious complications can occur at elbow injuries (Figs 12.1–12.3).



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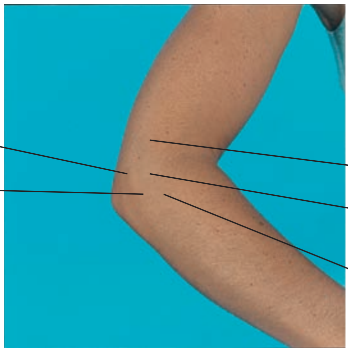

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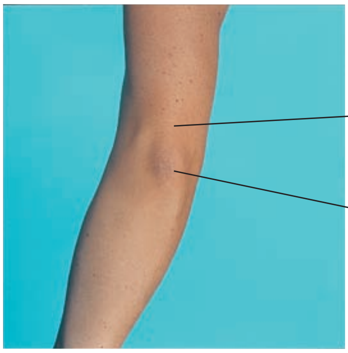


12.3

Figures 12.1–12.3 Localization of common injuries to the elbow.

Functional anatomy

The stability of the elbow is provided by the collateral ligaments and the fibrous capsules, as well as by the bones and the articulations, and the muscles and tendons. The passive stability of the elbow is guaranteed by the adjacent bones, i.e. the upper arm (humerus), the radius and ulna and the surrounding collateral ligaments and joint capsules (Fig. 12.4). Muscles and tendons contribute to the active stability.

The ulnar (medial) collateral (UCL) ligament is well-developed and forms three distinct bands: the anterior oblique ligament; a small, transverse ligament; and the posterior oblique ligament. The anterior oblique ligament is very strong: it is taut through the entire arc of elbow flexion and is the primary constraint of valgus stress of the elbow. The posterior oblique ligament is taut in flexion and lax in extension and does not have a primary role in elbow stability. The lateral collateral ligament stabilizes for varus stress.

On the lateral aspect are the muscles that extend the wrist, i.e. extensor carpi radialis longus and brevis, digitorum communis, digiti minimi and carpi radialis brevis, and originate from the lateral epicondyle (see Fig. 12.8). The three primary flexor muscles of the elbow are the biceps brachii, the brachioradialis and the brachialis. The triceps is the only effective extensor of the elbow.

The radial nerve runs anterior lateral of the elbow and divides into the posterior interosseous nerve and the lateral cutaneous nerve of the forearm. Entrapment can especially affect the interosseus nerve and its deep branch (ramus profundus). The median nerve remains anterior of the elbow in its course and passes between the two heads of the pronator muscle and can also become entrapped. The ulnar nerve passes through the triceps fascia as it approaches the ulnar groove on the medial posterior aspect of the elbow, where it can be compressed and cause distal problems.

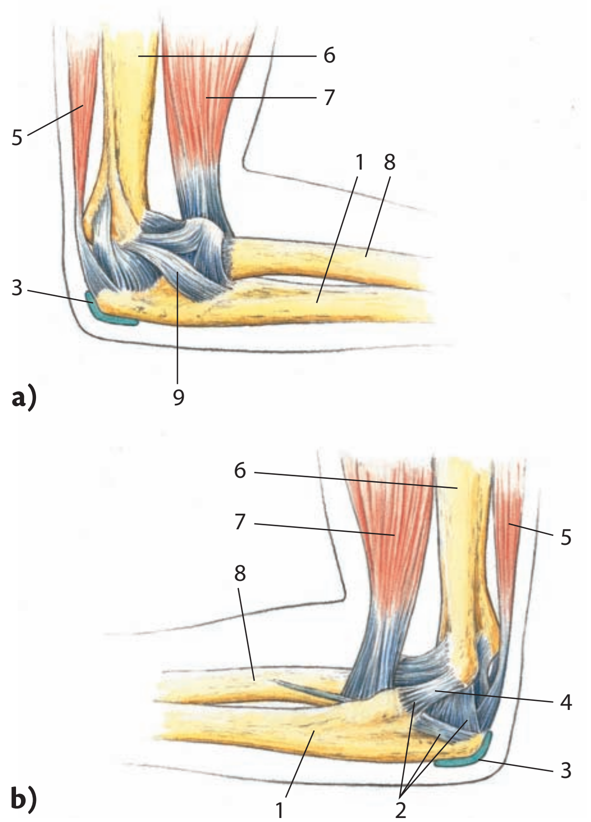


Figure 12.4 Anatomical overview of the elbow. 1: Ulna bone; 2: ulnar collateral ligament (medial); 3: bursa; 4: anterior oblique ligament; 5: three-headed muscle (triceps); 6: humerus bone; 7: two-headed muscle (biceps); 8: radius bone; 9: lateral collateral ligament **a)** View from the outside (lateral side); **b)** view from the inside (medial side).

The elbow joint can be moved about a longitudinal and transverse axis. Flexion–extension is provided by the humeroulnar joint. The rotational motion is provided by the unique articulation of the radius with the capitellum portion of the humerus and the ulna so that forearm pronation and supination can be carried out.

The normal range of motion (ROM) of the elbow is flexion and extension 0–145° with a functional arc of 0–130°. Pronation and supination can be carried out with 70–90° of pronation to 90° of supination. The axial rotation is around the center of the radial head. At full extension there is an extra twist (valgus carrying angle) of the elbow in valgus of 10–15°.

The injury mechanism for elbow injuries during throwing movements

The throwing mechanism is described in detail on p. 97, Chapter 6. The throwing motion can be divided into five different phases (see Fig. 6.12) in sports such as baseball, javelin throwing, handball (and to some extent even the serve in tennis) (Fig. 12.5).

Preparation phase –wind-up

The shoulder is extended, externally rotated and abducted. The elbow is flexed to 45°.

Cocking phase – the arm is pulled backwards, as well as the trunk

The shoulder muscles stabilize the scapula. The shoulder remains at 90° abduction. The shoulder externally rotates to 150–180°, causing the anterior capsule of the shoulder to stretch and increase in flexibility.

Acceleration phase – the forward movement is started for the arm

An explosive phase when the trunk is flexed forward into neutral position and the ball is thrown. The internal rotator of the shoulder is contracted and maximum speed is generated. The rotator cuff is very active and stabilizes the shoulder joint, which results in valgus stress (the forearm is bent outwards in relation to the upper arm) of the elbow. This phase is stressful for athletes with elbow pain.

Deceleration phase – arm braking

This is a short phase. The shoulder is internally rotated to 0°. An eccentric contraction of all muscles is required to slow down arm motion. This is the most harmful phase of throwing.

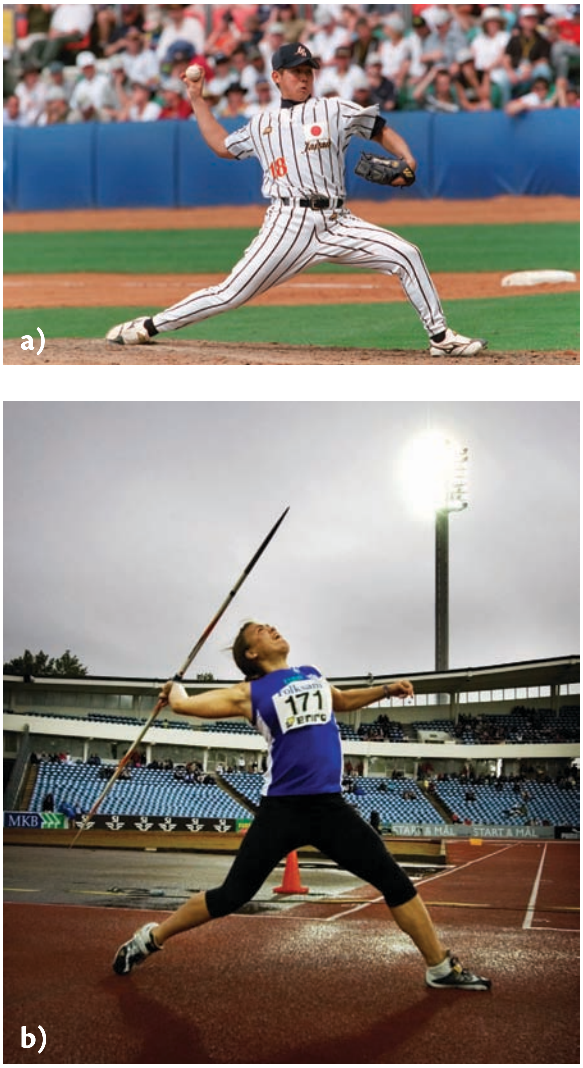


Figure 12.5 a, b) Examples of throwing sports, where the elbow is very much involved. (With permission, by Bildbyrån, Sweden.)

Follow-through phase – the arm is extended and internally rotated

Maximum internal rotation of the shoulder and the arm follows through the movement. The body weight is transferred to the front leg and the forward motion stops. The posterior shoulder muscles are active. The forearm goes into pronation. The elbow is maximally extended, so that the posterior upper part of the ulna, i.e. the olecranon, is pressed against the back of the upper arm and can cause impingement. This typical throwing movement can cause injuries in tennis and baseball such as tennis elbow, stretch laxity on the medial collateral ligaments, overuse injury on the outside, i.e. the lateral side, with possible cartilage damage on the lateral part of the elbow joint (capitellum). Compression injuries can occur when the elbow tip (olecranon) hits the posterior aspect of the humerus.

Elbow injuries in adults

Elbow injuries are classified as traumatic injuries and overuse injuries. The latter may be divided into those that arise on the lateral, medial, posterior or anterior parts of the elbow. Various injuries can occur in the elbow depending on the activity. In tennis the symptoms of recreational players are located around the lateral bony protuberance on the humerus, i.e. the lateral epicondyle, but for top players it is more often on the medial epicondyle (Fig. 12.6). Golfer's problems are usually localized to the medial epicondyle and baseball player's to the posterior part where the olecranon hits the humerus.

Lateral injuries

Lateral epicondylitis is very common and is caused by traction. As this area is subjected also to compression, other soft tissue injuries are less common. Osteochondritis dissecans can occur, resulting in loose bodies and post-traumatic arthritis.

Medial injuries

Medial injuries include medial epicondylitis, traction injury to the common flexors (inflammation or acute rupture), compression of the hypertrophied pronator teres by the overlying fascia, chronic elongation and/or rupture of the medial collateral ligament with or without spur formation and development of traction osteophytes medially. Ulnar nerve problems are also frequent.

Posterior injuries

Loose bodies may again result from traction injuries, such as overuse/overload of the triceps or compression of the tip of the olecranon in the olecranon fossa. Posterior elbow injuries occur with sudden extension and

Figure 12.6 Tennis involves a complex interplay of shoulder, elbow and whole body. (With permission, by Bildbyrån, Sweden.)

hyperextension of the elbow, resulting in compression of the olecranon against the humerus. Older baseball pitchers may develop flexion deformities that limit full extension. In these cases, an injury thought to be due to compression of the olecranon into the olecranon fossa may actually be an avulsion injury.

Anterior injuries

The distal biceps tendon may tear.

Elbow injuries in children

Unique bony problems of the elbow are seen in children and adolescents. The pathology of these problems corresponds to each stage in the development of the elbow: prior to the appearance of all the secondary centers of ossification in children; prior to fusion of the ossification centers in adolescents; and prior to the completion of bony growth in young adults. The majority of injuries are due to overuse resulting from an increase in frequency, speed and duration of throwing movements (Fig. 12.7).

Figure 12.7 Young baseball player. There are well-established rules for how much a young baseball player should throw due to the high risk of injury ('pitcher's elbow') if they throw too much. (With permission, by Bildbyrån, Sweden.)

Medial injuries

The medial side of the elbow is subjected to distraction forces, which may cause injury to the medial epicondyle and the medial soft tissues, including the capsular structures and the ulnar nerve. In children, ossification of the medial epicondyle may be disturbed by enlargement of the epicondyle or by osteochondrotic (bone–cartilage) changes. In adolescents, avulsion fractures of the medial epicondyle may occur. The epicondyle may occasionally displace in the joint causing mechanical derangement. After fusion of the medial epicondyle, muscular injuries are more frequent and may cause the development of osteophytes (bone spurs).

Lateral injuries

On the lateral side of the elbow, bony disturbance from repetitive compression and shearing forces may occur during childhood at both the head of the radius and the capitellum. Injury to the lateral aspect may affect the entire epiphysis (the rounded end of a long bone) with enlargements and fragmentation throughout. During adolescence, the periphery of the ossification center is affected more with avulsion fractures damaging the articular cartilage and forming loose bodies. The capitellum and sometimes the head of the radius are affected by lesions.

Posterior injuries

In children, stress fractures and non-union of the olecranon epiphysis (growth zone) may occur, as well as ectopic bone (bone that develops in abnormal sites) formation around the olecranon tip and loose body formation at a later date.

The various throwing injuries can be related to the various stages of the throwing mechanism (see above and Chapter 6, p. 97). An understanding of this mechanism, as well as of the stages of the skeletal maturation in the young athlete, is important in diagnosing and treating throwing injuries.

Clinical examination

Examination starts with inspection followed by palpation, evaluation of motion, strength testing and instability testing.

Any gross swelling or muscle hypotrophy should be noted. Holding the forearm and hand supinated and the elbow extended, the angle formed by the humerus and forearm is determined (the carrying angle). The average is 10° for men and 13° for women. An inflamed olecranon bursa with swelling on the posterior aspect is a sign of bursitis.

The bony landmark needs to be palpated. Any tenderness is noticed as this usually indicates the area of injury.

Motion is important in assessment of elbow function. The motion occurs around two axes: flexion and extension and forearm rotation with pronation and supination. Flexion and extension range from 0–140° or 1–10°, respectively. Pronation is often 70° and supination is 85–90°.

Flexion and extension strength testing is performed against resistance with the forearm in neutral rotation and the elbow at 90° of flexion. Elbow extension strength is normally 70% of flexion strength and is best measured with the elbow at 90° of flexion with the forearm in neutral rotation. Pronation and supination strength are also best studied with the elbow at 90° of flexion. Supination strength is normally about 15% greater than pronation strength.

The collateral ligament instability is evaluated with the elbow flexed at 30° and in full extension. Varus stress is applied with the humerus in full internal rotation and the lower arm pressed inwards. Valgus instability is best measured with the arm in full external rotation and the lower arm pressed outwards.

'Tennis elbow' (lateral elbow tendinopathy, lateral epicondylitis)

'Tennis elbow' has an incidence of 4.7 events per 1000 patients in primary care. These patients are usually between 35 and 54 years. Tennis elbow is most common in recreational players in tennis, who are often 30–50 years of age and have a high activity level, i.e. playing tennis more than three times a week for hour-long sessions. The degree of symptoms is directly related to how much they play tennis, with a direct connection between game sessions and pain. Even experienced players who play longer and more frequent sessions can suffer pain in the elbow.

The tennis player who most easily incurs tennis elbow is working with a demanding technique that is not matched by fitness level. Improper technique is one of the most common causes, and particularly common are incorrect backhand strokes. The serve can also cause elbow pain.

Of the 75% of the recreational players with tennis elbow, 40% received this affliction by a faulty backhand stroke combined with muscle weakness. 50% of female and 30% of the male professional players have had this problem caused by an overuse on the forehand and/or backhand.

It is the combination of extending the elbow and rotating the wrist in the ulnar (pronation) direction that causes the extensor carpi radialis brevis tendon to erode the lateral epicondyle.

An active tennis player is otherwise characterized by a marked increase in muscle mass in the proximal upper part of the forearm in the dominant arm compared with the other. Statistically, increased bone mass in the upper arm is also present in top players in tennis as well as 'hanging shoulder', i.e. the dominant shoulder and arm hangs down lower than the other side and can also cause a marginal secondary scoliosis (curvature of the spine).

Pathology

The pathoanatomy of lateral elbow tendinosis related to tennis involves primarily the extensor carpi radialis brevis and secondarily the extensor digitorum communis muscle tendons. The bellies of the relevant muscles are all located in the forearm, while the long tendons in the ends bridge the elbow and wrist joints, and distal ends insert on the metacarpals or phalanges (finger bones). The lateral epicondyle of the humerus forms a common origin for at least parts of all the extensors of the wrist and fingers (Fig. 12.8).

The disorder represents a degenerative process, including minor ruptures, poor orientation of the collagen, which builds up the tendon, and some fragmentation. There are usually no inflammatory cells present. The term 'tendinosis' represents the correct pathology replacing the term 'tendinitis'. The clinical term tendinopathy is today the most commonly used term to characterize this injury.

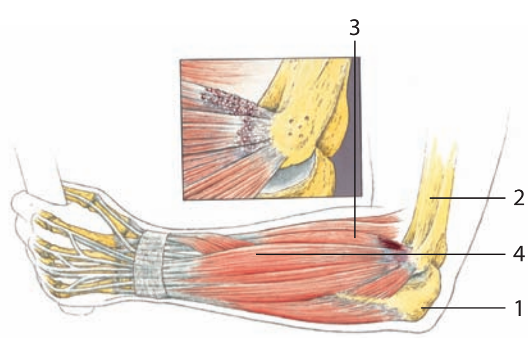


Figure 12.8 Tennis elbow with degenerative changes in the extensor carpi radialis muscle tendon where it attaches to the lateral epicondyle of the humerus. 1: Ulna; 2: humerus; 3: extensor radialis brevis muscle and its tendon; 4: extensor digitorum communis muscle.

Symptoms and diagnosis

- There is a history of repetitive activity or overuse, such as playing tennis intensively at a training camp, or resuming playing after a period of little activity. Problems can often occur after activities such as painting a house and the like.
- Pain mainly affects the lateral aspect of the elbow, but can also radiate upwards along the upper arm and downwards along the outside of the forearm.
- Weakness in the wrist can cause difficulty in carrying out such simple movements as lifting a plate or a coffee cup, opening a car door, wringing out a wet dishcloth and shaking hands.
- A distinct tender point is elicited by pressure or percussion over the lateral epicondyle (Fig. 12.9).

The 'Coffee cup' test, i.e. when the injured person lifts a cup of coffee, pain arises over the lateral epicondyle.

Pain occurs over the lateral epicondyle when the hand is dorsiflexed at the wrist against resistance (Fig. 12.10). This sign alone is sufficient to justify a diagnosis of 'tennis elbow'.

A positive middle finger test: there is pain over the lateral elbow when the middle finger is extended against resistance (Fig. 12.10).

Involvement of the extensor carpi radialis brevis is typical in tennis players. In lateral elbow tendinosis due to other causes, e.g. industrial work, it seems that the extensor digitorum communis is typically involved. This also leads to a positive middle finger test. In other words, there may be two different etiologies of lateral elbow tendinopathy with different locations of the problem.

An accurate diagnosis of tendinopathy includes an evaluation of the magnitude of pathological change, which is helpful as a prognostic predictor, as well as formulating the treatment protocol. The patient's description of time and intensity of pain is the best guide to evaluation.

The elbow can be X-rayed to exclude a loose body in the joint or a fracture. Other possible diagnoses are rheumatic disorders, trapping of a nerve (the deep branch of the radial nerve) and radiating pain caused by degenerative changes in the spine in the region of the fifth and sixth cervical vertebrae.

Prevention

- Correct playing and working techniques are the most important preventive measures.
- Sometimes a forearm brace (Fig. 12.12) or a heat retainer can be used as a means of dissipating the forces outwards before they reach the epicondyle.
- Asymmetrical training techniques should be avoided.

Figure 12.9 There is usually a distinct point of tenderness, which manifests itself when there is pressure over the bony prominence on the outside of the elbow.

Figure 12.10 Tennis elbow. **a)** Pain is present over the lateral bony prominence of the elbow (lateral epicondyle) when the athlete flexes his/her hand upward at the wrist (dorsiflexion) against resistance; **b)** positive Middle Digit Test: pain on the lateral side of the elbow can be triggered when the fingers are extended against resistance.

In tennis, the following points should be emphasized:

- Good footwork so that the player approaches the ball correctly.
- The ball should be hit correctly with the racquet and at the right moment.
- The shoulder and the whole of the body should take part in every stroke so that deceleration does not occur when the ball is hit. The stroke should be followed through and the wrist should be firm.
- The court surface should be slow in order to decrease the velocity of the ball. Fast surfaces such as grass or concrete cause the ball to hit the racquet with increased force, resulting in increased load on the player's arm.
- The balls should be light. Wet or dead balls become heavy.
- The correct equipment should be used. The racquet should be individually selected with regard to playing technique. It should be well-balanced and easy to handle, e.g. when making angled drop shots. The arm is likely most safe with a relatively heavy racquet, that is not balanced overly head-light, as more weight in the racquet head provides more resistance to torsion, which also enhances control.
- A tightly strung racquet increases the impact and tension forces. The stringing of the racquet should be individually adjusted and should not be too taut. Anyone troubled by tennis elbow should have the racquet strung more loosely as it spreads the force of the ball's impact over a longer period of time. The main disadvantage of looser strings is less control. Gut strings give more resilience and less vibration than nylon ones.
- The size of the racquet grip should be carefully chosen in order to fit the hand comfortably. A grip that is too large or too small may force the player to grab the handle too tightly and thereby increase the strain on the forearm. A too small grip is likely to be worse, as it more likely will try to twist the hand. A simple method of determining the appropriate size of grip is to measure the distance between the midline of the palm of the hand and the tip of the middle finger; this distance should equal the grip's circumference (Fig. 12.11). A grip that is too small can easily be corrected by adding an overwrap.

The impact between racquet and ball produces shock transmission from the racquet to the player. This may be increased unless the ball is hit exactly on the racquet's so-called 'sweet spot' (center of percussion). This is the area of the racquet face where minimal torsion occurs on impact. Hits outside this spot will increase torsion and unwanted forces and vibrations. These may not directly cause tennis elbow, but is considered to worsen this condition when established.

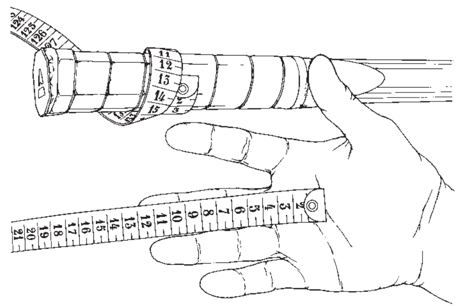


Figure 12.11 Measurement of appropriate circumference of the tennis racquet grip. The distance between the palm's second furrow and the peak of the long (middle) finger corresponds to the correct size of the grip.

Treatment

Treatment should follow the healing response; this includes three phases: (1) an acute inflammatory phase; (2) a collagen and ground substance production phase; and (3) a maturation and remodeling phase.

The athlete should:

- Reduce pain and inflammation when the injury is in its acute stage by the use of cooling for about 2 days (elevation and compression are not needed, as swelling is not a problem).
- Rest actively – i.e. rest the injured area and avoid movements that trigger pain, but continue with conditioning activity such as running or cycling.
- Continue with tennis, but avoid the strokes that cause pain.
- Apply local heat and use a heat retainer when the injury is no longer in its acute stage.
- Treat with ice massage, perhaps alternating with heat treatment.
- Try taping the wrist to support the elbow joint under load.
- Reduce the load on the extensors with the help of a brace, which should be applied when the arm is relaxed and kept in position until the rehabilitation period is over.

Counterforce bracing constrains key muscles groups. An air-filled bladder has been developed as a counterpressure element (Fig. 12.12). This constrictive band caused a significant reduction in integrated electromyography (EMG) activity of the extensor carpi radialis brevis and the extensor digitorum communis

Figure 12.12 Example of a brace that prevents and treats tennis elbow. (Aircast, ©2014 DJO, LLC, used with permission from DJO, LLC. All rights reserved).

when compared with controlled values and a standard band. More research is needed to confirm the effect of braces for the treatment of tennis elbow. Clinical experience indicates, however, that the use of such braces is a valuable complementary tool in the treatment of tennis elbow. The elbow bands can be combined with heat-retaining Neoprene sleeves add the positive effects of heat in stimulating healing.

Strength, stamina, and mobility should be improved by exercises once the pain and inflammation are under control, i.e. the athlete can tolerate the pain of a handshake. The training program should follow the guidelines set out below.

- Isometric training of the wrist extensors (see pp. 283, 307). The training is carried out with the wrist in three positions: first fully flexed downwards, then in a neutral position, and finally flexed upwards. The joint should not be under load and the exercise should be carried out 30 times a day. The wrist is flexed for 10 seconds at a time. When these exercises can be carried out without any pain, a load of 0.5 kg (1 lb) can be introduced.
- Dynamic training. An elastic band is slipped over the ends of the fingers, and then an attempt is made to spread the fingers against its resistance. Another method is to extend (concentric) and flex (eccentric) the wrist with a load of 1–2 kg (2–4 lb) 20 times a day.
- Eccentric training by flexing the wrist with a load of 1–2 kg 20 times per day is the central component of the training. This can be combined with the corresponding stretch at training of the wrist.
- Flexibility training (static stretching) of the wrist. The joint is bent at an angle of 90° and the opposite hand is used to provide counter pressure. The elbow of the injured arm should be held completely extended and the forearm should be rotated inwards (pronated). The bent wrist is stretched to its outer range and is held there for 4–6 seconds. After 2 seconds rest it is subjected to stretching for another 6–8 seconds. The exercise is repeated 15 times a day.
- Training of strength and mobility in shoulder and arm (p. 250).

The physician may:

- Prescribe anti-inflammatory medication.
- Prescribe ultrasound treatment, high-voltage galvanic stimulation, or/and transcutaneous nerve stimulation. There is no agreement on which treatment is most appropriate for this common condition.
- Prescribe shock wave treatment, which has been shown to have some effect in some studies. This treatment creates a tissue injury and thus initiates the healing process with increased circulation over a period of at least 2–3 months.
- Prescribe acupuncture.
- Administer local steroid injections in persistent cases and if pain interferes with the exercise program. This has for many years been a popular treatment for tennis elbow, probably used too much. Indications for a cortisone injection today are considered to be a chronic tennis elbow when a long period of training has not had the intended effect. Injections should be given subperiosteally (beneath the fibrous outer layer of the bone) to the extensor brevis origin. These injections have an early and beneficial effect. During the initial 24–28 hours, increased pain may be experienced. A steroid injection should be followed by 1–2 weeks' rest and should not be repeated more than 2 times. Steroid injection treatment seems to be effective for about 6 weeks according to evidence-based data, indicating that the patient must continue with the exercise program. It should be noted that the long-term effect after an injection is usually inferior compared with other treatment.

Failed healing is considered to have occurred if there are chronic symptoms of tendinopathy/pain for more than 6–12 months. If there is poor response to a rehabilitation program, if there is a history of persistent pain or if the patient has not been able to return to an acceptable quality of life, surgery may be indicated. In patients undergoing surgery it has been found that in 100% the tissue involved was from extensor carpi radialis brevis. Tissue from extensor digitorum communis, especially the anterior edge, was involved in 35%, and there was osteophyte formation of the lateral epicondyle in 20%. Surgery consists of resection of damaged tissue. The attachment of normal tissues should be maintained and the healthy tissues protected. There should then be quality postoperative rehabilitation. The elbow is protected at 90° for 1 week in a counterforce elbow immobilizer. Strength and endurance resistance exercises usually start 3 weeks after surgery. Postoperatively, 85% experience complete pain relief and full return of strength.

A recurrence rate of 18–66% is reported. The degree of pain prior to treatment is the most important predictor of complete recovery: the greater the pain, the more likely is the treatment to be completely successful. Arthroscopic treatment of this condition is now being developed.

Healing

A genuine tennis elbow is self-limited and mostly heals spontaneously and the prognosis is generally good. The symptoms can, however, persist for anything from 2 weeks to 2 years, especially if the athlete continues to load the arm. Strenuous activity can be resumed when the arm is fully mobile, has regained normal strength, and is pain-free. After surgery, 8–10 weeks should elapse before tennis is resumed.

Tip

Remember
Tennis elbow is a self-healing condition with a good prognosis. The injury persists for an average of 6 months to 2 years.

Osteochondritis dissecans (loose bone–cartilage)

In throwing movements the lateral part of the elbow joint is exposed to considerable loads, because of compression due to valgus loads (Fig. 12.13). This can cause the convex upper articular surface of the radius in the forearm to come into violent contact with, and even to injure, the lateral outer portion of the articular surface of the humerus at the elbow. Cartilage from the articular surface, together with a fragment of the underlying bone, may become detached and form a loose body in the joint (Fig.12.13C). Osteochondritis dissecans (loose bone cartilage) (p. 164) occurs most commonly in teenage boys.

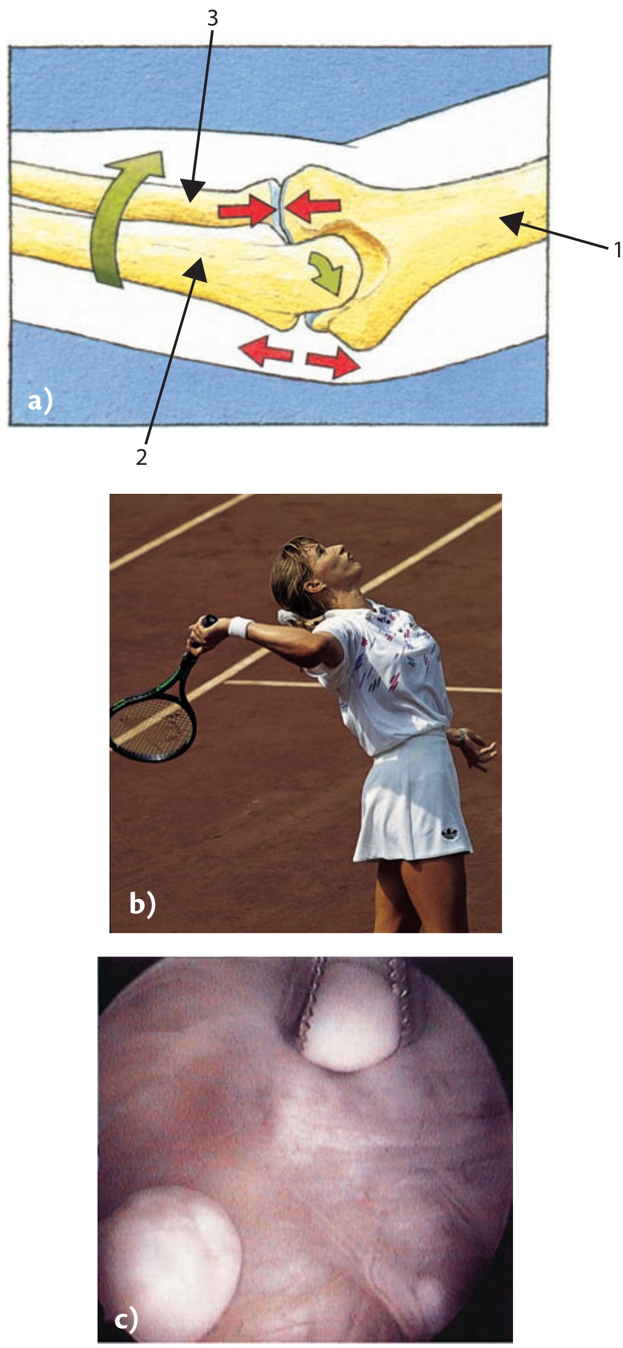


Figure 12.13 Valgus position of the elbow during a throwing motion or tennis serve. **a)** An injury mechanism for an elbow injury: forceful valgus load, causing compression on the outside (lateral side) of the elbow joint and extension of the joint inside (medial side). 1: Humerus; 2: ulna; 3: radius; **b)** the elbow is exposed to injury risk during a tennis serve; **c)** a free body in the elbow that has been taken with a grabber and removed with the aid of arthroscopy (courtesy of Professor Marc Safran, Stanford University, California, USA).

Symptoms and diagnosis

- Pain is felt in the upper outer aspect of the elbow, triggered mainly by throwing movements.
- Difficulties in straightening and bending the elbow joint are experienced.
- Locking of the joint occurs during elbow movements. The loose body prevents completion of the intended movement, and such an occurrence is always painful. Muscle cramp, swelling and – usually – the inability to extend the elbow. Temporary obstacles in the movement, so-called locking, is also common if the loosened fragment is still stuck in the surrounding cartilage–bone or if the free body slips out of the locking.
- Swelling develops around the elbow.
- Tenderness can be felt, mainly on the outer aspect of the elbow joint.
- Both elbow joints should be X-rayed, especially when the injured person is young and still growing. On the X-ray of the injured elbow joint the osteochondritis, the defect, or loose bodies (calcifications) can be seen.
- MRI or arthroscopy will confirm the diagnosis (Fig. 12.14).

Treatment

See p. 166.

Healing

The injured athlete can usually resume sporting activity 2–3 months after surgery.

Fracture of the head of the radius

The radius is thick and strong at the wrist, but considerably smaller in circumference and more fragile at the elbow. When the arm is stretched out to break a fall, the forces imposed are distributed through the forearm to the upper part of the radius. The radial head, which forms part of the elbow joint, can be fractured with the possibility of chronic problems. Sometimes the neck of the radius is fractured and the head dislocated. This can be identified by X-rays.

Symptoms and diagnosis

- Instant pain is felt when the injury occurs. This increases as the joint becomes swollen due to bleeding.
- Limitation of movement increases with the swelling. The elbow is usually held flexed at an angle of 90°.
- An X-ray confirms the diagnosis.

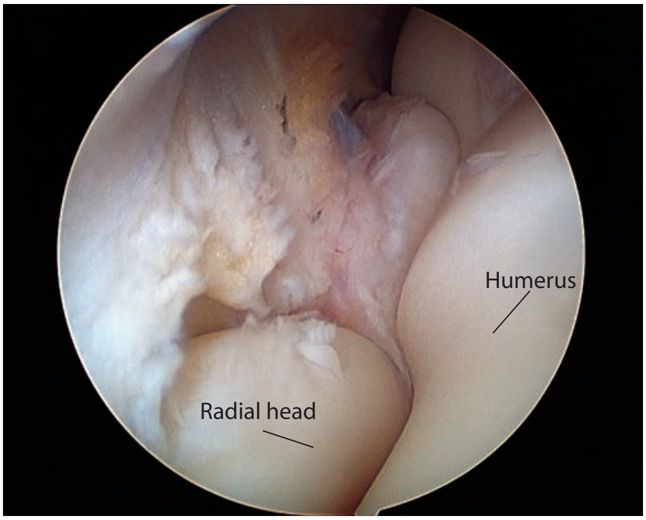


Figure 12.14 During arthroscopy the relationship between the radius upper part (radius head) and the lower part of the upper arm (capitellum of the humerus) can be seen from the lateral view of the elbow. If this delicate relationship is altered, e.g. by a fracture, it can affect the elbow function significantly. (Courtesy of Prof. Marc Safran, Stanford University, California, USA.)

Treatment

The physician may:

- Aspirate the blood from the injured joint with a syringe if severe swelling is causing pain.
- Apply a brace, which is worn for 1–2 weeks (after that the arm muscles should be strengthened by training).
- Operate if the head of the radius is badly fragmented or displaced.

Healing

A properly reduced fracture of the radial head heals in 6–8 weeks. Conditioning can be carried out through the rehabilitation period.

Medial elbow injuries

'Thrower's elbow', 'golfer's elbow' (medial epicondylitis, medial elbow tendinopathy)

Thrower's or golfer's elbow is similar to tennis elbow, but the symptoms are located over the inner (medial) epicondyle of the elbow. A right-handed golf player may well suffer from tennis elbow in the (leading) left elbow and golfer's elbow in the (following) right elbow (Fig. 12.15). Thrower's elbow is most common in javelin throwers, but also occurs in cricket and baseball players.

The primary pathological changes involved in medial tennis elbow are present in the origin of the pronator teres, palmaris longus, and flexor carpi radialis, close to the attachment of the medial epicondyle. Occasionally pathological changes also occur in the flexor carpi ulnaris.

The etiology of medial elbow tendinopathy is the same as for lateral tendinopathy. The majority of cases are due to faulty technique (Fig. 12.15A); however, top-level tennis players may develop medial epicondylitis owing to a serving action during which the wrist is bent at the same time as the forearm is turned inwards. Those who hit an exaggerated 'top spin' serve and in so-doing rotate the forearm vigorously inwards (excessive pronation) can also be affected. The flexor muscles that are principally responsible for these movements have their origins at the medial epicondyle of the elbow.

Figure 12.15 'Golfer's elbow'. A right-handed golfer can get "golf elbow" in the subsequent, right elbow. **a)** A golfer hitting the ground or with faulty technique may sustain 'golfer's elbow'; **b)** all golfers can get elbow problems. (Courtesy of Bildbyrån, Sweden.)

Symptoms

The symptoms are similar to those of tennis elbow (p. 269) but are located on the inner aspect of the elbow. There is pronounced tenderness when the medial epicondyle is subjected to pressure, and flexing the hand downwards (palmar flexion) at the wrist joint against resistance causes pain (Fig. 12.16).

Treatment

The treatment is the same as for tennis elbow. However, rehabilitation can sometimes take a little longer after surgery.

Healing

The prognosis for medial elbow tendinopathy is worse and the healing time is longer than for the lateral side. It can sometimes take 6–12 months before a return to tennis is possible. Patients should be told this, so that their expectations are realistic.

Figure 12.16 Test for 'golfer's elbow': distinct tenderness occurs when the examiner puts pressure on the elbow's medial epicondyle, and the patients feel pain when the hand is flexed downwards at the wrist (palmar flexion) against resistance on the fingers.

Tip

Have great respect for medial elbow tendinopathy, because this injury can be difficult to treat and cause long-term problems.

Elbow instability – rupture of the ulnar (medial) collateral ligament

Instability may occur after a fall in contact sports or rotation trauma, e.g. in wrestling and repeated overuse in racquet sports, pitchers, javelin throwers, quarterbacks in American football, volleyball and water polo players. The valgus stress overload syndrome can cause medial tension resulting in torsion of the UCL. This ligament, especially its anterior band, is of great importance for elbow stability. It is composed of two parts of triangular form: the anterior band, whose origin is attached on the front of the medial epicondyle and inserts with its broader base in ulna; the posterior band, which is attached with its apex to the lower posterior part of the medial epicondyle and inserts with its distal broader part in the medial margin of the olecranon.

The posterior portion of the UCL contributes little to valgus stability. The radial head contributes significantly to stability at 0, 45 and 90° of flexion, but the UCL is the most important stabilizer except at full extension. The anterior band is the major stabilizer from 20 to 120° of flexion.

Symptoms and diagnosis

- Pain on the medial side of the arm occurs during throwing (cocking phase) or serving.
- Tenderness if felt on the ligament.
- There is a sensation of the elbow 'opening' or 'giving way'.
- A valgus instability is tested with a valgus stress test. The shoulder is then externally rotated, the elbow flexed 30° and in full extension and a valgus load is applied (Fig. 12.17). An opening of the joint indicates instability.

A valgus instability test can be performed arthroscopically with the elbow flexed 60–70°. An opening of the joint between the ulnar and humerus can be seen. An opening of more than 3 mm seen during radiology, MRI or arthroscopy is considered diagnostic of valgus instability.

The pathology involves edema (swelling) and inflammation or scar formation late stage within the ligament. There can also be calcifications within the scar or ossifications within the ligament. Ruptures can also occur. These changes can be verified by an MRI.

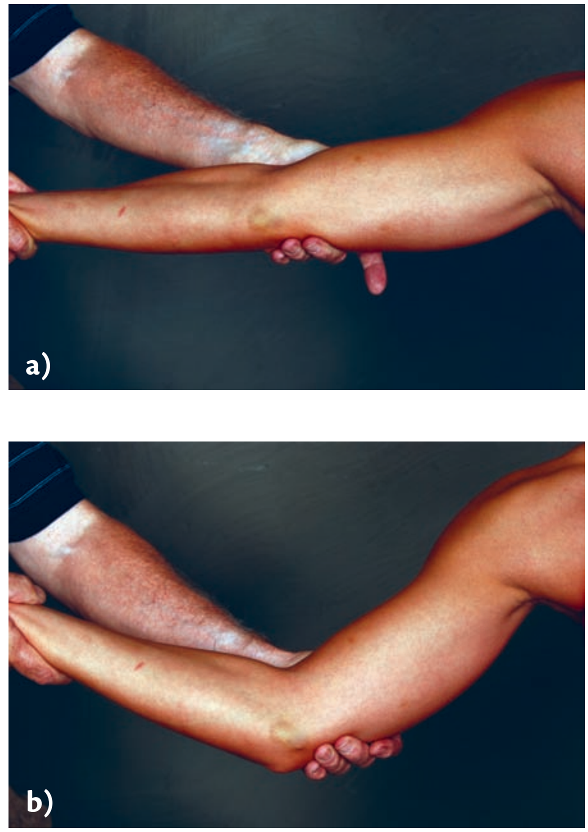


Figure 12.17 Valgus stress test examines valgus instability, i.e. the medial stability that exists when the forearm is moved outward in relation to the elbow. **a)** Stability is tested with the elbow extended; pressure is applied over the outside (lateral side) of the elbow. If excessive laxity in the joint is experienced it is a sign of serious instability; **b)** the shoulder is held externally rotated and the elbow bent to a 30° angle. Pressure is applied to the outside (lateral side). If there is excessive laxity present it is a sign of instability.

Treatment

The treatment includes rest and ice, generally followed by rehabilitation with strengthening exercises as the main focus. Non-operative therapy is mostly recommended initially, as a large percentage of patients will respond well. Surgery is indicated for severe acute injury in some top level pitchers or if 6 months of conservative therapy is unsuccessful. Frank Jobe, USA, developed a technique in 1974 of medial collateral ligament (MCL) reconstruction, which was dubbed the 'Tommy John procedure'.[1] This procedure is by many considered to be a success and is now used as the treatment of choice for many athletes especially baseball pitchers.

Return to throwing sport after surgery can sometimes be a test of the athlete's patience. Although some throwing is possible after 3–4 months, competitive throwing should be delayed for 9–12 months, providing that the shoulder, elbow, and forearm are pain-free while throwing and have full strength and ROM. Professional pitchers may need 12–18 months before reaching full capacity.

In other sports return is possible at 3–4 months. Overall the clinical outcomes for MCL reconstruction have been reported to be 68–93% with good to excellent results.

Entrapment of the ulnar nerve (ulnar neuritis)

If the medial posterior aspect of the elbow is accidentally hit, pain can be felt radiating to the fourth and fifth fingers of the hand. The ulnar nerve runs along the medial edge of the elbow just behind the epicondyle to which the flexor muscles of the wrist are attached. In throwing or racquet sports the nerve can be stretched or slid out of its groove with subsequent mechanical irritation.

The majority of nerve lesions in athletes can be described as neuropraxia, the mildest form of nerve injury. It is characterized by a conduction block along a nerve where all nerve elements, axons, and connective tissue remain in continuity. The prognosis for complete recovery may be good, provided no irreversible tissue damage has occurred due to long-standing compression.

The nerve can be injured by friction, compression, contusion, tension (traction) or a combination of these. The ulnar nerve is also susceptible to stretch injury, although it may stretch up to 20% before damage occurs. Valgus extension overload during serving and pitching creates significant tensile overload on the medial elbow ligament structures and compressive loads laterally. The medial part of the ulnar nerve can elongate 4.7 mm (0.2 in.) during extension to full flexion. It can be moved 7 mm (0.3 in.) medially by triceps. These tensile loads also affect the ulnar nerve as it crosses through the cubital tunnel, causing nerve friction, irritation and compression. The nerve may become unstable as the elbow is flexed.

Ulnar nerve entrapment was found in 60% of surgical cases of medial tennis elbow. These entrapments were found distal to the medial epicondyle at the medial and muscular septum, as the nerve enters the flexor carpi ulnaris. The nerve entrapment may be secondary to elbow instability, spurs, synovitis and more proximal compression.

Symptoms and diagnosis

- Pain arises from the medial aspect of the elbow, typically after long tennis matches or golf sessions, or throwing the javelin.
- Pain may increase and radiate to the fourth and fifth fingers of the hand.
- Numbness and impaired sensation may be present in the little finger and half the ring finger.
- Tenderness may occur over the nerve on the medial dorsal side of the elbow (Fig. 12.18).
- In serious cases even tapping the ulnar nerve lightly can cause pain extending as far as the ring finger.
- Dislocation of the nerve from the cubital tunnel on palpation (that is, the nerve moves over the medial epicondyle during activity).

Treatment

The athlete should rest the arm.

The physician may:

- Prescribe anti-inflammatory medication.
- Operate if the injury persists in order to free the nerve or move it to a position in which it is subjected to less tension. Surgery usually gives good results. In a chronic phase, especially if the nerve is subluxated, the nerve can be treated surgically with transposition of the nerve in front of the epicondyle and decompression for at least 5 cm (2 in.) distal to the epicondyle.

Little Leaguer's elbow

During pitching i.e. when a ball is thrown in baseball, there is a valgus stress on the elbow and the wrist and the fingers are vigorously pronated. These activities may cause injury to the elbow. The muscles responsible for this movement are all located in the inner (medial) compartment of the forearm. The force of the throw is transmitted up through the arm to the weakest part of

Figure 12.18 'Entrapment' of the ulnar nerve. Tenderness may be present over the nerve on the medial-dorsal side of the elbow.

the muscle group, which is the medial epicondyle from which the muscles originate. In growing adolescents these muscle origins are attached to a growth plate, that is considerably weaker than the adjacent bone, and problems are caused by the increased traction on the epiphyseal junction (epicondylar apophysis).

Symptoms and diagnosis

- Pain in the elbow often starts gradually. If the pain appears suddenly the epiphysis may have been torn off, which sometimes necessitates surgery. The pain can be induced when the elbow joint is flexed.
- There is stiffness in the elbow.
- Local tenderness is felt directly over the medial epicondyle.
- Both the elbows should be X-rayed. A fissure (separation) in the epiphysis can be seen if present.

Treatment

The athlete should:

- Rest from painful activity.
- Give up throwing movements completely until the pain has resolved (usually after 8–9 weeks).
- Continue with conditioning and general strength training.

The physician may:

- Prescribe rest and sometimes immobilize the elbow. If there is a fissure in the epiphysis, a cast may be used.
- Operate if displacement is significant. Neither steroid injections nor anti-inflammatory medicines should be given to growing adolescents.

Healing

If the epiphysis has been injured, throwing training can be resumed at the earliest 8 weeks after the injury occurred. Prior to that, careful rehabilitation should aim to maintain muscle function.

Posterior elbow injuries

Posterior tennis elbow (posterior olecranon impingement, hyperextension elbow injury)

Posterior tennis elbow, also known as posterior olecranon impingement or hyperextension elbow injury, is associated with aggressive elbow extension during the follow-through phase (Figs 12.19, 12.20).

The olecranon can impinge on the posterior aspect of the humerus and cause problems, such as triceps tendinopathy. Osteophytes can form on the olecranon by forced hyperextension of the olecranon into the olecranon fossa, or by shear forces between the posterior medial aspect of the olecranon and the olecranon fossa secondary to the valgus movement placed on the elbow during the serve.

Pathological changes in the posterior compartment can be evaluated arthroscopically through a posterior lateral portal. The osteophytes are usually located on the posterior medial aspect of the olecranon. Treatment is usually conservative, but surgery is increasingly used to remove osteophytes and/or loose bodies. Return to sport is possible within 2–4 months.

Strain of the tendon of the triceps muscle

Falling on the hand when the arm is flexed or forceful throwing can cause a rupture in the tendon of the triceps, and sometimes the tendon attachment can be torn away from the tip of the elbow.

Symptoms and diagnosis

- Pain occurs in the tip of the elbow where a gap can be felt in the tendon.
- There is impaired power in the arm or inability to straighten the arm at the elbow. An X-ray is needed to exclude bony injury.

Treatment

- In cases of minor ruptures no treatment, apart from rest, is necessary.
- Surgery should be carried out when young, active athletes have suffered a total rupture of the tendon or the tendon attachment.

Bursitis (‘student’s elbow’)

Just below the tip of the elbow (olecranon) there is a bursa into which bleeding can occur following an accidental trauma to the area or a fall on the elbow (Fig. 12.21). In many sports, including orienteering, wrestling, volleyball, basketball, football/soccer, rugby, and team handball, this injury is common as the participants wear no elbow guards; in others, such as ice hockey, the guards may provide incomplete protection.

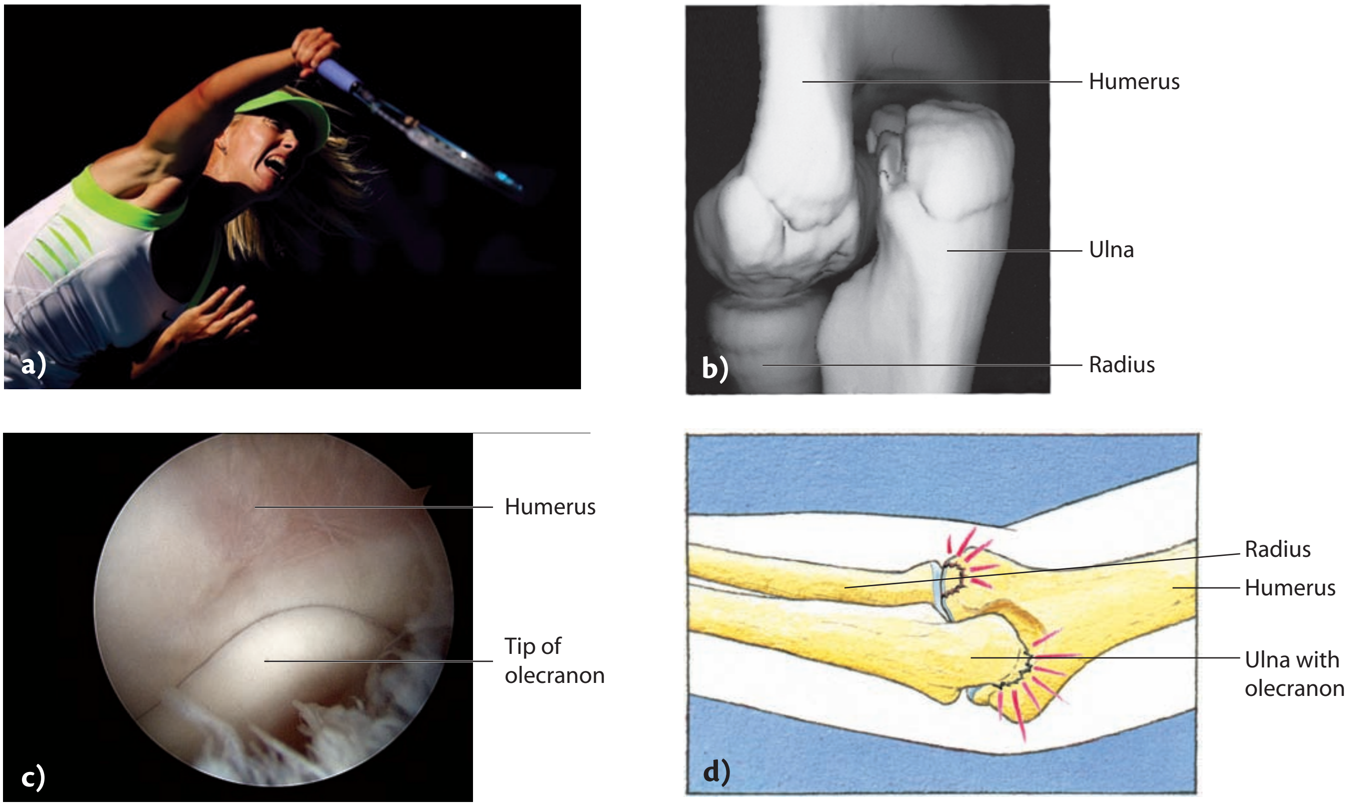


Figure 12.19 Posterior tennis elbow, also called posterior olecranon impingement or hyperextension of the elbow. **a)** Tennis serve in the final stages when the arm is reaching full extension and rotates inward (Courtesy of Bildbyrån, Sweden); **b)** when extended with force, for example, at the end phase of a boxer's punch or at the final stage of a tennis serve, the olecranon can come in contact with the posterior side of the humerus in the olecranon fossa; **c)** during arthroscopy it is possible to see the olecranon rest against the humerus posterior lower end (olecranon fossa); **d)** the posterior medial side of the elbow can collide with the humerus causing free bodies or osteophytes (bone spurs) to be formed.

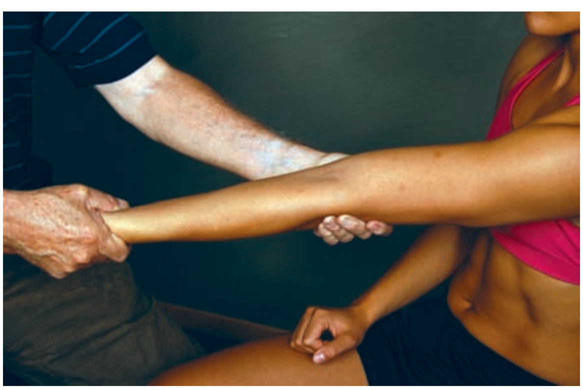


Figure 12.20 Pain may occur during hyperextension of the elbow.

After bleeding into the bursa, and also after prolonged loading of the elbow, the bursa can become inflamed and swollen. The condition is often called 'student's elbow' since it was popularly supposed to have affected students who rested their elbows on the desk while supporting their head in their hands when studying.

Symptoms and diagnosis

- Pain is felt at rest and during movement.
- Swelling and tenderness occur over the tip of the elbow after acute bleeding into the bursa following a violent impact. Sometimes the skin is damaged.
- Small blood clots form in the bursa and cause irritation of the surrounding tissues. This results in inflammation and effusion of fluid.
- When there is inflammation of the bursa, or when it has been subjected to prolonged pressure, it becomes distended with fluid and the overlying skin becomes red and tender. The swelling can extend to the forearm.
- There is limitation of mobility in the elbow joint.

Prevention

Elbow guards, that protect the olecranon (p. 59) should be used, especially by goalkeepers in team handball and football/soccer.

Treatment

The athlete should rest until symptoms have resolved.

The physician may:

- Puncture the bursa and drain out blood or fluid.
- Apply a bandage to be kept in position for 4–7 days.
- Administer a local steroid injection when inflammation is persistent.
- Remove the bursa surgically if it has been affected by repeated inflammation, especially when loose bodies or adhesions are present. This can be done arthroscopically.

Healing

After an episode of mild inflammation of a bursa in the elbow, the athlete can return to training 1 week after medical treatment has started. A severe bursitis can force rest for a long period.

Fracture of the olecranon

A fracture of the olecranon process can be caused by a fall on a bent elbow during contact sports, or in speedway racing and horse riding. The symptoms are swelling and tenderness over the elbow and an inability to straighten the joint (Fig. 12.22). Surgery is often required as the triceps tendon pulls the fractured surfaces away from each other. It is 2–3 months before sporting activity can be resumed after an injury of this nature.

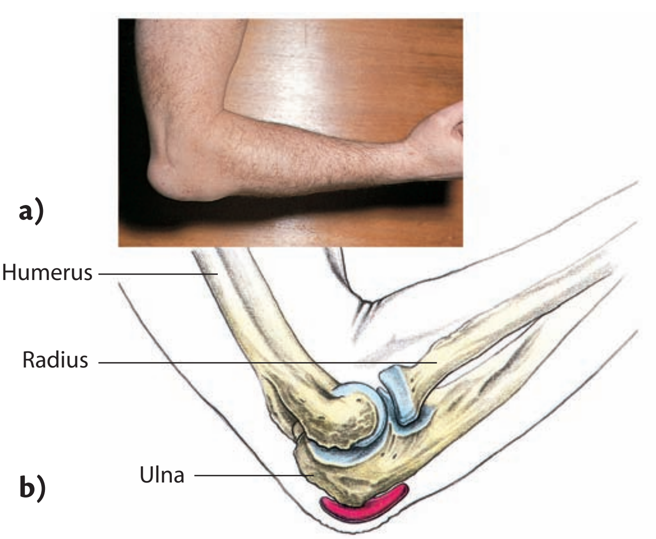


Figure 12.21 Below the tip of the olecranon a bursitis may develop following a blow to the area or fall on the elbow on a hard surface. **a)** Bursitis at the tip of the olecranon; **b)** drawing of a bursitis at the tip of the olecranon.

Anterior elbow injuries

Rupture of the distal part of the biceps tendon

The biceps tendon inserts distally into the radial tuberosity in the proximal forearm. It is responsible for flexion in the elbow and also for some supination. The tendon is susceptible to degenerative changes and ruptures occur in athletes over 35 years old. The injury mechanism is usually a sudden extension of the elbow when the elbow is forcefully flexed.

Symptoms and diagnosis

- There is a history of a sudden snap in the elbow region during an eccentric, sudden load of the elbow (Fig. 12.23).
- Moderate pain occurs over the anterior aspect of the elbow.
- Palpation reveals tenderness over the radial tuberosity and the anterior aspect of the elbow.
- Swelling occurs over the distal anterior aspect of the upper arm.
- It is difficult to contract the biceps against resistance at the elbow in the acute stage.
- There is weakness of the elbow in flexion.

Treatment

The athlete should consult a physician for advice.

The physician may:

- Prescribe careful mobilization with strengthening and stretching exercises (conservative therapy may result in a strength deficit of about 20–40%).

Figure 12.22 Tenderness can be palpated over the olecranon in injuries such as a fracture.

- Operate on a complete tear in a young active person. The indication for surgery is the need of the athlete to regain full strength. The procedure consists of reattaching the distal tendon to the radial tuberosity.

Healing

Early mobilization with strength and stretching exercises can begin as soon as pain and inflammation start to subside. Following surgery, healing usually takes 6 weeks, but ROM exercises should start after 2–3 weeks. Strength training can be resumed around 6–8 weeks. Throwing activities are usually not allowed until after 4–5 months. The prognosis and results are good.

Entrapment of the radial nerve

The posterior interosseous or superficial radial nerve branches just below the elbow in the lateral part. It can occasionally be subjected to compression, when it passes through the arcade of Frohse in the supinator muscle, which supinates the forearm. The symptoms may be similar to those of tennis elbow.

Symptoms and diagnosis

- Point tenderness may be present below and slightly in front of the lateral epicondyle, directly over the area of nerve entrapment (Fig. 12.24).
- Pain is felt and strength impaired when the wrist joint is extended and the forearm is supinated.
- EMG and nerve conduction studies may be helpful in identifying which motor segment is involved.

Treatment

The athlete should rest and gradually increase activities. The physician may:

- Prescribe anti-inflammatory medication.
- Operate to free the nerve and enlarge the canal in which it runs. Surgery usually gives good results.

Entrapment of the median nerve (pronator teres syndrome)

The median nerve runs in front of the elbow joint and passes through the pronator muscle. Entrapment of this nerve is a rare condition in sport. Overuse is a common cause.

Symptoms and diagnosis

- Pain and tenderness occur in the middle anterior aspect of the elbow (Fig. 12.25).
- Numbness is felt in the second and third fingers, and in the radial half of the fourth finger.
- Pain can be elicited by pronation of the lower arm against resistance.
- Weakness is present in palmar flexion of the hand.
- Discomfort during resisted elbow flexion and forearm pronation can support the diagnosis.

Treatment

The athlete should:

- Rest from painful activity.
- Use heat.

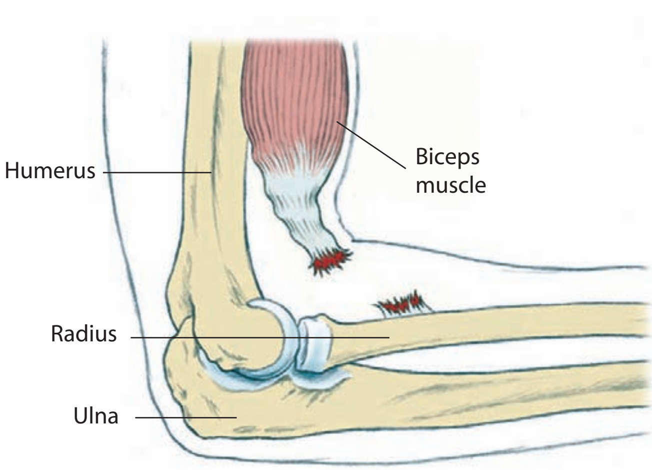


Figure 12.23 Rupture of the distal tendon insertion of the biceps can occur with a sudden extension of a bent elbow or a heavy lift. (Courtesy of Tommy Berglund.)

Figure 12.24 Tenderness may be present on palpation below and in front of the lateral epicondyle if an entrapment of the radial nerve is present.

Figure 12.25 Tenderness may felt in the middle of the elbow on the anterior side if an entrapment of the median nerve is present.

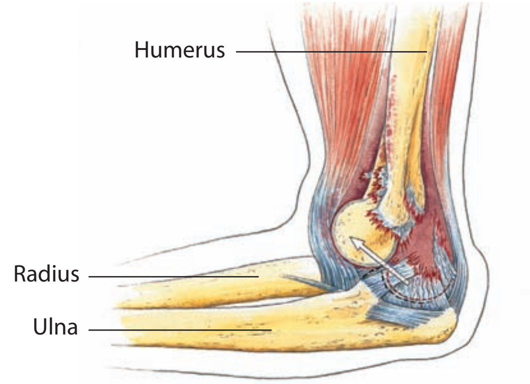


Figure 12.26 Posterior elbow joint dislocation (luxation) of the ulna and radius in relation to the humerus (upper arm).

The physician may:

- Prescribe anti-inflammatory medication.
- Immobilize the elbow for a short time.
- Operate in chronic cases.

Fractures and dislocations

Dislocation

Dislocation of the elbow joint occurs mainly in athletes participating in contact sports, such as American football, rugby, and ice hockey, but can also occur in riders, cyclists, wrestlers, skiers and squash players. A common cause of this injury is falling on the hand with a bent elbow. A similar injury can occur if the elbow is overstretched in a fall.

A backward (posterior) dislocation of the elbow joint is most commonly seen (Fig. 12.26) and may be combined with a fracture. Dislocations always involve injuries to surrounding soft tissues, such as the medial and lateral collateral ligaments and joint capsule, so that even when the injured joint is realigned promptly it can take some time for complete healing to take place.

Symptoms and diagnosis

- Intense pain, swelling, tenderness and limitation of mobility are experienced.
- There is deformity of the elbow joint.
- An X-ray confirms the diagnosis.
- Stability testing of the collateral ligaments at 20–30° of flexion and in extension will show the extent of ligament injury after reduction.

Treatment

The physician may:

- After having checked nerve function and circulation, replace the joint to its normal position and test it for stability; the sooner this is done, the easier the manipulation.
- X-ray the joint after it has been restored to its correct position.
- Immobilize the elbow joint in a brace for a few days depending on the extent of the injury. Mobility training (p. 282, 307) should start as early as possible.
- Operate if there are extensive ligament injuries and instability in the joint.

Healing and complications

When the brace has been removed, the injured athlete can resume conditioning exercises such as running. The athlete's usual sport should not be resumed until 9–10 weeks after the occurrence of the injury, when the ligaments have healed and full mobility is restored.

Nerve and circulatory injuries may occur and give permanent symptoms in the forearm and hand. If a dislocated elbow is treated inadequately, the result may be incomplete healing of the ligaments and joint capsule, and a susceptibility to recurrent dislocation.

Fracture of the lower end of the humerus (supracondylar fracture)

Children often sustain fractures of the lower part of the humerus because of falls from gymnasium apparatus, and in riding or cycling falls (Fig. 12.27).

Symptoms and diagnosis

- Intense pain is felt during arm movements.
- There is tenderness on pressure.
- Swelling and bruising are noticeable.
- Contour changed.

Treatment

The injured person should be taken to a physician as quickly as possible. Fractures of the lower part of the humerus very often require hospital treatment, especially in children or adolescents, as the important nerves and blood vessels situated near the broken ends of the bone can be affected by the resultant bleeding and are vulnerable to damage. Pulse and sensation below the injury should be checked.

The physician will attempt to realign the fractured bones, and if this is not possible, surgery may be necessary.

Healing

Mobility exercises (p. 283, 307) are started at an early stage if the injury is not too serious. After 8–10 weeks, when full mobility of the arm has been regained, sporting activity can be resumed.

Arthroscopy of the elbow

Arthroscopy is more and more commonly used for diagnosis and treatment of many elbow injuries. By avoiding a large capsular incision, many of the problems of postoperative scarring and capsular contraction of the elbow can be avoided.

Elbow arthroscopy should be performed slowly and deliberately, by a surgeon who is experienced in Sports Medicine. Usually a 4 mm, 30° angle arthroscope provides optimal visualization of the elbow; sometimes a 1.6 mm flexible arthroscope can be used (Fig. 12.28).

The anterolateral portal, 2 cm distal and 3 cm anterior to the lateral epicondyle, is commonly used. The lateral antebrachial cutaneus nerve and the posterior branch of the medial antebrachial cutaneous nerve must be avoided. The instrument should be directed toward the center of the elbow with the elbow flexed at 90° at all times. The arthroscopic instruments pass within a mean distance of 4 mm of the radial nerve regardless of the flexion or extension of the elbow when the elbow is not extended with fluid. However, when 35–40 ml of fluid is inserted into the elbow capsule, the radial nerve moves an additional 7 mm anteriorly. The maximum distention of the elbow should be maintained at all times, particularly when establishing the initial arthroscopic portals.

Through a medial portal, 2 cm proximal and 1–2 cm anterior to the medial epicondyle, the radial head and the capitellum can be well visualized. The anterior and posterior branches of the medial antebrachial cutaneous nerve should be avoided.

The posterolateral portal is sited 3 cm proximal to the olecranon superior and posterior to the lateral epicondyle. The olecranon fossa and tip of the olecranon can be seen as well as the distal humerus. It should be remembered that this portal is established with the elbow at 20–30° of flexion.

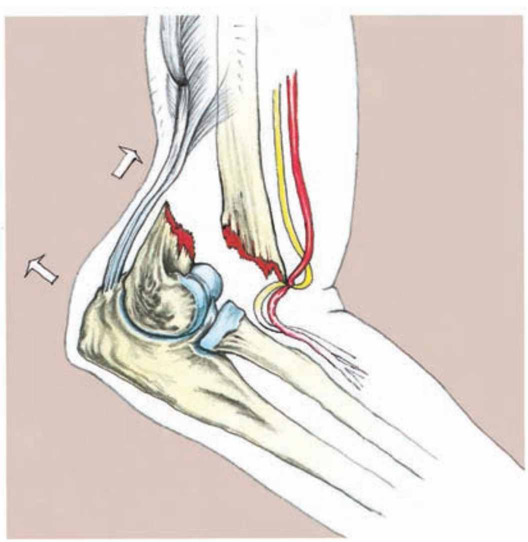


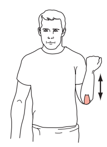
Figure 12.27 Fracture of the humerus (upper arm) lower part. Bone fragment may press against and/or damage nerves and blood vessels.

Figure 12.28 Examination of the elbow via arthroscopic surgery. (Courtesy of Prof. Marc Safran, Stanford University, California, USA.)

Rehabilitation program: elbow, wrist and hand

Elbow rehabilitation

Whatever the injury, the rehabilitation program must address inflammation, restricted mobility, pain, weakness and functional disability. The dangers of elbow joint immobilization, arthrofibrosis, and adhesive capsulitis (joint stiffness) have been well documented. It is imperative that early ROM exercises be initiated to minimize the degenerative effects of immobility. As with all rehabilitation, strength is important for proper function. The initiation of muscle activity early in the process is important to prevent tissue hypotrophy, and to re-educate muscle. Athletes whose sports involve throwing should include scapular stabilization exercises along with strengthening exercises for the whole shoulder–elbow complex.



Elbow flexion and extension

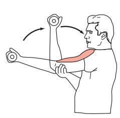
Standing with your arms down at your side, slowly bend and straighten your elbow as far as possible. Hold each position 5 seconds, repeat 10 times.

Infraspinatus

Lie on your back, with one arm to the side. Bend your elbow to 90° degrees. Use the other arm to press your hand against the floor / surface as far as possible.

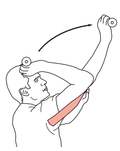
Tennis elbow (stretching of wrist extensors and pronators)

Stand with the back of the hand, of the injured side, resting against a table, keep the elbow straight. Apply a downward force towards the table. Grab the hand of the injured side with the other hand and rotate the wrist and hand outward while maintaining flexion of the wrist. The strain should be felt over the top of the upper arm and the upper side of the wrist. Hold for 15–20 seconds, repeat 5–6 times.



Biceps curl

Support the involved arm at the elbow with the opposite hand. Slowly bend your elbow as far as possible, and then extend the elbow as far as possible. Hold for 3 seconds at the end of each motion. Repeat.



Triceps curl

Raise the involved arm overhead. Provide support at the elbow with the opposite hand. Straighten the elbow overhead, then slowly return. Hold for 3 seconds at the end of each motion. Repeat.

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13 Forearm, Wrist and Hand Injuries in Sport

Forearm injuries

Forearm injuries are not common in sports but can occur from overuse in racquet sports or from high-energy falls in other sports.

The forearm serves as an anchoring point for the muscles and tendons that pass to the wrist and hand and to the fingers. The two bones of the forearm (radius and ulna) can rotate over each other. This provides power and allows for precise hand positioning for specialized functions. The forearm can therefore internally rotate (pronate) in the wrist and externally rotate (supinate) in the wrist (Fig. 13.1).

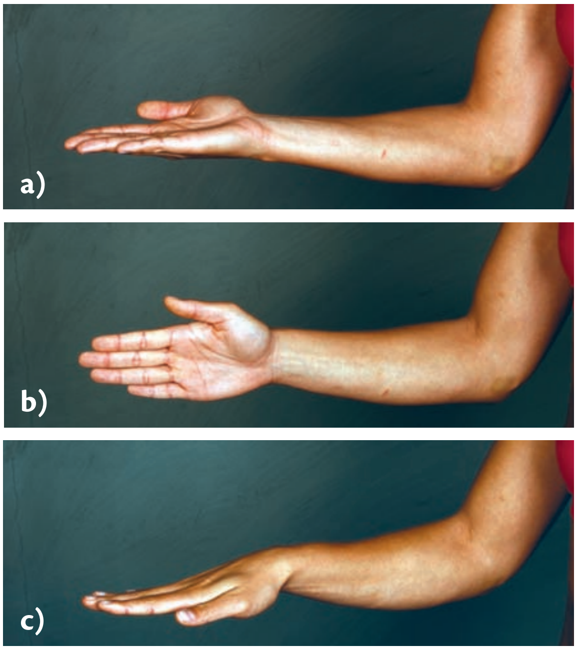


Figure 13.1 Forearm usual positions. **a)** Supination; **b)** neutral position; **c)** pronation.

The muscles that create flexion and extensions of the fingers extend over the entire forearm. Forearm muscles thus affect both the elbow joint and the wrist and finger joints.

Overuse injuries

As a result of external pressure or repetitive one-sided movements, the extensor and flexor muscles of the forearm and their tendons and tendon sheaths are subject to overuse injury (Fig. 13.2). The injury occurs mainly in rowers and canoeists at the start of their intensive training periods at the beginning of the season, but tennis, squash, table tennis and badminton players, skiers and others can also be affected.

- Pain occurs when the hands are flexed and extended (Fig. 13.3).
- Local swelling and tenderness occur over the affected muscle and tendon.
- Tendon crepitus (creaking) is felt over the affected tendons on the back of the hand and the forearm when movements are made with the fingers and wrist.

Inflammation may be prevented by:

- Rest from painful activities.
- Gradually increasing training and load.
- Varied training avoiding one-sided movements.
- Correct technique and equipment.

The athlete should rest from painful activities; the injury often heals spontaneously, though it can take a considerable time to do so.

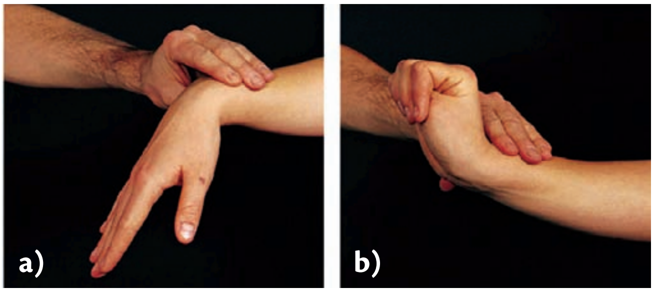


Figure 13.2 Inflammation due to overuse of forearm flexor and extensor muscles. **a)** Pain may occur during wrist flexion movements of the hand; **b)** pain may occur during wrist extension movements of the hand.

Figure 13.3 Wrist pain is common in hand intensive sports. **a)** Top-level tennis can create wrist discomfort; **b)** snowboarders use their wrists often and therefore have wrist guards. (With permission, by Bildbyrån, Sweden.)

The physician may:

- Treat with a brace or a splint for 1–4 weeks.
- Prescribe anti-inflammatory medication.

Compartment syndrome

Compartment syndrome (compare p. 475) is a rare injury. It occurs in motorcycle sports such as motor cross and is characterized by an exercise-induced ache or pain with a sensation of increased pressure or tightness. Intermittent weakness or numbness may be noted. Because the causes of compartment syndrome are poorly understood, it is difficult to diagnose this injury. Direct evaluation of intramuscular pressure is helpful. As conservative treatment is rarely successful for these chronic conditions, treatment is usually surgical fasciotomy.

Fractures

Fractures of the forearm can occur after a fall or a direct blow and usually involve both the radius and the ulna. Fractures of the ulna alone can occur when parrying a blow with the forearm.

A fracture of the ulna can be combined with a dislocation of its articulation at the elbow joint (Monteggia's fracture). The elbow should therefore be examined and X-rayed when fracture of the ulna occurs.

It is important that the two bones, the ulna and the radius, are restored to their precise anatomical positions. Immobilization in a cast for 6–10 weeks is advisable, and surgery is frequently indicated, especially in cases of displacement.

When the cast is removed the arm should be strengthened by training for 6–10 weeks before the injured athlete can return to sporting activity.

Wrist injuries

Trauma to the wrist constitutes between 3 and 9% of all sports-related injuries. In some disciplines, such as snowboarding and martial arts, the prevalence, however, can be up to 35%.[1] Wrist problems are more common in hand-intensive sports and sports that entail gripping an object such as a tennis racquet or golf club. Most injuries are due to repetitive overuse (Fig. 13.4). In tennis, wrist injuries represent about 11% of all injuries in male world ranked players, and among female, about 15%.

Tennis players hold their racquet in various grip positions, which can affect stroke biomechanics and the overall biomechanical loads on the upper extremity. There are four different grip positions used to hit a forehand: Continental, Eastern, semi-Western and full Western (see Fig. 6.17) An Eastern grip can contribute to injuries to the radial side of the forearm, e.g. flexor carpi radialis tendinopathy, DeQuervian's tendinopathy, and a Western or semi-Western grip can cause injuries on the opposite ulnar side, e.g. extensor carpi ulnaris tendinopathy and triangular fibrocartilage pathology.[2]

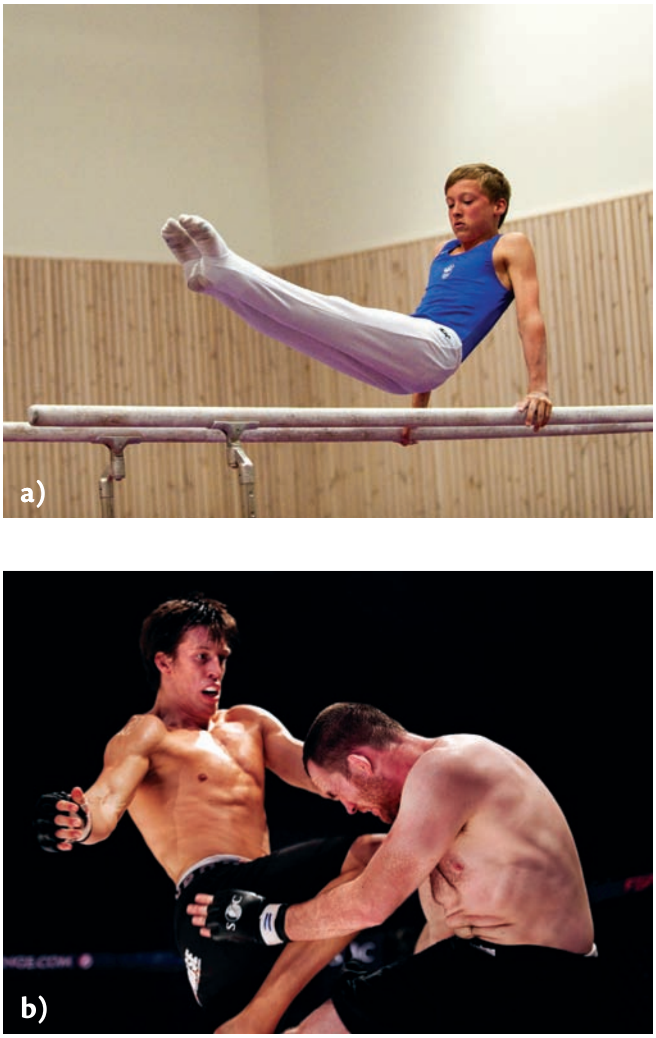


Figure 13.4 Examples of athletes using their wrists. **a)** Gymnasts are exposed to wrist problems when they perform an abundance of handstands and jumping with their wrists extended, placing great pressure on the wrist; **b)** martial arts can produce considerable compression to the wrist through impact. (With permission, by Bildbyrån, Sweden.)

Injury mechanisms

Wrist fractures can occur in sports with high-energy falls, such as snowboarding, skiing and skating. Falling and landing with the wrist in dorsal flexion with the load is towards the ulnar, palmar side of the wrist. Common injuries include fractures of the radius and scaphoid, injury to the ligaments results in instability and triangular fibrocartilage complex (TFCC) injuries.

Falling on a flexed wrist can result in a compression injury on the wrist's flexion side. Similar injuries occur as with the wrist in dorsal flexion.

With a failed swing with a golf club or a baseball club, a hamate fracture can occur if the force of the club goes beyond the grip strength, i.e. the hypothenar (outer part) of the palm can be subjected to an impact. A similar mechanism may occur when a golfer hits the ground instead of the ball.

In non-professional tennis players who get wrist injuries, different racquet grips are related to the injury localization: an Eastern grip causes injuries to the radial side, and a Western or semi-Western grip to the ulnar side (see Chapter 6, Fig. 6.17). Sport activities can produce compressive loads, for example, cycling can cause compression of the ulnar nerve at the Guyon's canal, resulting in pain radiating to the little finger.

Gymnastics with different forms of handstands and jumping with wrists extended produce large pressure on the dorsal side of the wrist, which may cause synovitis and bone hypertrophy of the ulna and scaphoid. Another common injury in gymnastics is TFCC problems.

The wrist is composed of seven carpal (midhand) bones that are joined together and stabilized by joint capsules and by ligamentous structures (Fig. 13.5). Disruption of the ligaments generally requires high-energy trauma, but when it does occur it can be very debilitating. An eighth

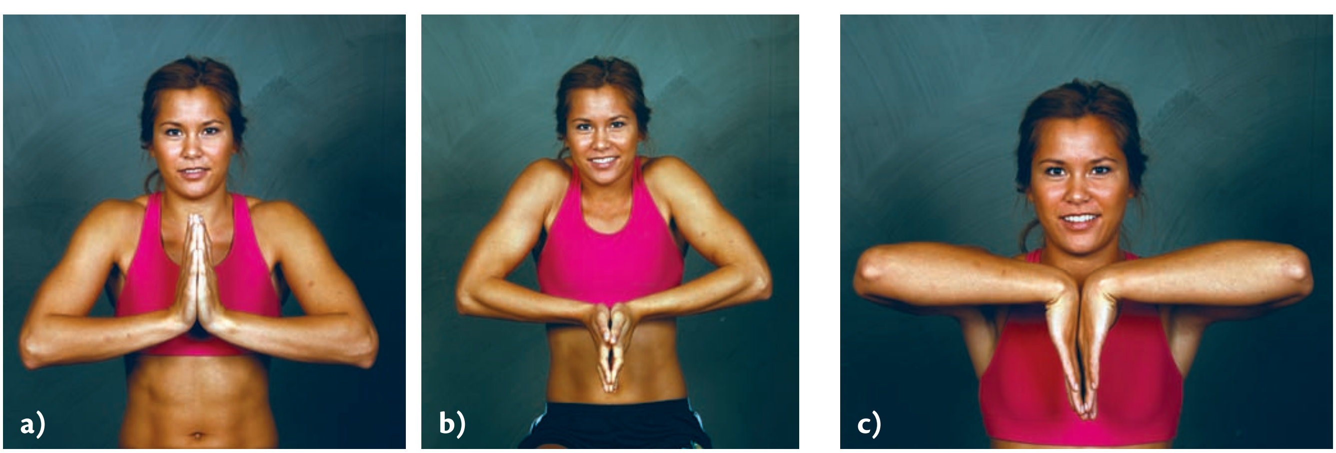


Figure 13.5 a–c) The wrist has very good mobility.

carpal bone lies within one of the flexor tendons of the wrist and glides over another carpal bone as a 'sesamoid bone'.

Fractures of the distal radius and ulna

Fractures of the wrist are basically three different types, Colles', Smith's and Barton's fractures. Comminuted fractures can also occur, which is fractures with multiple fragments.

Colles' fracture

Colles' fracture is the most common (85%) of all types of fracture and comprises fracture of the distal radius just above the wrist. The fracture occurs usually by falling on an outstretched arm so that the hand is forced backwards and upwards (Fig. 13.6).

Smith's fracture

Less common are fractures of the ulna, which is caused by palmar flexion of the wrist. Smith's fracture accounts for 15% of wrist fractures. This fracture may be caused by high-energy trauma such as motorcycle accidents or contact sports such as hockey, football, rugby and handball, but are not uncommon in riders, wrestlers, skiers, etc.

Barton's fracture

Distal radius fracture with intra-articular fragments in the wrist, which can be dislocated dorsally or anteriorly.

Symptoms and diagnosis

'Dinner fork' deformity of the wrist is characteristic of Colles' fracture (Fig. 13.6). The position is caused by the fractured fragment of the distal radius being driven backwards (dorsiflexed) in relation to the forearm. In Smith's fracture a forward (palmar flexion) dislocation of the distal radius is present.

- Swelling and tenderness occur in the wrist.
- Pain is felt on wrist movements.
- In milder cases, swelling and displacement may be minor. The injury may then be mistaken for a sprain, but when this is so, the wrist should be X-rayed to reveal any bony injury.

The physician may:

- For Colles' fracture:
- Restore the fractured ends of the bone to their correct position.

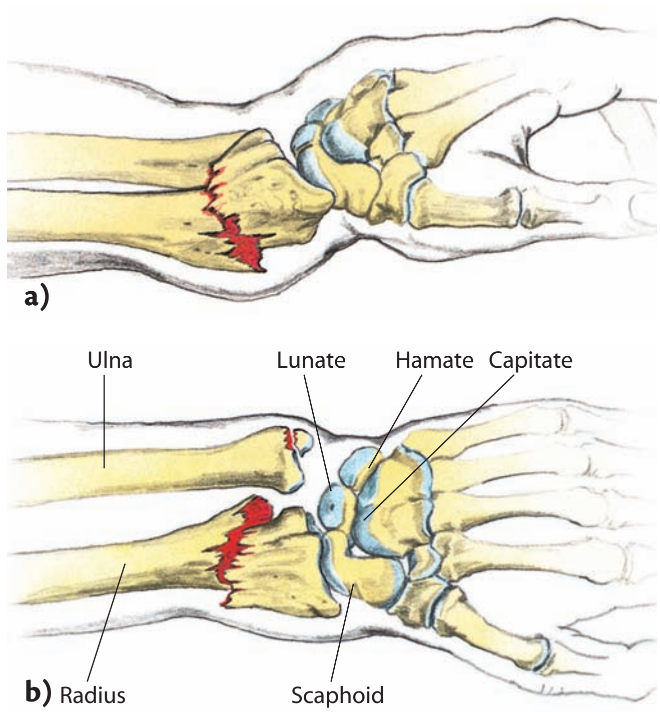


Figure 13.6 Fracture of the distal radius just above the wrist (Colles fracture). **a)** 'Bayonet position' side view of the fracture; **b)** fracture as viewed from above.

- Apply a plaster cast (usually a splint or brace that can be removed after 4–5 weeks if the fracture is uncomplicated). The wrist is later strengthened by training.
- X-ray surveillance 1, 2 and 5 weeks after that the fracture has been restored. If the malalignment reoccurs there may be a need to restore the correct position, i.e. alignment.
- Operate in cases of more serious fractures.
- For Smith's fracture, which is often unstable: consider operative treatment.

The treatment of these fractures varies greatly. The lack of optimal care of the distal radius fractures is one of the most common reasons for patients receiving patient compensation. Conditioning can often be maintained during immobilization of the wrist. Other forms of sporting activity involving the wrist can be resumed after 8–12 weeks.

Fracture of the scaphoid

A fracture of the scaphoid bone in the wrist can result from a fall with the wrist bent backwards on an extended arm (Fig. 13.7). The injury is particularly common in contact sports such as football/soccer, American football, rugby, ice hockey, and team handball, but can also occur in skiers and other athletes.

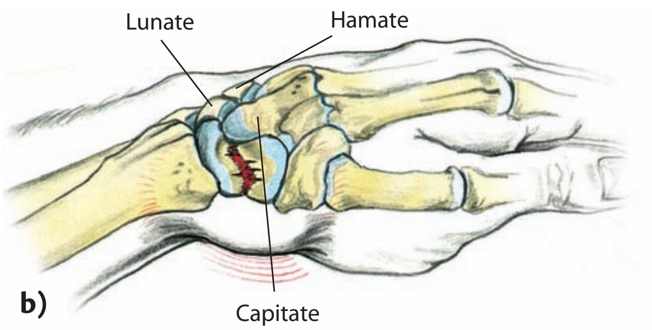


Figure 13.7 Fracture of scaphoid. **a)** Elite athletes can get scaphoid fracture with falls (with permission, by Bildbyrån, Sweden); **b)** fracture of scaphoid bone.

Tip

The blood flow to the scaphoid is easily compromised, especially in fractures of its middle portion, and this slows the healing process. Athletes often find it difficult to accept the prolonged treatment that is needed for this injury to heal.

Symptoms and diagnosis

- Moderate pain is felt with tenderness and swelling in the scaphoid region (the hollow formed at the base of the extended thumb: the 'anatomic snuffbox' (Fig. 13.8).
- Power is moderately impaired during hand movements.
- The injury is often disregarded and is looked upon as a sprain because of the apparent triviality of immediate symptoms.
- An X-ray and bone scan or magnetic resonance imaging (MRI) will confirm the diagnosis.

Figure 13.8 Moderate pain with tenderness and swelling in the depression that appears at the thumb–wrist junction when the thumb is extended and abducted ('anatomical snuff box').

The athlete should consult a physician for an X-ray in the case of any hand injury that could involve a fracture of the scaphoid (Fig. 13.9).

The physician may:

- Apply a plaster cast or a brace when there is a suspected fracture, even if the early X-ray does not show one.
- And be aware that scaphoid fractures not always are visible on an acute X-ray but only after 7–10 days. If a scaphoid fracture is suspected an MRI scan or new X-ray should be taken after 10–14 days.
- In an acute undislocated fracture treat with plaster cast for 8–10 weeks. Among athletes, the plaster cast can sometimes be replaced after a few weeks by an orthosis. The healing process is checked after 6–8 weeks with X-ray. If there is doubt it can be monitored with computed tomography (CT).
- A poor healing prognosis of these fractures has been observed with conservative treatment, which has resulted in operative treatment becoming more common. These fractures should particularly be operated on if there is a malalignment in the fracture.

Healing and complications

It is not unusual for the injured athlete to fail to consult a physician and for the early symptoms to disappear. In these circumstances, healing may not occur and a false joint can be formed. This may ultimately cause

Tip

A fall on the wrist with pain should always be suspected to be a scaphoid fracture.

Remember that a scaphoid fracture does not always show on an acute X-ray but may be apparent after 7–10 days. An MRI or repeat X-ray should be done after 10–14 days if there is suspicion of a scaphoid fracture.

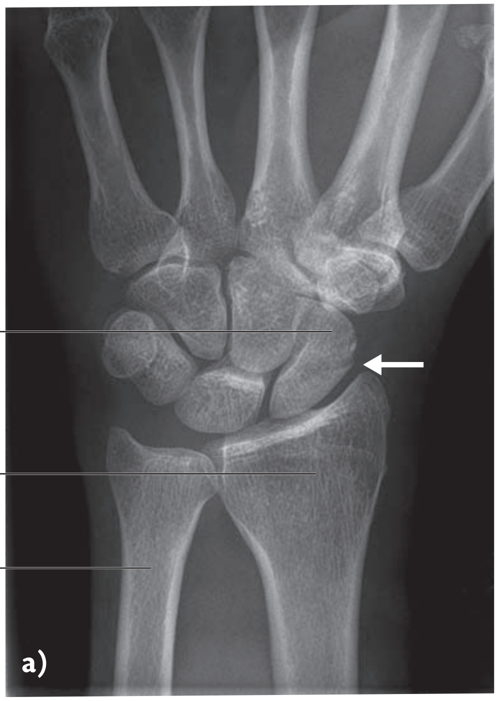


Figure 13.9 Radiology and imaging will secure the diagnosis of scaphoid fracture. **a)** X-ray of the wrist showing a scaphoid fracture (arrow); **b)** CT scan will show a scaphoid fracture (see arrow).

degenerative changes in the wrist with discomfort, pain during movement, stiffness and impaired function.

Premature cessation of treatment, or sometimes even adequate treatment, can be followed by formation of a false joint (pseudarthrosis). A pseudarthrosis of the scaphoid should have surgical fixation.

Athletes can, in spite of a fracture of the scaphoid, continue with acceptable conditioning activity.

Fracture of the hook of the hamate

The hook of the hamate bone projects anteriorly on the lateral side of the palm. A compression fracture of this bone is a rare injury, but it may occur in racquet sports, baseball, ice hockey and cycling if the handle of the racquet, bat, club, stick or handlebar is compressed on to the hook of the hamate. The incidence of this fracture is higher in athletes, about 2–4% of wrist injuries.

Symptoms and diagnosis

- Pain and tenderness are felt on the little finger side of the palm.
- The grip has decreased power.
- Numbness of the little finger is caused by irritation of the ulnar nerve.
- An X-ray with a carpal tunnel view, or a CT scan, is necessary to verify the diagnosis. These fractures may be missed on both conventional radiography and special X-ray projection. Therefore, if there is strong clinical suspicion of this fracture it is recommended to proceed with a CT scan to confirm the diagnosis.

The athlete should:

- Rest and cool the injury.
- Consult a physician.

The physician may:

- Verify the diagnosis with X-ray or CT scan.
- Recommend a period of rest to allow symptoms to decrease.
- Be more active in the treatment of this injury considering the risk for non-healing (non-union) in cases treated conservatively is 80–90%. These fractures heal poorly due to the continuous movement of the fourth and fifth fingers in the cast, poor circulation, delayed diagnosis and displacement of fracture fragments. Athletes with this fracture should be sent to a hand surgeon for a decision on whether surgery is indicated or not.
- Operate and remove the hook in some displaced fractures or when non-union remains symptomatic.

Healing and complications

- This fracture is easily overlooked.
- Healing of this fracture is rare even with internal fixation, but non-unions of hamate fractures are often not painful.
- One complication is a compression of the ulnar nerve at the level of Guyon's canal. The hook of the hamate

is located at the distal lateral border of the canal, i.e. near the motor branch to the ulnar nerve when crossing the canal. This can result in inflammation in the lower portion of the ulnar nerve.

Flexor tendon injury

The athlete can usually return to sport as soon as symptoms allow.

Dislocations around the wrist

Dislocations around the wrist are rare in sports, but are important to recognize because a good recovery depends on early and correct diagnosis and treatment. Even with proper treatment, these injuries often have long-term residual symptoms.

Separation between the scaphoid and lunate

Scapholunate dissociation may occur in forced dorsiflexion of the wrist. Ligamentous disruption between the scaphoid and lunate bones will cause the two bones to separate. This injury is felt to be a less severe form of the same mechanism that causes perilunate dislocation.

Symptoms and diagnosis

- Pain is felt on movement.
- There is swelling of the wrist, and tenderness over the lunate and scaphoid (Fig. 13.10).
- An X-ray shows an increased joint space between the scaphoid and the lunate and/or an abnormal angle between the scaphoid and lunate.

The athlete should:

- Cool, compress, and elevate the wrist.
- Consult a physician.

The physician may:

- Verify the diagnosis by X-ray.
- Surgically reduce the displacement, suture the ligament and joint capsule, and hold the reduction with pins or steel wire.
- Immobilize the joint for 8–12 weeks.

Perilunate dislocation

Perilunate dislocation is a dorsal dislocation of the capitate (see location of the lunate and capitate bones in Fig. 13.7) in relation to the lunate bone, which may sometimes be dislocated anteriorly at the same time. It may occur in association with a dislocation or fracture of the scaphoid and is caused by forced dorsiflexion or axial compression of the wrist.

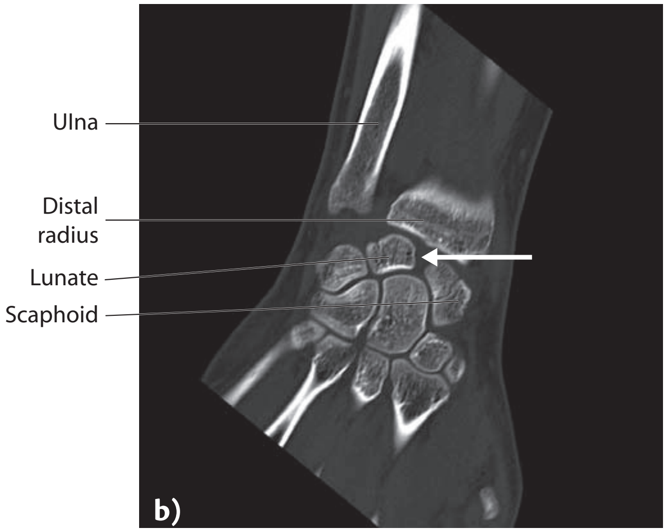


Figure 13.10 Separation injury of the scaphoid and lunate bone. **a)** Site of discomfort between the scaphoid and lunate bone; **b)** tomography (CT) right wrist shows fracture through scaphoid without deformity (arrow) and separation between the scaphoid and lunate bone as a sign of ligament and capsule damage.

Symptoms and diagnosis

- Changed contour is visible on the dorsal aspect of the wrist.
- Swelling and tenderness are present.
- Movements are painful and restricted.
- X-rays show the posterior dislocation of the capitate.

The athlete should:

- Cool, compress and elevate the wrist.
- Consult a physician immediately.

The physician may:

- Verify the diagnosis by X-ray.
- Operate to reduce the dislocation and hold it in position with pins or steel wires.
- In addition, repair the torn ligaments.

The lunate (see Fig. 13.7) can dislocate both posteriorly (in a dorsal direction) and anteriorly (in a palmar direction). This injury is really just a continuation of the perilunate dislocation and scapholunate dissociation. With increasingly severe trauma, the injury progresses from scapholunate dissociation to perilunate dislocation and then to true lunate dislocation.

Malacia of the lunate (Kienböck's disease)

Lunatomalacia may occur as a result of repeated trauma or impacts, usually among younger people 15–40 years of age. There are a number of tennis players that have sustained this injury. The circulation of the lunate is disturbed, and the bone softens and becomes devascularized. This injury is associated with a slightly shortened ulna in relation to the radius at the wrist (this is called negative variance).

Symptoms and diagnosis

- Movements are painful and restricted.
- Radiation of pain in the forearm.
- Restricted dorsal flexion.
- Swelling and tenderness occur over the lunate.
- Weakness of the hand.
- Passive dorsal flexion of the middle finger produces pain.
- Decreased size and sclerosis (increased bone density) of the lunate are seen on X-ray.The lunate can collapse and affect the stability between the carpal bones.

The athlete should:

- Rest the wrist.
- Avoid compression of the lunate area.
- Consult a physician.

The physician may:

- Verify the diagnosis by X-ray or bone scan.
- Immobilize the wrist in the acute stage.
- Refer to a hand specialist.
- Resort to surgery to relieve stress on the lunate in mild cases, or perform fusions for advanced cases.
- The decision to return to sport will depend on individual circumstances.

Carpal tunnel syndrome

The carpal tunnel is a narrow tunnel between the carpal bones and a strong ligament on the palmar side of the wrist (Fig. 13.11). Through the carpal tunnel pass the median nerve and nine tendons of the muscles that flex your fingers. Carpal tunnel syndrome is when the median nerve is compressed in the carpal tunnel.

Carpal tunnel syndrome is most often caused by overuse of the wrist, which in turn causes narrowing

Figure 13.11 Carpal tunnel syndrome. **a)** Localization for tenderness over the carpal tunnel area where the palm begins just below the wrist; **b)** test of the median nerve by the patient pressing the thumb against their little finger and the examiner testing the resistance.

and inflammation of the tunnel that houses the nerves and tendons that lead from the forearm to the wrist. Compression of the median nerve causes the symptoms. Overuse is common in hand-intensive activities, particularly when the wrist is used for support, as in cycling.

Symptoms and diagnosis

- Tenderness over the palmar aspect just distal to the wrist (Fig. 13.11A).
- Athletes with this injury may have intermittent tingling and numbness in the thumb and the next two and a half fingers (Fig. 13.12). The tingling will be more prominent with the wrist in hyperflexion or hyperextension.
- The pain may also radiate up to the shoulder. Pain is most common at night. Longer-term, the sensory function of the fingers that are affected deteriorate, and in some of the muscle on the thumb side of the hand.
- The athlete will sometimes complain of clumsiness and loss of dexterity.
- In prolonged severe cases there may be loss of grip strength and hypotrophy of the thumb muscles.
- Holding the wrist in hyperflexion (Phalen's manoever, Fig. 13.13) for a 30 second period causes numbness in the hand.
- Electromyography (EMG) studies may be helpful to confirm the diagnosis, but they are not always positive.

The athlete can:

- Prevent, by varying the load so that hands and arms are not exposed to excessive repetitive movements over a long time.

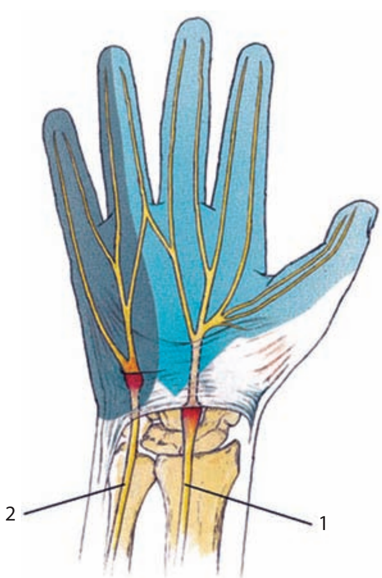


Figure 13.12 Carpal tunnel syndrome. Pain radiating, tingling and numbness may be felt in thumb, index finger, middle finger and half the ring finger, the areas the median nerve innervates. 1: median nerve radiation; 2: ulnar nerve radiation.

Figure 13.13 Phalen's test. Sharp downward bending (dorsiflexion) of the wrist for 30 seconds produces numbness in the hand.

- Pause from load, rest and try to relax.
- Move the fingers often so that blood flow in the hand increases.
- Keep the wrists straight during sleep by using a wrist support.

The physician may:

- Advise a change in training.
- Apply a splint to rest the wrist and avoid extremes of range of motion (ROM). Depending on the degree of symptoms the splint or brace may be worn only at night, during activities, or continuously.
- Give anti-inflammatory medication.
- Inject steroid into the carpal tunnel in refractory cases.
- Operate to release the ligament overlying the carpal tunnel in cases refractory to the above measures (this increases the space available for the nerve). This surgery can be 'arthroscopic' (endoscopic).
- The athlete may return to sports as soon as symptoms allow, often within 2–4 weeks of surgery. Taping, bracing or splinting may be helpful during activities.

Distal ulnar neuritis (Guyon's canal syndrome)

The ulnar nerve can be subjected to pressure where it crosses the wrist on the inner aspect of the hand (Fig. 13.14). The pressure is caused by friction or impingement of the local tissues against the nerve causing mechanical irritation, as can happen during cycling (Fig 13.14). The symptoms of ulnar neuritis are pain and numbness in the little finger and half the ring

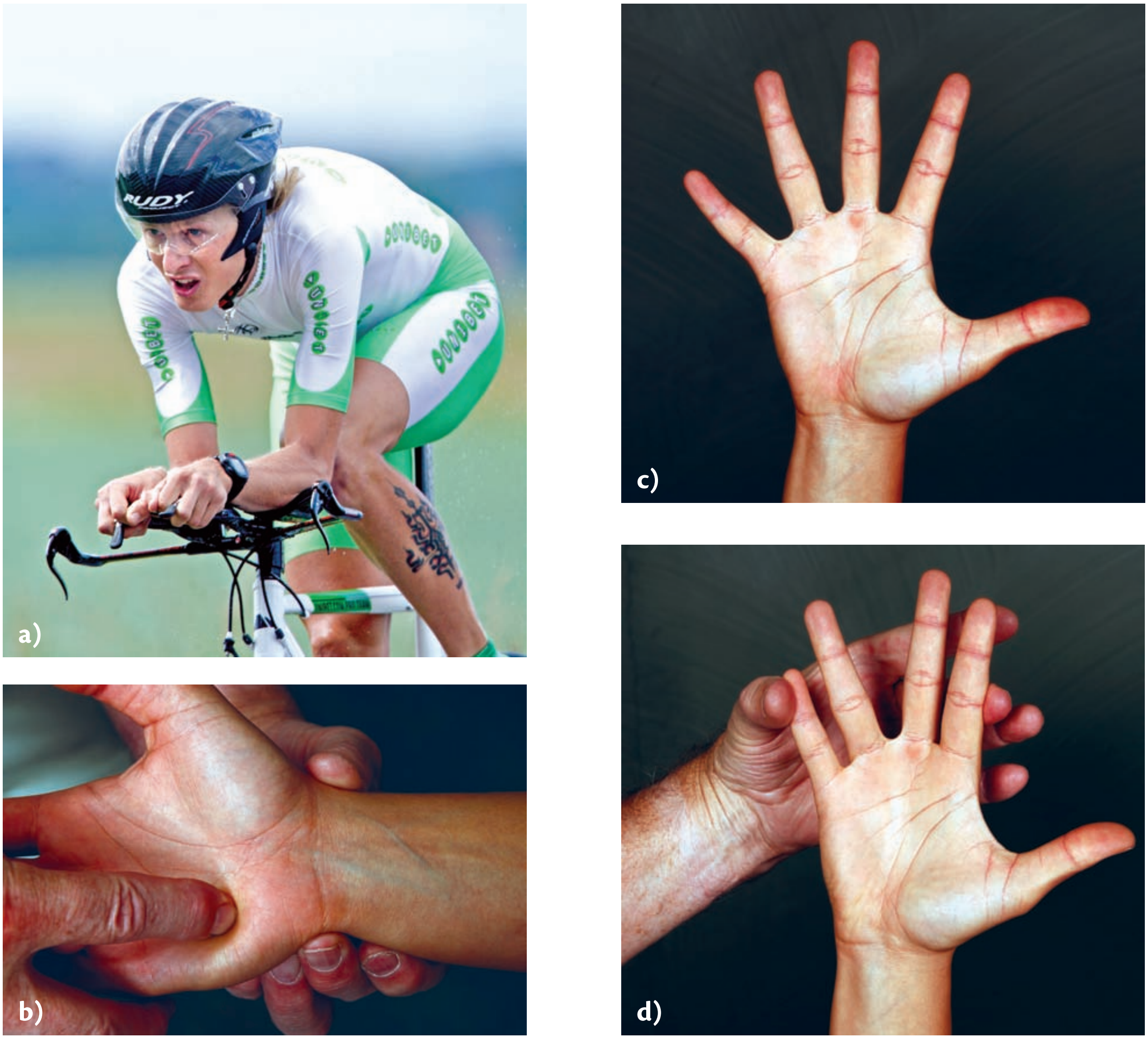


Figure 13.14 Abnormal pressure on lower part of ulnar nerves (distal ulnar neuritis). **a)** Cyclists expose themselves to increased pressure against the ulnar nerve after gripping the handlebars for long periods of time; **b)** tenderness where the ulnar nerves pass through Guyon's canal; **c)** test for ulnar nerve function by spreading the fingers; **d)** test of strength for ulnar nerve function.

finger, with muscular weakness on attempting to spread the fingers. The initial treatment is rest from painful activities and anti-inflammatory medication, but if this fails, surgery to decompress the nerve gives good results.

De Quervain's disease

Inflammation of the sheath of the short extensor tendon (extensor pollicis brevis) and long abductor tendon (abductor pollicis longus) to the thumb can occur. This is most commonly caused by repetitive thumb and wrist movements.

This injury can occur in sports that require powerful grip or repeated use of the thumb with the wrist ulnar deviation such as the left thumb of a right-handed golfer, tennis player, javelin throwers, etc.

Symptoms and diagnosis

- Pain and tenderness are located at the base of the thumb where the tendons cross the wrist (Fig. 13.15A).
- Pain occurs with active thumb extension and abduction against resistance.
- Pain is elicited by placing the thumb in the palm followed by ulnar deviation of the wrist (Finkelstein's test) (Fig. 13.15B-D).

The physician may:

- Confirm the diagnosis by good clinical examination and ultrasound scan showing an inflammation of the tendon.
- Advise a change in training.

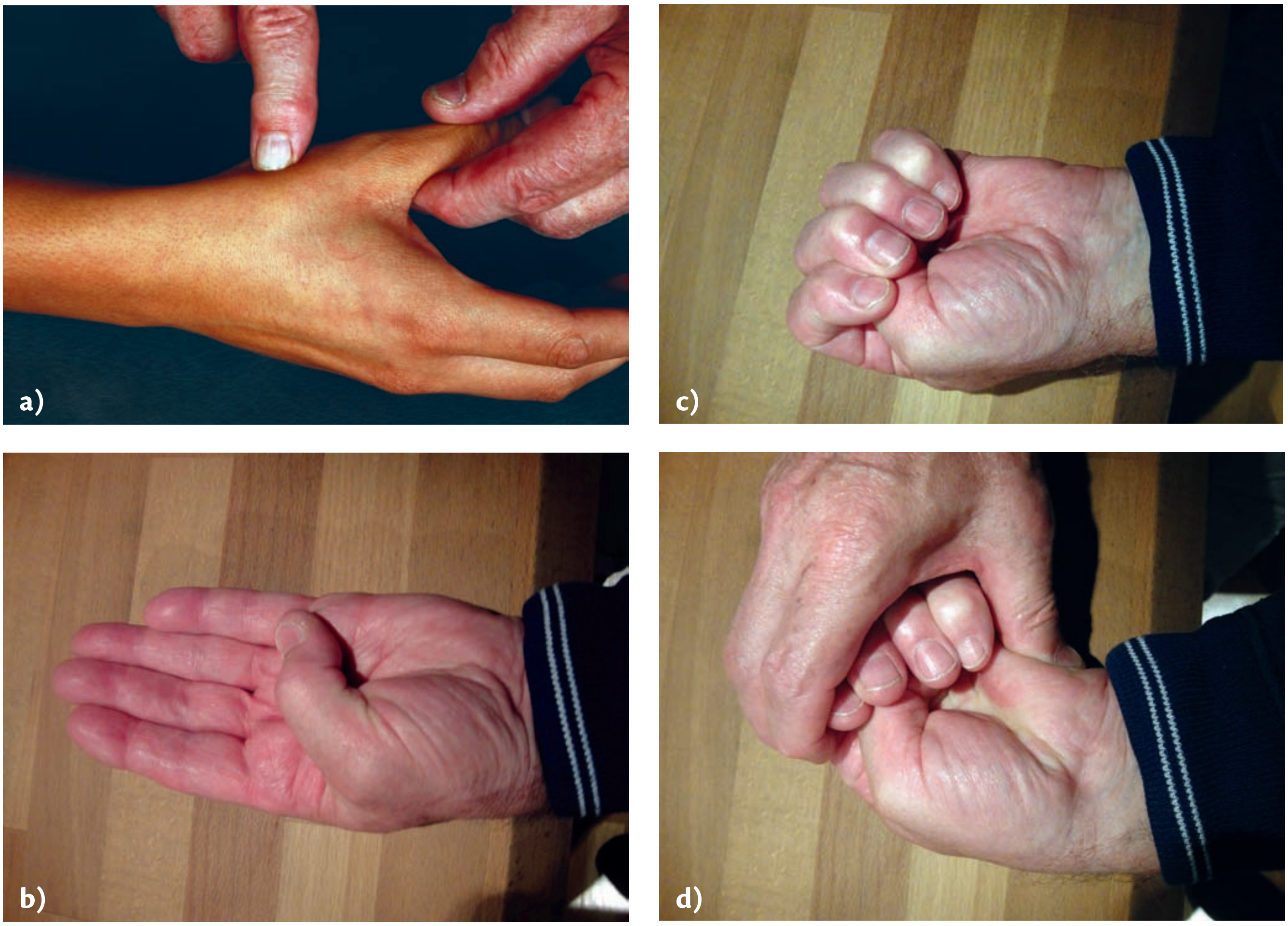


Figure 13.15 De Quervain's disease. **a)** Tenderness of the tendon sheaths of the extensor pollicis brevis tendon and abductor pollicis longus tendon to thumb; **b)** Finkelstein's test. 1: The thumb is placed in the palm; **c)** 2: the other fingers hold tightly over the thumb; **d)** 3: the examiner performs an ulnar deviation, i.e. hand is flexed towards the little finger side.

- Apply a splint to rest the thumb (depending on the degree of symptoms, the splint may be worn only at night, during activities or continuously).
- Give anti-inflammatory medications.
- Inject steroid in the sheath around the tendons.
- Operate to release the sheath covering the tendons in cases refractory to the above measures.
- The athlete may return to sports as soon as symptoms allow. Taping, bracing or splinting may be helpful during activities.

Extensor carpi ulnaris instability and rupture

The extensor carpi ulnaris (ECU) muscle provides stability to the ulnar side of the wrist. In recent years, problems from the ECU tendon have been identified (Fig. 13.16). Pain on the ulnar side of the wrist is common in tennis players, especially at the elite level and in golfers and rowers. Three clinical patterns have been described:

- Acute instability of the ECU.
- Rupture of the ECU.
- Tendinopathy.

These conditions are treated differently and it is therefore important to be able to distinguish them. Among the differential diagnoses include fractures, bone bruise edema, ligament injuries, TFCC, etc.

Acute ECU instability

This injury is characterized by sudden pain on the outside of the wrist, i.e. the ulnar side. This can be seen in tennis players with two-handed backhand, but also sometimes at a forehand stroke. Sometimes a total ECU dislocation or injury to the tendon sheath to the ECU can occur.

Figure 13.16 a, b) Two-handed backhand can cause extensor carpi ulnaris (ECU) instability. (With permission, by Bildbyrån, Sweden.)

Symptoms and diagnosis

- Intense pain with passive supination.
- Pain and tenderness on palpation of the ECU tendon (Fig. 13.17).
- Slight local swelling.
- Isometric testing can be used to reproduce instability.
- Diagnostic ultrasound at rest and under supination is effective to test the stability of the ECU.
- MRI examination during pronation and supination.
- Often there is a rapid return to everyday activities, but an athlete will experience pain with playing.

Rupture of the ECU

The tendon sheaths (subsheath) to the ECU are totally ruptured. ECU is thus unstable.

Symptoms and diagnosis

- The ECU is unstable during supination.
- An ultrasound with a stress test of the ECU ensures the diagnosis.
- There is also a type of injury where the ECU's tendon sheath (subsheath) is damaged but not totally ruptured. The ECU's tendon sheath is then released from the medial portion of ulnar head and therefore cannot ensure stability of the ECU under stress.

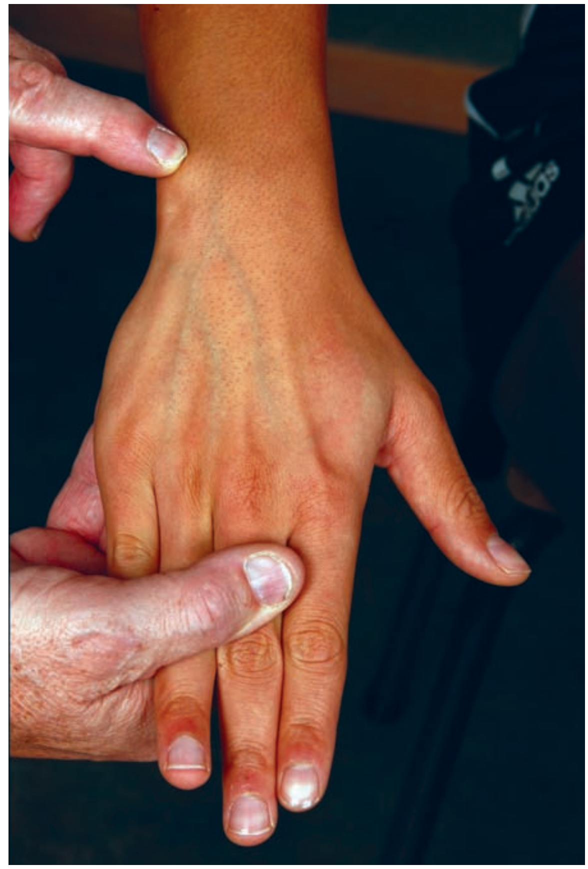


Figure 13.17 Extensor carpi ulnaris (ECU) instability. Tenderness over the ECU tendon.

Treatment

- Surgery is often necessary. Thereafter immobilization for 4–6 weeks.
- Non-surgical treatment includes a cast for 2–4 months. Stress testing is performed after 2 months.
- No return to play before stability of the ECU in their anatomical localization exists.
- Custom-made orthosis can replace the cast after 1–2 months (Fig. 13.18).
- The athlete can return to tennis at competitive level after 5–6 months.

ECU tendinopathy

This condition should be suspected when the athlete has pain located to the ulnar side and has difficulty hitting a two-handed backhand.

Symptoms

- Pain develops gradually.
- This pain feels better after warm up.
- Pain is experienced when the wrist is forced in supination – tenderness in the ECU.

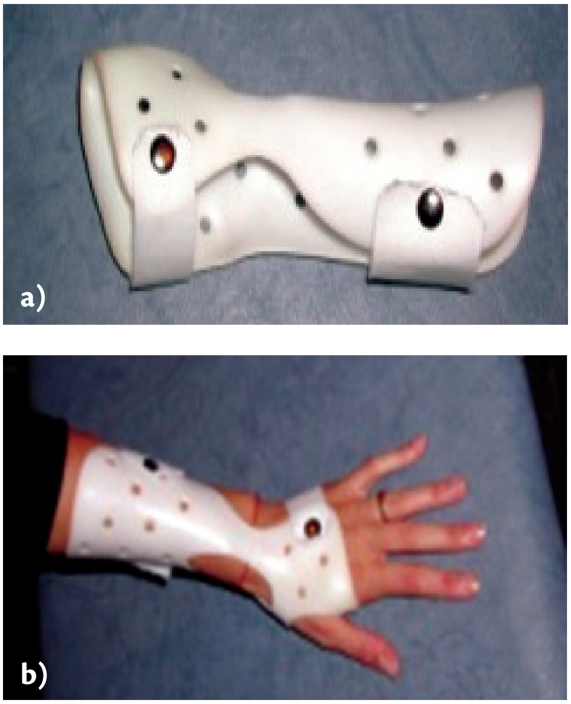


Figure 13.18 a, b) Specially made wrist orthoses can often be effective. (Courtesy of Dr. Berhard Montalvan, French Tennis Federation, Paris, France.)

Tip

Anatomical identification of ECU's subsheath and retinaculum and its injuries is crucial for the stability of the ECU. The diagnosis of this injury often requires superspecialist knowledge. Diagnostic ultrasound with stress tests are very useful as diagnostic tools and to guide the healing process.

Triangular fibrocartilage complex tears

The triangular fibrocartilage (TFC) is a cartilaginous disc, much like the meniscus cartilage of the knee, which overlies the distal aspect of the ulna in the wrist joint. It is part of the TFC complex (TFCC) that supports the carpal bones on the ulnar side of the wrist and provides some stability for the distal radioulnar joint (part of the wrist).

The TFCC allows the wrist to move in six different directions, i.e. flexion, extension, rotation and side-to-side. The TFCC is located between the ulna and two metacarpal bones (lunate and triquetral). The TFCC stabilizes the wrist (radioulnar joint) and improves ROM. There is a small cartilage disc in the center of the complex that is shock absorbing. The TFCC includes several ligaments in the wrist.

Figure 13.19 Rupture of the triangular cartilage discus. Triangular fibrocartilage complex (TFCC) injuries can occur in multiple sports. **a)** Gymnasts use their wrists in very fast loaded movements; **b)** a tennis player using two-handed backhand is at risk due to the wrist being exposed to excessive or repeated ulnar directed movements and/or extreme forearm rotation. (With permission, by Bildbyrån, Sweden.)

An injury to the TFCC is caused by a trauma. A fall with an outstretched arm is the most common cause of a TFCC injury. Tennis players and gymnasts at the elite level have the greatest risk of incurring this injury (Fig. 13.19).

Tears of the TFCC can occur from trauma, overuse, or tissue degeneration. Tears are often associated with a long ulna in relation to the radius at the wrist joint (positive ulnar variance). The traumatic tears are caused by injuries with impaction, rotation and ulnar deviation (Fig. 13.20).

Symptoms and diagnosis

- Symptoms are often vague.
- ROM restriction.
- Ulnar-sided wrist pain is felt (Fig. 13.21A).
- Pain is elicited when testing with compression, ulnar deviation and circumduction. A painful click or clunk may be felt during this manoever and on anterior position movement of the ulna (Figs 13.21B,C).
- The injured person may feel a painful snap and a click can be heard when the wrist is bent and also when the ulna is pushed forward in the wrist.
- Tests that support the diagnosis include a test with hypersupination by over rotating the forearm with the palm up and the wrist loaded in a position

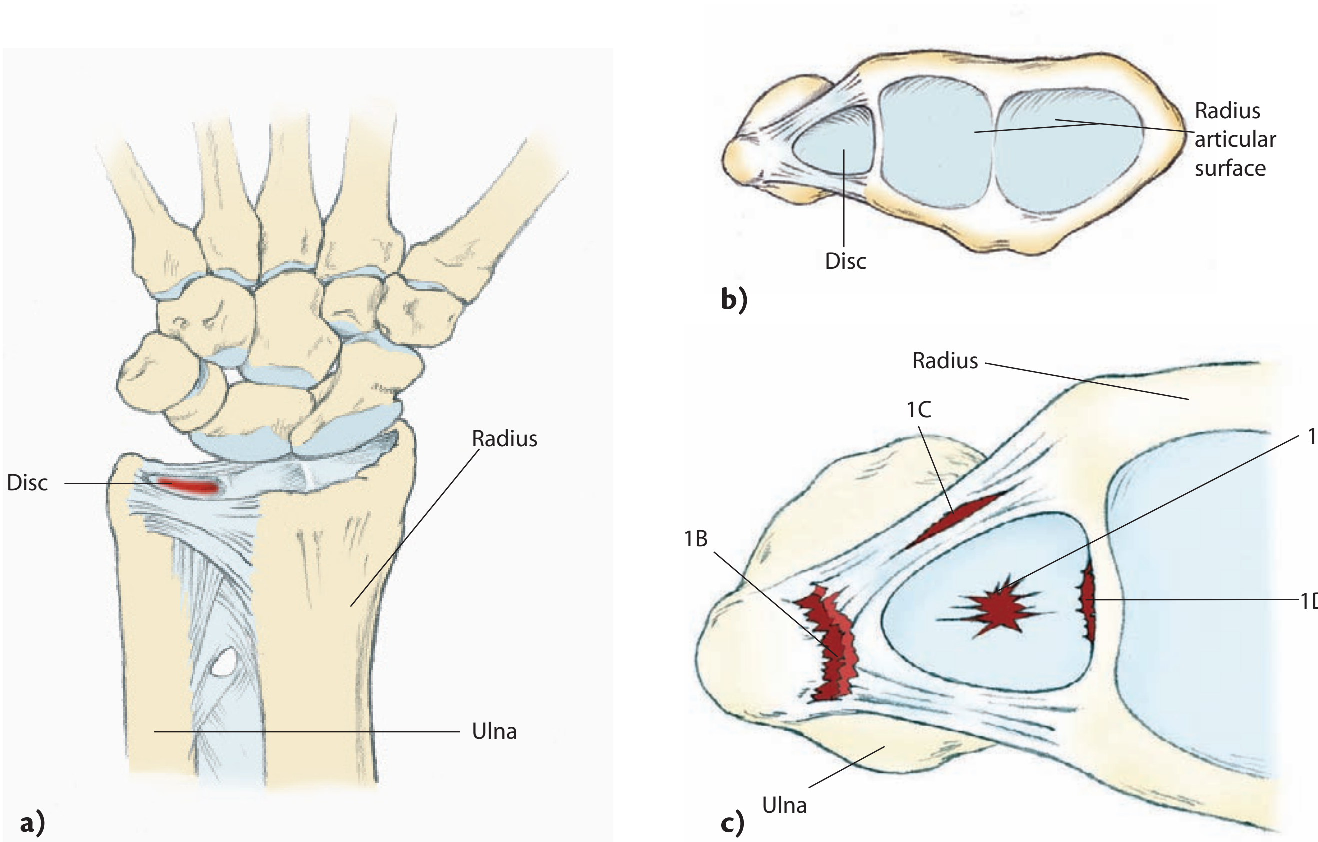


Figure 13.20 Rupture of the triangular cartilage discus, which is part of the triangular fibrocartilage complex (TFCC). **a)** A snapshot of the wrist with the rupture in red. The triangular cartilage discus viewed from above lies between the radius and ulna; the joint surfaces of the lunate and scaphoid bones are seen to the right; **b)** a sectional view of the distal wrist area; **c)** Palmer's classification of acute ruptures of the TFCC. The arrows indicate: Class 1A, i.e. a central rupture of cartilage tissue; Class 1B, i.e. a peripheral detachment of the discus on ulnar side; Class 1C, i.e. a rupture of the ulnar outer ligament (volar ulnar extrinsic ligaments); Class 1D, i.e. a peripheral detachment of the discus on the radial side.

corresponding to ulnar deviation, i.e. wrist moving away from the thumb (Fig. 13.21D).

- An MR arthrogram of the joint and arthroscopy will secure the diagnosis.
- Arthroscopy of the wrist is in fact the best way to adequately evaluate how serious the injury is.

The physician may:

- Immobilize the wrist for 4–6 weeks.
- Operate if symptoms persist after immobilization and a rehabilitation program. Surgical options include repair or excision of tissue.
- Arthroscopy has been useful in the diagnosis and treatment of TFCC injuries.
- Return to sports such as tennis may be possible in 3–4 months.

Dorsal impaction syndrome

Dorsal impaction is a chronic pain syndrome caused by repetitive axial loading of the wrist in dorsiflexion. This injury is common in young gymnasts.

Symptoms

- Pain is felt on the back of the wrist.
- The pain is increased with dorsiflexion and loading of the wrist.

Treatment should include:

- Modification of training programs.
- Wrist strengthening exercises.
- The use of wrist guards or a brace to prevent excessive dorsiflexion.
- For more severe pain, complete rest and immobilization.

Weakness in the wrist

Women about 20 years old of slender build sometimes complain of pain in the wrist with exertion (often disappearing at rest), which radiates along the upper side of the forearm. On examination, a degree of hypermobility and laxity of the wrist may be noticed, but often no significant abnormality can be found. Sometimes a small swelling, or ganglion, can be found on the back of the hand. This should not prevent training, but a

Figure 13.21 Rupture of the triangular cartilage discus, which is part of the triangular fibrocartilage complex (TFCC). **a)** Localization of tenderness and pain in the wrist ulnar side between radius and ulna; **b)** pain can be elicited by twisting the wrist outward in ulnar deviation; **c)** pain elicited when the radius bone and ulna are pressed together, when the ulna is pressed dorsally and in volar direction; **d)** test hypersupination by excessively rotating the forearm with the palm up and loading the wrist in a position corresponding to the ulnar deviation.

support bandage should be applied around the wrist and strength training carried out in parallel with the usual training. The symptoms often disappear in time.

If an athlete has persistent pain in the wrist 2 weeks after a normal sprain the wrist should be further examined.

Hand and finger injuries

The hand is a body part that is particularly prone to injuries associated with sports activity. A recent American study suggests that injury in boxing is increasing and constitutes 12.7 per 1000 participants. The most frequent injuries in boxing are fractures (27%), of which 33% are located in the hand.

Hand injuries are generally important because they often affect the person's professional/workplace activities and thus can often lead to impairment of working capacity.

The palm consists of five metacarpal bones, one for each digit. The metacarpals in the middle of the hand have very little motion and provide a stable palm, while the little finger and especially the thumb have significantly more motion to allow the hand to grasp objects. Without the large motion allowed by the joints of the thumb metacarpal the thumb would not be able to oppose to the palm for grasping. Fortunately, severe injuries to the thumb are rare, but they can be devastating.

Each of the four fingers has three phalangeal bones: a proximal phalanx (closest to the palm), a middle phalanx and a distal phalanx. The proximal interphalangeal (PIP) joint lies between the proximal and middle phalanges, and the distal interphalangeal (DIP) joint lies between the middle and a distal phalanges. The thumb has only two phalangeal bones, a proximal and a distal phalanx. Between the fingers and palm are the metacarpophalangeal (MCP) joints: these are almost exclusively for bending and straightening the fingers and have very little side-to-side movement; this allows the hand to conform to objects for better grasping and allow precise finger placement during detailed work.

Contusions and lacerations

Contusions are the most common injury in the hand. Principles for their treatment are described on p. 189. Care must be taken to rule out more serious injuries such as fractures and ligamentous or tendinous injuries. A contusion can lead to trauma-induced tendinopathy; however, the majority of these, too, can be treated with time and conservative measures.

Lacerations of the hand also are very common in sports. They require thorough evaluation of the tendons, nerves and blood supply, with particular attention to the nerves of the fingers. Simple lacerations can be treated with irrigation, loose closure and protection as necessary. Lacerations over the joints require careful evaluation of extension into the joint. The position of the hand when the injury occurred is important: with a clenched fist laceration the lesion may appear not to have penetrated the joint when the hand is flat –the so-called 'tooth injury', which is often overlooked. If there is extension into the joint, or an associated fracture, a physician should be consulted immediately. The physician will perform a thorough irrigation and debridement, and prescribe antibiotic prophylaxis for at least 48 hours. For all lacerations the athlete should ensure that anti-tetanus vaccination is up to date.

If lacerations are neglected and not properly cleaned, bacterial infection may ensue, necessitating prolonged treatment. If an infection does occur, a physician should be consulted immediately. Treatment includes antibiotics and possibly surgical drainage to clean out the wound and prevent further spread. Infected wounds on the hand must never be neglected, since the consequences can be catastrophic.

Metacarpal bones

Fractures

Fractures of the metacarpal bones are particularly common among handball players, but also occur in volleyball, ice hockey, basketball, football/soccer, American football and cricket. Such fractures can be caused by forcible straightening of the fingers (e.g. during shooting in team handball, when the hand hits the covering arm of the defensive player) or as a result of a direct blow. Even a blow to the end of the bones, as in boxing and ice hockey, can result in fractures of the metacarpal shafts (Fig. 13.22).

Symptoms and diagnosis

- Tenderness, swelling, and pain occur in the hand.
- There may be deformity or loss of prominence of the knuckle.
- An X-ray will confirm the diagnosis.

Treatment

- In most cases, treatment with a plaster cast or splint for 3–4 weeks is sufficient.
- In cases with severe angulation or shortening, or with rotational malalignment, surgery may be indicated.
- The athlete can return immediately to participation in sports that do not require grasping, provided a splint is used for protection. Team handball and other hand-intensive sports may be resumed 6–8 weeks after injury.

Joint fractures of the thumb metacarpal bone (Bennett's fracture)

A Bennett's fracture is a fracture of the joint surface at the proximal end of the thumb metacarpal (Fig. 13.22). The significance of this fracture is that the deep ulnar ligament that stabilizes the carpometacarpal joint is attached to the small non-displaced fragment and the abductor pollicis longus tendon is attached to the metacarpal shaft. The pull of the abductor causes displacement of the metacarpal shaft, resulting in significant fracture displacement and joint malalignment. Surgery is needed to reduce the fracture and hold it with wires. If good fixation is obtained, casting can be discontinued after the incision has healed. Protection in a splint is needed during sports participation for at least 6–8 weeks longer for a contact sport. Failure to obtain adequate reduction of the fracture can result in post-traumatic arthritis of the thumb carpometacarpal (CMC) joint.

Fractures of the base of the fifth metacarpal bone ('baby Bennett')

Fractures of the base of the fifth metacarpal are similar to the Bennett's fracture at the base of the thumb metacarpal, but are much less common. The metacarpal shaft

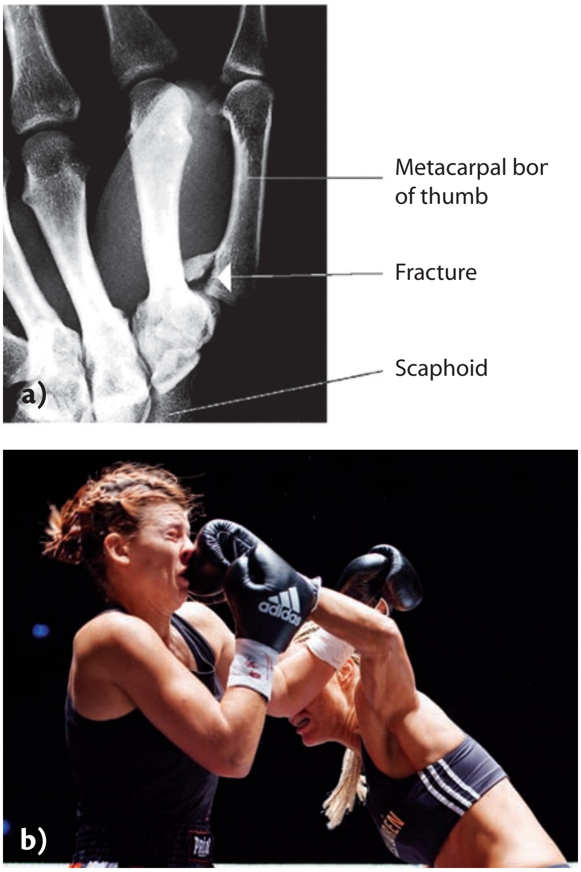


Figure 13.22 Fracture of the thumb's metacarpal (Bennett's fracture) spreads into the joint (intra-articular). **a)** X-ray of fracture of the thumb's metacarpal; **b)** boxing entails a risk of injury to the metacarpals. (With permission, by Bildbyrån, Sweden.)

Figure 13.23 a, b) Damage to the ligaments of the fingers is common in sporting activities. (With permission, by Bildbyrån, Sweden.)

angulates backwards and away from the palm, with the small fracture fragment being held in place by ligaments attaching it to the fourth metacarpal and wrist bones. The main problem with these fractures is recognition of the backward displacement of the metacarpal shaft. Careful examination of the X-rays is needed to detect this. If the joint's malalignment is undetected and untreated, chronic pain and instability can result. The principles of treatment are the same as those for the Bennett's fracture. Surgery is usually needed to reduce the fracture and hold it with wires.

Ligamentous injuries and dislocations

Injury to the ligamentous structures surrounding the fingers and thumb is common during sports activities, especially those that involve ball handling or heavy physical contact (Fig. 13.23).

The key to the treatment of hand injuries is to make an accurate diagnosis through careful history and examination. Failure to recognize the importance of these injuries leads to poor outcomes. The majority of these injuries can be treated non-operatively, and they rarely result in prolonged loss of participation.

PIP joint injuries

The PIP joint (of the two finger joints, this is the joint nearest to the palm) is the most commonly injured joint in the hand. Loss of motion is common following injury to the joint and may even be seen in uninjured joints that have been immobilized for other reasons. Any fixed deformity of the joint causes significant disability.

Collateral ligament injuries

Injuries of the collateral ligaments (the side ligaments of the PIP joints) are quite common in athletics. They often occur in sports such as team handball, volleyball, basketball and rugby.

Symptoms and diagnosis

- Pain and distinct tenderness occur in the injured area at the side of the joint.
- Mobility is impaired.
- Instability (increased side-to-side movement of the joint) can be present if the tear is complete.

Treatment

Collateral ligament injuries can be treated by bandaging or taping the injured finger to an adjacent finger for support ('buddy taping') (Fig. 13.24). Active motion exercises of the injured finger can then start without any side-to-side loading. The bandage is worn for about 2 weeks for minor injuries and longer for complete tears. 'Buddy taping' should be used during athletic competition for several months. As a rule, surgery is not needed except for injuries to the ligaments of the thumb.

- Major ligament injuries are treated with a cast. No surgery is needed in most cases except for thumb ligament injuries.
- Residual effects with slight swelling and stiffness of the injured finger can continue for a long time (6–9 months) after the injury has occurred.
- Protected early return to sport is usually possible.

Dislocation of PIP joint

Dislocation of the PIP joint (Fig. 13.25) is a common injury that often affects team handball, basketball and volleyball players, and cricketers. In 80% of cases it is the little finger that is damaged. The most common mechanism of injury is axial loading and hyperextension of the joint causing dorsal dislocation (dislocation upwards and backwards). The dorsal dislocation always results in disruption of the anterior capsular ligaments and volar plate. Lateral dislocation (dislocation to the side) of the PIP joint occurs when a single collateral ligament ruptures with a portion of the volar (palm) plate. The rare volar (forwards into the palm) dislocation of the PIP joint is a more serious injury. This dislocation results in disruption of the extensor tendon and one of the collateral ligaments. Because of rupture of the extensor tendon this injury can result in a deformity. Many dislocations of the PIP joint go untreated by a physician because they are reduced by the athlete or coach on the sideline. Lack of treatment can cause permanent disability, particularly in the case of a missed fracture/dislocation.

Figure 13.24 **a)** Finger injuries are common in sports such as handball; **b)** taping the injured finger to the adjacent uninjured finger is often effective.

Figure 13.25 Dislocated finger joint. **a)** X-ray luxation (dislocation) of the finger joint; **b)** an injury not unusual in handball. (With permission, by Bildbyrån, Sweden.)

Symptoms

- Pain is accompanied by tenderness and impaired function.
- Deformity of the joint outline can be seen.

The physician may:

- Reduce the joint back into its normal position. The sooner this is done after injury, the easier the procedure. If manipulation is carried out within a few minutes, severe pain is not generally experienced.
- Tape the digit to the adjacent finger (buddy tape) or, in severe injury, immobilize by applying a splint, which is worn for 1–2 weeks, to block extension. Buddy taping should be used during athletic competition for several months.
- Splint only the PIP joint in continuous extension for 6–8 weeks for dislocations toward the palm.
- X-ray the joint, as a bone fragment may have been torn loose.
- Allow protected early return to sport, which is usually possible.

MCP joint injuries

Collateral ligament injuries

Collateral ligament injuries are occasionally seen in the metacarpophalangeal (MCP) joints (the joint between the palm of the hand and the fingers). The mechanism of injury is side-to-side force placed on a bent MCP joint.

Symptoms and diagnosis

- Pain and distinct tenderness occur in the injured area at the side of the joint in the web space.
- Mobility is impaired.
- Instability (increased side movement of the joint) can be present if the tear is complete. In the MCP joint, this is tested with the joint flexed.

Treatment

- Splinting and/or taping to the finger beside it (buddy taping) are usually sufficient treatment. Active motion exercises without any side-to-side load can begin immediately. The bandage is worn for about 2 weeks for minor injuries and longer for complete tears. Buddy taping should be used during athletic competition for several months.
- X-rays should be taken to be sure no bone fragments are lodged in the joint.
- Pain can persist for up to a year following the injury.
- Protected early return to sport is usually possible.

Dislocation of MCP joint

Dislocation of the MCP joint is a rare injury. When it does occur the border digits (the index and little fingers) are most commonly affected. Dorsal dislocation of the MCP joint occurs following forced hyperextension (bending backwards) of the fingers. The volar (palm) plate is ruptured and the head of the metacarpal can sometimes be buttonholed through the volar plate and surrounding structures (complex dislocation). This can make reduction difficult. A characteristic dimple in the palm is often seen in this variety of dislocation.

Symptoms

- Pain occurs together with tenderness and impaired function.
- Deformity of the joint outline can be seen.
- For complex dislocations, a characteristic dimple may be present in the palm.

The physician may:

- Reduce the joint back into its normal position. Failure of attempted closed reduction is typical of complex dislocation.
- Operate: open reduction is usually required for complex dislocation.
- Apply a splint to stop the finger from straightening all the way. This is worn for 2–3 weeks. Active motion in the splint should begin as early as possible to avoid stiffness. Buddy taping should be used during athletic competition for several months.
- X-ray the joint to make sure there is no fracture.
- Protected early return to sport is usually possible.

Thumb ligament injuries

Thumb IP joint injuries

The thumb interphalangeal (IP) joint (thumb tip joint) is similar to the PIP joint of the fingers, and injuries should be treated in the same way. Mild stiffness of the IP joint of the thumb is generally well tolerated. In the injured thumb IP joint with hyperextension laxity and a suspected volar (palm) plate injury, it is important to rule out a rupture of the flexor pollicis longus tendon. A tendon rupture should be surgically repaired. Less frequently, rupture of the extensor pollicis longus may occur; this also requires surgical reconstruction.

Thumb MCP joint dislocations

The MCP joint is capable of a large degree of motion. The supporting structures of the thumb–MCP joint are uniquely developed. Dorsal (backwards) dislocation of the thumb MCP joint is a similar clinical entity to dislocation of the MCP joints of the fingers, with volar plate disruption and possible entrapment of the metacarpal head by the buttonholed tissue. Closed reduction by gentle manipulation is possible more often than in similar injuries to the finger joints, though surgical open reduction is still sometimes necessary. If closed reduction of the dislocation is possible and the collateral ligaments are stable, then 4 weeks of immobilization to block the thumb from straightening and to allow active bending should be adequate.

Lateral ulnar ligament injuries (skier's thumb, gamekeeper's thumb, Stener's lesion)

Around 10% of all injuries in alpine skiing involve the ulnar collateral ligament complex of the thumb (the side ligament at the thumb web space), making this the second most common injury sustained by skiers.

Lateral ulnar ligament injuries occur from a side stress placed on the thumb while the MCP joint is straight (Figs 13.26, 13.27). This can occur when a skier falls on an outstretched arm, and in so doing, forces the thumb upwards (abduction) and backwards (extension) against the ski pole. This injury is also not uncommon in cross-country skiing. In this sport the strap is grasped between the palm of the hand and the pole grip, so injury can occur when carrying out a forceful pole-plant (Fig. 13.26); it also occurs in ice hockey when a player's stick becomes trapped and forces the thumb backwards.

Symptoms and diagnosis

- Pain occurs in the thumb web space.
- Tenderness is noted when pressure is applied to the thumb web space at the side of the MCP joint.
- Bruising and swelling can be seen in the thumb web space.

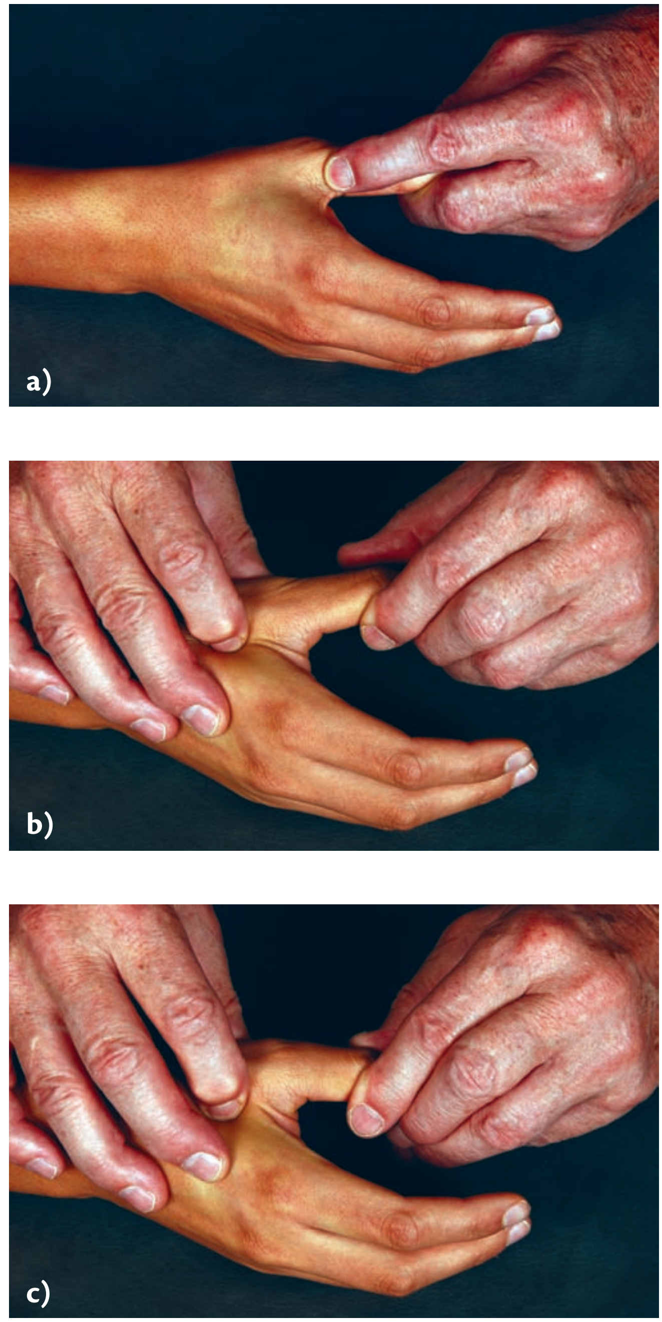


Figure 13.26 Damage to the thumb's internal lateral ligament, 'gamekeeper's thumb', 'Stener's lesion'. **a)** Localization of tenderness for damage to the internal ulnar collateral ligament at the base of the thumb; **b)** test ligament with thumb joint stretched; **c)** test ligament of the thumb joint in 20° flexion.

Instability of the joint is found when the thumb is tested in abduction (movement away from the palm) at an angle of 20–30° (Fig. 13.26C). The critical degree of laxity (i.e. the degree of laxity that indicates a total rupture has occurred) is 30° greater than the normal opposite

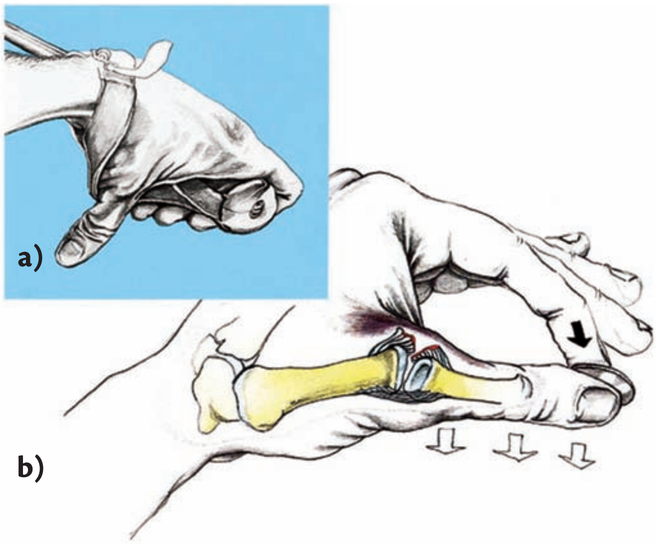


Figure 13.27 Damage to thumb ulnar collateral ligament, 'gamekeeper's thumb', 'skiers thumb', 'Stener's lesion'. **a)** Falls with ski pole still in the hand can cause rupture of the ulnar collateral ligament at the base of the thumb; **b)** rupture of the ulnar collateral ligament at the base of the thumb.

thumb. In total rupture, the ligament can be displaced to such an extent that the ulnar extension of the adductor aponeurosis becomes lodged between the ruptured end of the ligament and its attachment to the base of the first phalanx (Stener's lesion).

- An X-ray may demonstrate a collateral ligament bone fragment off the ulnar side of the proximal phalanx.
- Stress films, arthrograms or an MRI may assist with diagnosis of complete tears with Stener's lesions (adductor aponeurosis interposition).

The athlete should:

- Cool the injury with ice packs, apply compression, and keep the thumb elevated.
- Consult a physician.

The physician may:

- Carry out a thorough stability examination.
- For partial ruptures, apply a thumb spica cast (body cast) for 4 weeks.
- Operate; because of the frequency of Stener's lesion in complete tears, surgical repair is recommended for acute complete ruptures of the lateral ulnar ligament.
- Rehabilitation is similar for both surgically and conservatively treated injuries. The thumb is immobilized in 20° of flexion in a cast for 4 weeks. The IP joint is left free to allow for active motion to prevent scarring of the extensor tendon. A removable splint is fabricated at 3–4 weeks, and active exercises are allowed several times a day. The splint may be removed at 5–6 weeks for normal activity. For participation in sports, the thumb is protected for 3 months either by taping it to the index finger or by a silicone cast.
- If this injury is inadequately treated, there is a risk of permanent instability, resulting in weak grasp and arthritis. Surgery on a neglected injury can often be effective.

Lateral radial ligament injuries

The lateral radial ligament of the MCP joint of the thumb (the side/collateral ligament away from the palm) is less commonly injured. The mechanism of injury is usually a forceful rotation of a bent MCP joint. Injuries to this ligament are treated in a similar fashion to those of the ulnar ligament. The conservative regimen and indications for surgery are identical.

Carpometacarpal joint injuries

The biconcave shape of the CMC joint of the thumb (the joint of the extension of the thumb to the wrist) makes it anatomically different from the other hand joints. This saddle joint permits the special function of opposition of the thumb to the little finger. The volar oblique ligament is the most important structure in maintaining stability. Complete dislocations of the CMC joint without associated fracture are relatively rare. The most common mechanism of injury is a fall on the outstretched hand.

Symptoms

- Pain occurs together with tenderness and impaired function.
- Deformity of the joint outline can be seen.

The physician may:

- Reduce the joint back to its normal position.
- Immobilize the joint for 4–6 weeks in a cast or splint.
- Recommend surgery when the stability of the joint is in doubt, surgically inserting a wire through the joint to hold it in position.
- In cases of chronic instability, surgical reconstruction of the volar ligament may be indicated. In cases of recurrent laxity following reconstruction, or where joint changes are present, removal or fusion of the CMC joint may be the ultimate treatment.

Tendon injuries

Closed injuries to tendons of the hand and wrist are common in the athlete. These problems are often neglected and may not be seen by a physician until the end of the season, when the athlete notes a significant disability. Failure to initiate treatment in the acute stages may jeopardize the final result. Every effort should be made to ensure early evaluation and treatment of these injuries.

Attachment rupture of the long extensor tendon (mallet finger, mallet thumb)

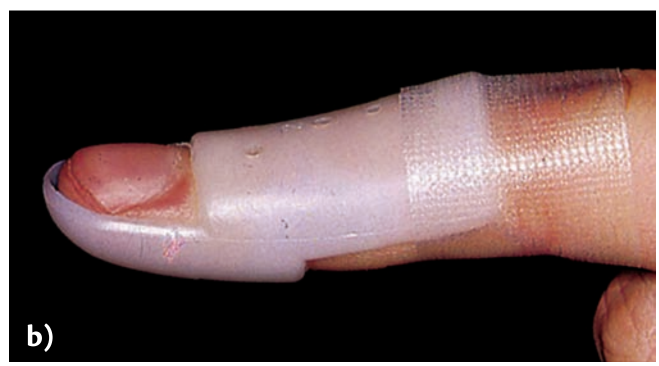
The extensor tendon of the finger is attached to the terminal phalanx (distal end of the finger). Disruption of the extensor tendon at this insertion (mallet finger) is one of the most common tendon injuries in sports. It is especially common in ball-handling sports. (Fig. 13.28) The usual mechanism of injury is that of a forceful bending applied to an actively straightening joint, typically when a ball unexpectedly hits the fingertip and forces the finger to bend. A small bone fragment may sometimes be torn loose together with the tendon. The bone fragment will show up on X-rays.

Mallet thumb is much less common than mallet finger. It is diagnosed from the inability to actively straighten the tip of the thumb.

Symptoms

- Slight tenderness is found between the nail and the first joint (DIP) of the finger.
- The fingertip is slightly bent and the first (distal) joint cannot be actively extended.

The physician may:



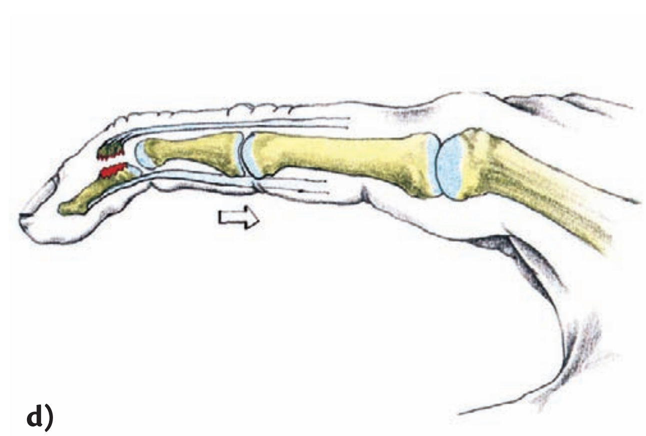


Figure 13.28 Injury to the attachment of the long extensor tendon of the finger. **a)** Inability to actively extend the finger joint; **b)** the injured finger can be immobilized in an extended position with a plastic splint or tape; **c)** volleyball and other sports can cause this type of injury (with permission, by Bildbyrån, Sweden); **d)** rupture of the attachment to the long extensor tendon of the finger.

- X-ray the finger to evaluate for fracture fragments or malalignment of the joint.
- Treat with a splint to keep the first (distal) finger joint extended. The splint should keep the first joint completely straight while allowing free motion of the PIP joint (Figs 13.28B, D). The splint should remain in place continuously for a minimum of 6 weeks.
- Operate, if a large bone fragment has been torn away and there is malalignment of the joint.

Healing and complications

- Participation in sports is allowed during treatment of mallet finger as long as the finger is continuously splinted in extension.
- Splinting has been shown to be effective in injuries left untreated for 3 months after injury.
- Chronic mallet injuries, if left untreated, may progress to a flexion deformity at the DIP joint, and hyperextension deformity at the PIP joint (swan-neck lesion).

Avulsion of the flexor digitorum profundus tendon ('Jersey finger')

Avulsion injury of the flexor digitorum profundus (FDP) tendon (that bends the tip of the finger) at its attachment to the distal phalanx is an injury often seen in athletes. The injury occurs most often during American football or rugby, and usually results from grasping the jersey or shirt of an opposing player. As the player pulls away, the finger is forcibly straightened, while the profundus flexor tendon continues to try to bend the finger. Although any digit may be involved in profundus avulsion, the ring finger is most commonly affected. Profundus avulsion injuries frequently go undetected in the acute stages.

Symptoms

- Athletes with this injury will be unable to bend the tip of the finger.
- Tenderness is felt at the ruptured insertion site at the distal finger crease.
- Tenderness occurs elsewhere along the finger or in the palm. The precise localization of tenderness is important in order to identify the level of retraction of the avulsed tendon.

The physician may:

- X-ray the finger: plain X-rays may show an avulsion fracture, which can help to show where the end of the tendon is located.
- Operate. Urgent open repair restores tendon and joint function. The operation should be performed within a few days, as the healing potential reduces dramatically beyond that time.

Healing and complications

- Following repair, the wrist and hand are splinted. Passive ROM exercises may be started within the first few days but splinting is continuous for 4 weeks. At 4 weeks, intermittent splinting begins. The individual should not be allowed maximum gripping activities for 10–12 weeks after repair.
- In sports in which grasping is not essential, return to competition within 2 weeks is possible with use of a 'mitten' splint or playing cast.
- In considering treatment options for athletes during the playing season, all should be informed that best results are obtained from early repair regardless of the level of tendon retraction.
- For chronic injuries, treatment options include: (1) neglect, in cases in which symptoms are minimal; (2) excision of the retracted tendon in the palm, if painful; (3) fusion of the joint at the tip of the finger. Independent profundus function in the ring finger is necessary for musicians and certain other highly skilled professions; most others do well without active fingertip flexion and the majority do not need late surgical procedures.

Fractures

The fingers

Fractures of the phalanges are not particularly common, but may occur in team handball, volleyball, basketball, football/soccer, cricket and other sports. Rotational alignment is critical when treating phalangeal shaft fractures. Rotation may be difficult to judge because the finger may look straight when it is extended but may overlap an adjacent finger when a fist is made.

Symptoms and diagnosis

- Tenderness, swelling, and pain occur in the finger.
- There may be deformity.
- An X-ray will confirm the diagnosis.

Treatment

- Most phalangeal fractures may be treated with a plaster cast or splint for 2–4 weeks. Immobilization should not exceed 3–4 weeks owing to stiffness problems.
- If the phalangeal fracture is displaced and unstable, or if the fracture involves the joint surface, surgery may be needed. One advantage of internally fixed fractures is that motion can begin earlier, but this must be weighed against the risk that the greater trauma to the tissue may increase scarring and stiffness.
- Sporting activity can resume if a splint can be worn and the finger can be adequately protected.

Rehabilitation of the wrist and hand

Whatever the injury, the rehabilitation program must address inflammation, restricted mobility, pain, weakness and functional disability. The dangers of immobilization of the wrist and hand joints, such as arthrofibrosis, and adhesive capsulitis (joint stiffness), have been well documented. It is imperative that early ROM exercises be initiated to minimize the degenerative effects of immobility. As with all rehabilitation, strength is important for proper function. The initiation of muscle activity early in the process is important to prevent tissue hypotrophy, and to re-educate muscle. Athletes whose sports involve throwing should include scapular stabilization exercises along with strengthening exercises for the whole shoulder–elbow–wrist–hand complex.

Because the function of the wrist and hand is essential for daily activities, special care is needed to avoid compromising the functional integrity of these structures. In addition to ROM and strengthening exercises, attention should be paid to dexterity exercises and to tactile senses. The wrist and hand are a series of complex joints that work together to give great mobility and range of function. Immobilization can result in joint contractures and stiffness, therefore active ROM exercises should begin as soon as safely possible. A thorough understanding of the action of the hand musculature is necessary to isolate joint movement. Mobility of the metacarpal bones should be checked manually by the therapist. The elbow and forearm should be stabilized for rehabilitative exercises to minimize compensatory movements.

ROM exercises

Wrist flexors

- Extend the elbow with the palm upward, and grab the hand with the other hand. Pull it down / backwards as far as it goes. The strain should be felt along the entire underside of the forearm. Hold for 15–20 seconds, repeat 5–6 times.

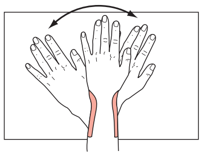
Wrist extensors

- Extend the elbow with the palm down, and grab the hand with the other hand. Press the hand downwards as far as possible. The strain should be felt over the top of the forearm. Hold for 15–20 seconds, repeat 5–6 times.

Wrist pronation and supination

- Rest your forearm on a table, with your hand over the edge.
- Begin with the palm facing upwards, then rotate your hand all the way outwards (supination) and all the way inwards (pronation).
- Hold each position 5 seconds, repeat 10 times.

Wrist radial and ulnar deviation



- Resting your forearm and hand on a table, palm facing downwards, move your hand from side to side, keeping it flat on the table.
- Hold each position 5 seconds, repeat 10 times.

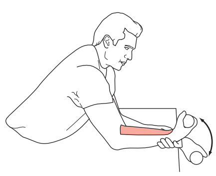
Wrist and hand strengthening

- Use a small dumb-bell or rubber tubing for resistance.
- Perform 2 or 3 sets of 10–15 repetitions.

Wrist extension

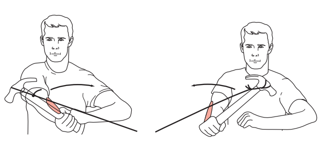
- Rest your forearm on a table, hand over the edge, palm facing down.
- Slowly raise the wrist up and down as far as possible, being sure not to lift the forearm off the table.
- Hold each position 3 seconds.
- Repeat.

Wrist flexion



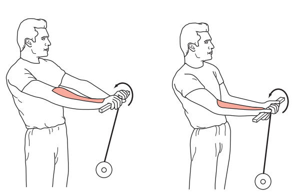
- Rest your forearm on a table, hand over the edge, palm facing up.
- Slowly raise the wrist up and down as far as possible, being sure not to lift the forearm off the table.
- Hold each position 3 seconds.
- Repeat.

Pronation/supination



- Rest your forearm on a table, with your hand over the edge.
- Beginning with the palm facing upwards, rotate your hand all the way outwards (supination) and all the way inwards (pronation) against the resistance of rubber tubing.
- Hold each position 3 seconds.
- Repeat.

Curl ups



- This exercise requires a 30–60 cm (1–2 ft) cane, broom handle or stick, with a 1.2–1.5 m (4–5 ft) cord attached in the middle. Attach a 0.5–2.25 kg (1–5 lb) weight on the other end of the cord.
- Extensors: grip the stick on either side of the cord, palms down. Curl the cord up by rotating the stick toward you; lower it slowly.
- Flexors: same as for extensors, but with the palms facing upwards.
- Note: Use this exercise with caution if the patient has shoulder impingement symptoms.

Hand and finger strengthening

Elastic band exercise

- Hold your fingertips together and put an elastic band around them.
- Spread your fingers out against the resistance of the band.

Ball squeeze

- Hold a tennis ball or racqeet ball in your hand and squeeze it repeatedly at a rapid pace.

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14 Head and Face Injuries in Sport

Head injuries

Head injuries can occur in most sports, particularly in contact sports and in riders, downhill skiers and boxers.

Although serious injury can occur without any loss of consciousness, in general the severity of the injury is related to the degree of memory loss and the period of unconsciousness (Fig. 14.1). An attempt should therefore be made as soon as possible after an incident involving a blow to the head to determine the patient's cognitive ability and to decide whether unconsciousness has indeed occurred.

Concussion (commotio cerebri) in sport

Concussion is the most common type of traumatic brain injury. Although young children have the highest concussion rate among all age groups, it is young adults that most often sustain concussion. Concussion has become increasingly common in sports, especially in contact sports such as American football, football/soccer and ice hockey:

- There are large unrecorded numbers in most sports. It is estimated that up to 5% of sports injuries are concussions.
- 2–10% of all injuries in Swedish football/soccer and handball is considered to be concussion.
- There is an incidence of 160 concussions per 1000 match hours for teams in Swedish ice hockey.

In football/soccer, there are risks when competing for a high ball and when heading the ball. A kicked ball in flight can reach a speed of 100 km/h (60 mph) and weighs about 450 g (1 lb) (even more if it is wet), so considerable forces can be transmitted from the ball to the head.

Figure 14.1 Trauma to the head can cause concussion. **a)** A hard tackle in hockey against the boards or a fall to the ice can cause concussion; the helmet protects against this to some extent; **b)** boxing can produce brain damage. Head protection is recommended. (With permission, by Bildbyrån, Sweden.)

Figure 14.2 Trauma that can produce concussion in football/ soccer may occur in different ways. **a)** Kick to the head in football/ soccer; **b)** two players butt heads together, showing signs of concussion afterward; **c)** players with signs of a head injury should be quickly examined by medical personnel. (With permission, by Bildbyrån, Sweden.)

In recent years concussions have become common from elbows to the head in struggles for the ball. This has now resulted in players that injure another player with an elbow to the head risk receiving a red card from the referee (Figs 14.2, 14.3).

Tip

Concussion is a major problem in sport and this is why it has to be taken very seriously.

A manifestation of this is the consensus meetings, where experts work on a common approach to how these injuries should be dealt with. International consensus meetings have been held initially in Vienna in 2001 and then in 2004, 2008 and 2012 (in Zurich).[1] There are therefore now clear guidelines available today for the safe care of these athletes.

Figure 14.3 In football/soccer an elbow tackling to the head can cause a concussion. Relatively recently there has been a major rule change, that if this happens it is a red card, i.e. expulsion from the game. (With permission, by Bildbyrån, Sweden.)

Tip

A concussion is defined today, by the consensus reports as: 'A complex pathophysiological process affecting the brain, which is initiated by external traumatic biomechanical forces'.

It was agreed that concussion typically involves temporary impairment of neurological function that heals by itself with time and that there are no gross structural changes to the brain on neuroimaging.

Signs of concussion

- Occurs after direct or indirect trauma towards the head. Should be suspected after nose fractures, neck injuries.

- Great variety of clinical symptoms, including unconsciousness.
- Rapid neurologic disability that eventually spontaneously regresses.

Symptoms after concussion

The patient experiences:

- Headache, dizziness, nausea/vomiting.
- Memory lapses, disorientation in time and space, unawareness of current events.
- Fatigue/ 'slow thinking'.
- Unsteadiness.

Clinical findings after concussion

- Impaired balance, uneven and unsteady gait.
- Latency in response to the questions, impaired concentration, such as reduced working memory, impaired memory.
- Emotional imbalance e.g. laughter and tears.
- Impaired physical performance.

Classification of severity

This can only be determined AFTER recovery.

- Simple concussion:
  - ✓ The patient is completely recovered after 10 days.
  - ✓ Have not had concussion within the near past.
- Complex concussion:
  - ✓ Loss of consciousness for more than 1 minute.
  - ✓ Longer recovery time than 10 days.
  - ✓ Recurrent symptoms during rehabilitation.
  - ✓ Repeated concussions, mostly if the trauma has become milder.

Acute care

- Cancel all physical activity. This also applies to what may be perceived as a milder blow to the head.
- Normal ABC procedure. Establish good working routines and responsibilities.
- Be aware of possible neck injury. If the injured person is unconscious, the cervical spine should always be fixed with a rigid neck collar before any transfer takes place (Fig. 14.4).
- Follow the patient to a calm environment. Patients should be monitored, cannot be left alone and should be evaluated by a physician.
- Note that it is not uncommon for the athlete to trivialize their symptoms in order not to have to interrupt their activity.
- If unconscious or exhibiting obvious neurological symptoms, the patient should be sent to the nearest emergency clinic, where a computed tomography (CT) scan may be performed. If this is normal, the risk of permanent damage is very small.

Figure 14.4 When neck and even head injuries occur, a neck collar should be used directly on the field. (With permission, by Bildbyrån, Sweden.)

- When the symptoms are stabilized the patient can leave the hospital, but the close relatives should be contacted.
- Note that the reduced level of consciousness, neurological deficiency symptoms, increasing headache, vomiting, confusion or seizures may occur up to 48 hours after the trauma.
- The athlete may not resume activity again until a physician has given approval, even if the symptoms subside.
- Contact with the hospital should be made if symptoms get worse.

Brain Ladder – rehabilitation through gradual return to sport

Rehabilitation and return to sport after concussion should follow a program where the demand on the brain is gradually increased.[2]

The Brain Ladder rehabilitation program is used to guide the athlete easily and safely back to full activity. The rehabilitation program should always be adjusted based on the sport and individual exercise capacity. The following should be taken into account:

- At least 24 hours free of symptoms before physical activity may begin.
- Basic rule: only one new, previously done, activity per day!
- If symptoms occur during a step, wait until asymptomatic, rest for 24 hours and re-do previous asymptomatic step.

- All known elements in the current sport or activity must have been introduced in the Brain Ladder before returning to unrestricted activity.
- If symptoms recur on two occasions during the Brain Ladder, stop and examine.

Practical advice[2]

Step 1: Brain rest

- The athlete rests entirely from both physical and mental load.
- Minimize exposure to external stimuli such as radio, music, watching TV, games.
- Step 1 is started when the patient has been completely asymptomatic for at least 24 hours.

Step 2: Aerobic exercise

- Aerobic exercise 30–40 minutes, e.g. on an exercise bike. Effort according to Borg scale 12 (fairly light).
- Step 2 is completed if the training does not produce symptoms, and if no symptoms occur within 24 hours.

Step 3: Individual sport specific training

- Jogging, warm up with the team, technique training with a ball. Difficulty is adjusted to the individual's own level.
- Step 3 is completed when the activities can be done with normal fatigue and without symptoms. 24 hour rule applies here too.

Step 4: Training without body contact

- Full physical load on sport-specific exercises, all elements of risk eliminated. Technique training. Strength training.
- Heading a ball is progressively introduced in conjunction with Step 4:
  - ✓ Heading the ball, the player throws it to him/herself.
  - ✓ Heading the ball with both feet on the ground, and between two players.
  - ✓ Heading the ball and jumping at the same time.
  - ✓ Heading the ball at corner kicks, free kicks and goal kicks.
- Step 4 is completed when the athlete is able to have a normal training environment, without physical contact or risk factors, with full physical load without symptoms (within 24 hours).

Step 5: Full training with body contact

- Body tackles in hockey and heading in soccer is allowed.
- No game or competition.
- No restrictions, besides the actual competition element.
- Is the athlete fully recovered?

Brain card

- Immediate assessment: questions to ask: Where are we? What is the score? Who scored?
- Symptoms Scale: 18 symptoms – no, moderate, severe.
- Brain function – memory, concentration.
- Neurology.
- Memory tests: questions, e.g.: Do you remember the words? (Five words are given, to be repeated by the athlete.)
- Concentration tests: questions, e.g.: When is your birthday? Counting the months backwards from their birth month.
- Neurological assessment.
- Assess: speech, eye movement, pupil reaction, balance/gait, motor skills.
- Ask the patient: Do you feel 100% fine?

Baseline test

It is important to know the individual's capacity before the injury, i.e. what is normal for them?

Adults can handle:

- Words: men 5 of 5 directly, women 5/5; on a second test for men, 4/5.
- Numeric memory: women are able to repeat 6 digits, men 5.

Children/young people can handle:

- Words: 5 of 5 directly, 3/5 on a second test.
- Numeric memory: girls 4/5 while boys have more difficulty with this.[3]

Step 6 Return to match/competition

- Who gives the go-ahead in the organization?
- Will be introduced from step 4.
- Symptoms that occur after heavy physical exercise may be similar to those experienced by the patient.
- 50% load to step 6 is accepted.
- No clear consensus on step 6.
- A gender difference may exist – women have a tendency to slightly longer recovery time.

The Zurich consensus meeting emphasizes that there is a difference between children and adults, but the same basic rehabilitation principles apply.

- Children and adolescents have more difficulty in describing symptoms.
- Double time in the Brain Ladder has been suggested as a possible way for children and adolescents.

Restarting with the aim to return to sport

For persons participating in athletics, the 2012 Zurich Consensus Statement on Concussion in Sport[1] recommended that participants be symptom free before restarting and then progress through a series of graded steps (see above). Only when symptom free for 24 hours, should progression to the next step occur.

Can all sports be treated the same way?

The principles are the same in all sports, with the development of 'ladders' for hockey, basketball, handball, equestrians, downhill skiing, American football and football/soccer.

Prevention

- Follow the rules that exist.
- Create role models.
- Use protective equipment adequately: protective equipment, such as helmets and intraoral mouth guards do not prevent concussion, but can reduce the severity. The helmet is especially designed to protect against skull fractures and bleeding in the brain (intracranial).

Tip

Perhaps the most important preventive measure in contact sports is a change of attitude, which can increase respect for the opponent as an individual and thus can certainly eliminate a lot of the unnecessary trauma against the head.

It must also be pointed out that strict obedience of the laws of the game can reduce concussions.

Summary

- Concussion is more common than you might think and can cause prolonged absence from sport.
- Concussion in sport can present many different symptoms; ask the patient if he or she is 100% restored.
- Return to sport and activity should be done step-wise and if recurrent symptoms arises one should seek medical advice.
- The Brain Ladder is a way to control the rehabilitation.
- Brain rest is probably the most important phase and is likely to be very important initially; do not rush to the next step.
- Children and adolescents are treated in the same way as adults, but may need longer time in the Brain Ladder.
- Note the small symptoms; the player can easily 'hide' these symptoms.
- Memory/concentration tests are good instruments, but be aware of individual differences.
- Always test the stabilizing muscles in connection with the transition to active rehabilitation in the Brain Ladder.
- Be strong and support each other in the medical team!

Unconsciousness

Head injuries should, whether unconscious or not during the examination, always be regarded as serious as life-threatening complications can occur.

Trauma with unconsciousness

Actions at the accident site

Unconsciousness caused by head injuries, which have arisen in connection with trauma against the head (e.g. falls and during a crash), must be differentiated from loss of consciousness that occurs in failing blood circulation during long-distance running or sudden cardiac arrest after just falling down without trauma. Anyone who takes care of the injured person must make an assessment of the causes of unconsciousness and then take the necessary action.

Tip

It is important to know that it is common for cervical spine injuries to be associated with head injuries. For that reason, all care is focused on protecting the spine. Every unconscious person must be assumed to have a spinal injury.

An immediate assessment must be made to ensure that the victim has a palpable pulse and free airways, as these are essential for survival. An accident with loss of consciousness that proves fatal is often due to airway obstruction or failing blood circulation due to cardiac arrest. If breathing or the heart stops for about 3–5 minutes then permanent brain damage will have occurred.

An injured person that breathes by themself should not be placed in another position, but only assured of a free airway. If the injured person is wearing a safety helmet this should be left on the athlete's head – removal involves a risk in itself for a possible worsening of a neck injury. Face guards should however be removed.

If the injured person is not breathing, artificial respiration must be provided (i.e. mouth-to-mouth resuscitation). The injured person is laid on his back. This action requires aides because the cervical spine is of paramount importance. One person gently holds the head so that it is aligned with the spine. When the unconscious person is entirely on their back mouth-to-mouth resuscitation can be started as follows:

- The oral cavity is cleared from objects such as mouth guards, dentures, loose teeth, earth, stomach contents, etc.
- The lower jaw is lifted and the head is slightly bent backwards. The tongue can fall against the posterior pharyngeal wall and pose a respiratory obstruction in unconscious athletes. A slight backward head tilt and simultaneous support under the chin is often a sufficient measure to provide a free airway. The head is stabilized by a holding a hand to the forehead and at the same time pulling the jaw forward. Excessive backward bending of the neck must be avoided to prevent a possible worsening of a cervical spine injury.
- Administering cardiopulmonary resuscitation (CPR), or even just compressions to the chest, can improve the chances of survival until emergency personnel arrive. To administer mouth-to-mouth resuscitation (the 'kiss of life'), take a deep breath, open your mouth wide and press it as closely as possible to that of the injured person (Fig. 14.5). Two rescue breaths should follow 50 chest compressions.
- The unconscious person should be taken to hospital as soon as possible.
- While waiting for transport the patient should be kept covered and something warm, such as a blanket, should be placed beneath the person's body.
- A person who is or has been unconscious should not be given anything to eat or drink and should never be left alone.

Complications

In cases of head injury, it may take hours or days for evidence of complications to appear. Internal bleeding from ruptured blood vessels may occur even if there is no bony injury to the skull, and unless controlled will gradually compress the brain (Fig. 14.6)

The increased pressure on the brain tissues can affect the breathing center, and breathing may stop. Only an immediate operation to stop the bleeding and relieve the pressure will give the injured athlete a chance to recover.

Bleeding from the ears or bleeding with a simultaneous flow of fluid from the nose suggests that a fracture of the base of the skull may have occurred. This may indicate a very severe injury and requires emergency room evaluation. A variety of different techniques may be used for investigation, including X-rays, specialized scans and ultrasonography.

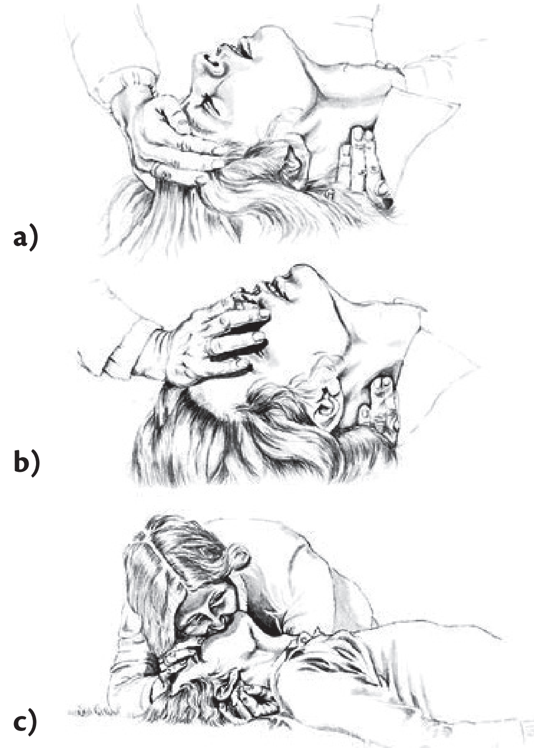

Figure 14.5 Mouth-to-mouth resuscitation. **a)** Bend the head back while supporting the injured neck; **b)** pinch the nostrils; **c)** blow air into the injured player's mouth.

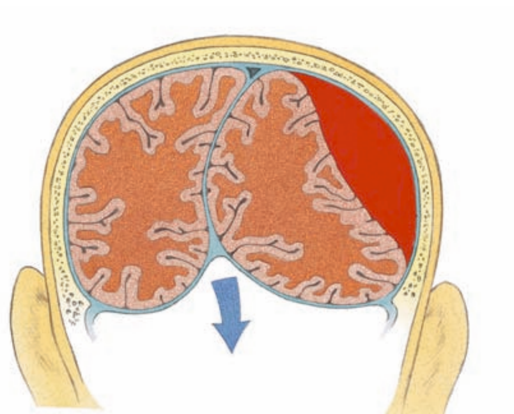

Figure 14.6 Bleeding (cerebral hemorrhage) can occur between the skull and the brain. The increased pressure is distributed downwards towards the base of the skull.

Cardiopulmonary unconsciousness

Cardiopulmonary resuscitation (CPR)

Technique for CPR is described in Chapter 7 p. 129. The order of interventions was changed in 2010 for all age groups to:

- Chest compressions.
- Airway.

- Breathing.
- The patient's pulse should be checked. If no pulse is present, cardiac chest compression should begin, following the guidelines from the American Heart Association for basic cardiopulmonary resuscitation. They recommend that everyone, regardless of education level begin CPR with chest compressions.
- If the person at hand is not trained in CPR, then provide hands-only CPR. That means uninterrupted chest compressions of about 100/min until paramedics arrive. According to recent recommendations there is no need to try rescue breathing.
- If the person at hand is well-trained and confident, he/she can begin with chest compressions instead of first checking the airway and doing rescue breathing. Start CPR with 30 chest compressions before checking the airway and giving rescue breaths.

Summary

Immediate chest compressions are considered most important, according to the International Liaison Committee on Resuscitation guidelines. They are as follows:

- Place the heel of your hand on the center of the person's chest.
- Then place the heel of your other hand on top of your first hand.
- Keep arms straight and your shoulders directly over your hands.
- Compress the chest by pushing hard and fast at least 5 cm (2 in) deep.
- Compress at least 100 times per minute.
- Continue until emergency help is on site.
- Try to use an automated external defibrillator (AED) as soon as possible. They should be available at the arena/sports ground.
- It is far better to do something than to do nothing at all.

Facial injuries

Open wounds

Wounds on the forehead and scalp may occur in association with injuries to underlying tissues. Such injuries often occur in contact sports, such as ice hockey, rugby and soccer, as well as in riders, downhill skiers and others. When there is copious bleeding, face lacerations that require suturing or a risk of skeletal injuries, the injured person should see a physician. For general treatment of wounds see p. 189.

Tip

In ice hockey a preventive face guard could be worn, which would largely eliminate facial injuries.

Fractures

Fracture of the maxilla

Fractures of the maxilla (upper jawbone) occur in contact sports such as football, ice hockey, rugby, handball and boxing (Fig. 14.7). This injury should be suspected if:

- The upper jaw has been subjected to a blow.
- The teeth are out of alignment and there is pain on clenching the teeth.
- One half of the cheek feels numb.
- A tender irregularity can be felt in the bone edge along the lower border of the eye socket.
- There is double vision.

Fractures of the upper jaw are most often treated surgically and heal in 6–8 weeks.

Fracture of the zygomatic bone

The zygomatic bone runs between the cheek and the ear, and a fracture should be suspected if:

- The zygomatic bone or the upper jaw has been subjected to a blow.
- There is tenderness with swelling over the zygomatic bone.
- Chewing is painful.

If an X-ray shows that the fractured zygomatic bone is pressed inwards, the injury is operated on and heals in about 4 weeks.

Fracture of the mandible

A fracture of the mandible (lower jawbone) should be suspected if:

- The chin has been subjected to a blow, for example a punch in boxing.
- Pain occurs on opening the mouth or clenching the teeth.
- The teeth are out of alignment.
- There is local tenderness in front of the ear.

Surgery is necessary if displacement has occurred. The lower jaw is fixed to the upper jaw by wiring the teeth for 6–8 weeks.

Figure 14.7 Fractures of the face can occur in sports using equipment. **a, b)** A hockey stick in the face can cause serious injury such as nose and jaw fractures, eye injuries, etc., especially when the visor glides up; **c)** boxing can cause similar damage in these areas. (With permission, by Bildbyrån, Sweden.)

Nose-bleeds

A nose-bleed is caused by rupture of one or more blood vessels in the nose, and is common in contact sports such as handball, ice hockey, football and boxing. Note that a broken nose should be suspected when bleeding occurs after a blow and/or there is deformity or crepitus.

Treatment

The athlete should:

- Sit upright if possible.
- Place thumb and index finger over the nose and pinch the nostrils together for about 10 minutes, after which bleeding will stop in 9 out of 10 cases. Keep the head bent forwards rather than backwards.
- Put a ball of cotton wool or a compress in the nostril for about 1 hour. Make sure that it cannot be inhaled and do not forget to remove it.
- If the bleeding recurs, put a food oil-soaked cotton swab in the nose for a couple of hours. The oil will prevent the cotton from sticking to the wound.
- See a physician if the bleeding continues in spite of the above measures or if there is deformity.

The physician may:

- Insert a compress with vessel-constricting agents.
- Insert a pressure balloon in cases of severe bleeding.
- Cauterize the ruptured blood vessel.
- Perform a delayed reduction if deformity is present. Acute reductions can cause increased hemorrhage and are not advised.

Ear injuries

Injuries to the outer ear

Injuries to the outer ear are not common in sport. Repeated blows or repeated pressure against the ear, as in boxing and wrestling, can, however, cause bleeding that if untreated can result in a 'cauliflower ear' (Fig. 14.8). A similar acute injury is seen in rugby players.

Emergency treatment with cooling and compression should be applied in order to reduce the swelling to a minimum. Bleeding in the outer ear can be treated by aspiration and packing, or suturing to prevent later deformity. Treatment is not very effective, however, so prevention with protective headgear is preferable.

Injuries to the middle and inner ear

If a blow to the side of the head is followed by pain in the ear, slight bleeding or impaired hearing, a rupture of the eardrum should be suspected. These symptoms should always lead to a medical examination since injuries to the eardrum can result in permanently impaired hearing. However, the majority heal spontaneously.

Figure 14.8 'Cauliflower ear' is often seen in wrestlers.

It is now known that a sound level of 140 dB is harmful to the ear and can cause life-long impaired hearing, a level commonly experienced in pistol shooting. In 2006 new EU regulations were created that demanded that all workplaces with a noise level of 80 DB required hearing protection.

Those involved in shooting should always use effective ear defenders to avoid permanent hearing loss from damage to the inner ear. It should be noted that hearing protection for hunters in the trade are in no way enough for a pistol shooter. A pistol shooter needs more damping than a hunter. Disadvantages of good ear defenders is that they dampen all sound, so it can be easy to miss a command, e.g. to cease fire during competition (Fig. 14.9).

Figure 14.9 Passive hearing protection can be used for suppressing noise, e.g. **a)** in shooting competitions; **b)** in domestic activities. (a: courtesy of 3M/Peltor, Sweden.)

Eye injuries

The area around the eye is constructed in such a way as to give the eye the greatest possible protection against external impact. Direct impact against the eye from a large object, such as a football, can result in bleeding and swelling in the eyelid and surrounding soft tissues, but seldom injures the eye itself. However, blows from small or pointed objects, such as elbows, fingers, sticks, racquets, squash balls and pucks, can cause direct injuries to the eyeball (Fig. 14.10).

Most eye injuries are minor, but serious injuries need immediate attention to avoid loss of vision. Indications for which immediate contact with a physician is advised include:

- Severe eye pain.
- Double vision.
- Loss of visual acuity.
- Decreased field of vision.
- Blood or blurring at the pupil or iris.
- Abnormally shaped pupil.
- Suspected penetrating injury or tear.
- Decreased eye movements.

Inflammation and bleeding in the conjunctiva

The eye is relatively resistant to irritation, but swimmers can be affected by inflammation of the conjunctiva (which covers the whole of the eyeball) because of the chlorine in swimming pool water. The complaint can also be triggered by oversensitivity or overexposure to sunlight. It is harmless, and the problems can be relieved by eye drops. Swimmers can prevent the complaint by using protective goggles (Fig. 14.11).

Subconjunctival hemorrhage is probably the most common eye problem. It can occur from trauma to the

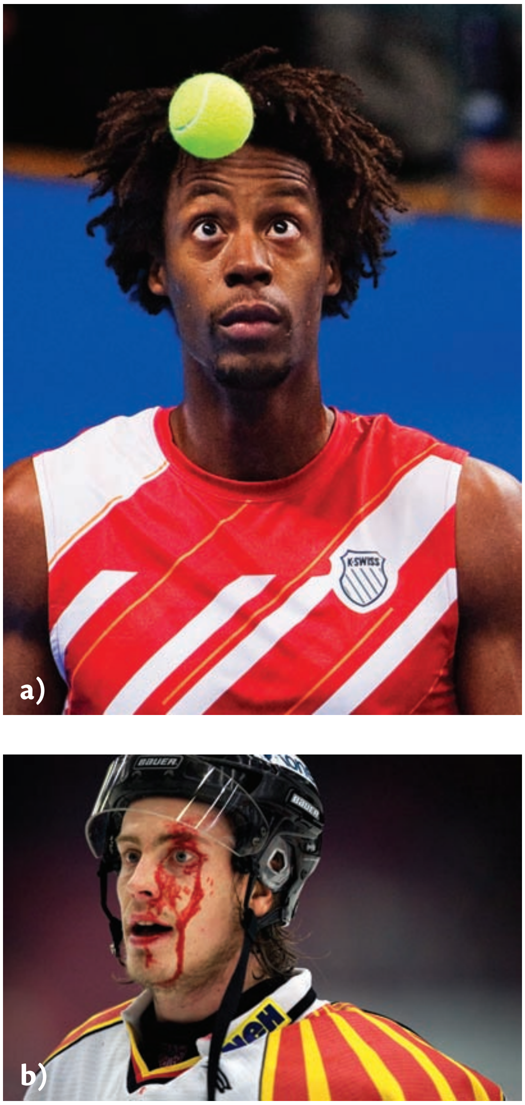

Figure 14.10 Good eyesight is essential in almost all elite sports. **a)** In tennis sight is important especially since it is such a fast game and anticipation is vital; **b)** lesions in and around the eyes are common in some sports and can occur despite the use of visors. (With permission, by Bildbyrån, Sweden.)

Figure 14.11 Eye protection is effective and is used in a variety of sports, e.g. swimming. (With permission, by Bildbyrån, Sweden.)

eye or by spontaneous rupture of blood vessels due to a sudden increase in blood pressure from exertion. So long as no visual symptoms or prolonged photophobia are present, this injury will resolve spontaneously and no treatment is required. Subconjunctival hemorrhage can sometimes mask other, more serious problems; if these are suspected, a physician should be consulted immediately.

Lid lacerations

Lacerations of the eyelids, especially those that involve the tear system at the inside corner of the eye, require meticulous repair. A physician should be consulted immediately.

Corneal abrasions

One of the most common eye injuries in sport is a small scratch on the cornea (the clear central part of the eye covering the iris). The wound can be caused by a fingernail, a foreign body in the eye or a contact lens. The affected person complains of pain and a gritty sensation in the eye, especially in bright light and when blinking. Increased tear flow is a common symptom. If a wound on the cornea is suspected, a physician should be seen for advice since the injury can affect the sight. The treatment is usually ointment or eye drops and rest; an eye pad may be applied for 1–2 days.

Bleeding into the anterior chamber of the eye

A blow to the eye with a blunt object can cause bleeding in front of the iris (hyphemia). The blood forms a fluid level between the iris and the cornea at the bottom of the anterior chamber of the eye (Fig. 14.12). If the trauma and bleeding is mild there is no need for emergency treatment; the injured should rest and be examined by an ophthalmologist within a few days.

For major bleeding with severe vision loss and/or severe trauma, the patient should be sent to an emergency physician for examination. Detachment of the iris may occur and is difficult to see with excessive bleeding. Large injuries at the edge of the retina must also be treated rapidly. There is an increased risk of acute increased pressure in the eyeball. The treatment consists of immediate rest and bed rest, because the bleeding may otherwise increase. Sometimes bilateral eye bandaging for 5–6 days is done to control additional bleeding. The

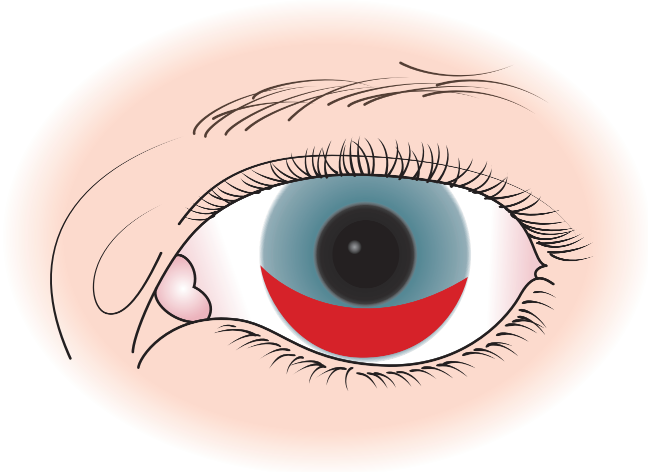

Figure 14.12 Bleeding in the anterior chamber of the eye.

injured person should see a physician for examination and observation. The condition often heals without any permanent disability, but secondary glaucoma and blood-staining of the cornea are worrisome complications that may impair sight.

Detached retina

The retina can be partly detached by a hard blow to the eye, and this should be suspected if the injured person has impaired sight within a limited field of vision. The injury should be examined by a physician.

Injuries to the mouth

Tongue injuries

The tongue can sometimes be bitten accidentally during sporting activity, leaving a bleeding wound that is painful but not serious. A gash that is less than 1 cm (0.5 in.) long does not need any treatment. More extensive wounds may need careful stitching by a physician.

Dental injuries

Dental injuries are especially common in children. One-quarter of all dental injuries in children occur during physical training or sporting activities. Collisions with opponents during contact sports are the most common cause, but direct blows from equipment such as hockey sticks or cricket balls may be to blame (Fig. 14.13).

In the majority of cases it is the front teeth of the upper jaw that are affected, and in half of these cases more than one tooth has been damaged. Dentists usually classify dental injuries in the following way:

- Fracture of the crown of the tooth affecting the enamel only.
- Fracture of the crown of the tooth affecting both enamel and dentine.
- Fracture of the crown of the tooth with exposed pulp.
- Injury of the attachment of the tooth in the jaw.
- Injury of the root of the tooth.
- Combination of fracture of crown and root.
- A lost tooth.

It is rare that a dental injury heals spontaneously without treatment. Dental injuries in children are serious, since injuries to teeth and jaws that are not fully developed can adversely affect them for life.

Treatment

The injured person should see a dentist immediately (the prognosis worsens with every hour's delay) in cases of the following types of dental injuries:

- A broken tooth.
- A tooth that is knocked out.
- A tooth that is loose and bleeding.

Figure 14.13 a, b) Dental injuries in hockey. (Courtesy of Dr. Paul Pincinnini, Ottawa, Canada.)

A tooth that has been knocked out should be kept, since it can sometimes be re-implanted successfully. The likelihood of this occurring depends on the length of time for which the tooth has been out of its socket and the degree to which the periodontal membrane has dried out. During the journey to the dentist the tooth should be kept moist, in a suitable medium so that drying of the periodontal membrane is minimized. Suitable media include sterile saliva or cold milk; it can also be kept under the tongue or in a saliva-soaked handkerchief.

Prevention

Different types of gum shields (mouth guards) for athletes have been constructed, including those suitable for use in ice hockey and boxing (p. 46). Unfortunately, in some sports there is resistance among top-level players to using these shields; this sets a bad example for young people. It should be a matter of course that all athletes in contact sports use this form of protection.

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15 Throat, Chest and Abdominal Injuries in Sport

Throat injuries

The risk of serious injury in the neck is relatively large, not least because there is no bone structure protecting vital soft tissues anteriorly; at the front and to the sides are only soft tissues such as skin, muscle, tendon and cartilage. The neck has large and important blood vessels and nerves, as well as the thyroid, trachea and esophagus. Trauma to the neck can result in a fatal injury.

With every injury to the throat, an assessment must be made to assess if the integrity of the cervical spine has been affected (see p. 331). Spinal injuries can sometimes be disguised by pain felt elsewhere. On suspicion of spinal injury to the neck, the head and neck should be immobilized and the injured athlete should be transported to the hospital immediately.

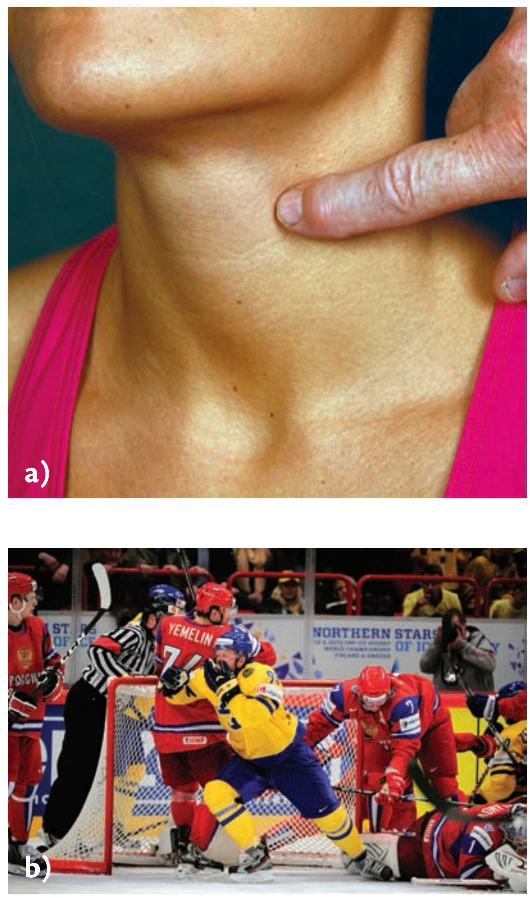

Figure 15.1 Injuries to the larynx can be serious. a) Location for larynx injuries; b) a hockey stick can be a dangerous weapon.

Larynx injuries

The larynx (voice box) is hollow and composed of elastic cartilage, lined on the inside with mucous membrane. The air we breathe passes the larynx between the vocal cords, which are essential for phonation. When an athlete is exposed to a headlock in wrestling or receives a blow to the front of the neck by an arm, stick, puck or ball, the cartilage of the larynx can be bent sharply inward (Fig. 15.1). When the violence against the neck ceases the cartilage pops back in shape by its own elasticity, but the mucous membrane lining is torn loose. Between the cartilage and lining bleeding occurs, which can spread and affect the vocal cords, causing swelling and hoarseness.

The swelling may gradually increase and eventually clog the opening between the vocal cords, which leads to increased respiratory obstruction. Children are especially prone to this injury.

Tip

Blunt force trauma to the front of the neck, followed by hoarseness should lead to a visit to a physician, because the consequences can be critical.

Laryngeal injuries heal usually without treatment other than rest and observation for any changes.

Open neck wounds

Wounds on the neck are an uncommon injury, but can be life-threatening as the large blood vessels that run through the neck to the brain can be affected. It can occur in such sports as bandy and ice hockey when a skate hits the throat of an opponent as well as in accidents in motor sports. A large, profuse bleeding occurs and must be stopped immediately, which can be achieved by pressing a towel against the wound and maintaining constant hard pressure. The injured should be immediately transported to a hospital. To prevent this type of injury in ice hockey a throat protector is mandatory for all players(see Fig. 4.12).

Thoracic injuries

Rib fractures

Fractures to the ribs are common in sports, especially in contact sports. The damage can occur by way of a direct blow with a blunt object, such as the shaft of an ice hockey club, or a sharp compression of the thorax by a hard tackle or body check (i.e. using body contact to gain a competitive advantage over an opponent).

Symptoms and diagnosis

- Pain over the fracture site, especially with deep breathing, coughing or sneezing.
- Tenderness and slight swelling over the fracture site (Fig. 15.2A).
- A compression of entire chest causes pain over the fracture site (Fig. 15.2B).
- Pain restricted movement. Often the injured athlete will sit and sleep in a chair.
- X-rays of the lungs should be done to confirm the rib injury and rule out underlying lung injury.

Treatment

A couple of simple or single rib fractures usually require no treatment other than pain relief; healing occurs spontaneously. Bandaging of the damaged area is not advised as this inhibits the ability of the lungs to expand.

Healing and complications

For fractures not causing any complications, the injured athlete should be able to return to their sport within 3–6 weeks, depending on the symptoms. If multiple rib fracturing is present, it may be necessary for the athlete to attend a hospital for observation because of the risk of respiratory complications (Fig. 15.3).

If the sharp fracture ends of a rib(s) penetrate into the lungs this can cause:

- Pneumothorax (collapsed lung), which is leakage of air from the broken rib end puncturing a hole in the pleura and lung, which may cause a lung collapse when the pleural cavity is filled with air.
- Hemothorax, bleeding from the damage to the lung tissue caused by the broken rib end, filling the pleural cavity and compressing the lung.

Respiratory problem increase should arouse suspicion of these complications. When they are encountered it may be necessary to puncture and drain the pleural cavity by extracting air and/or blood. If signs of these complications occur, the athlete should be sent to the hospital.

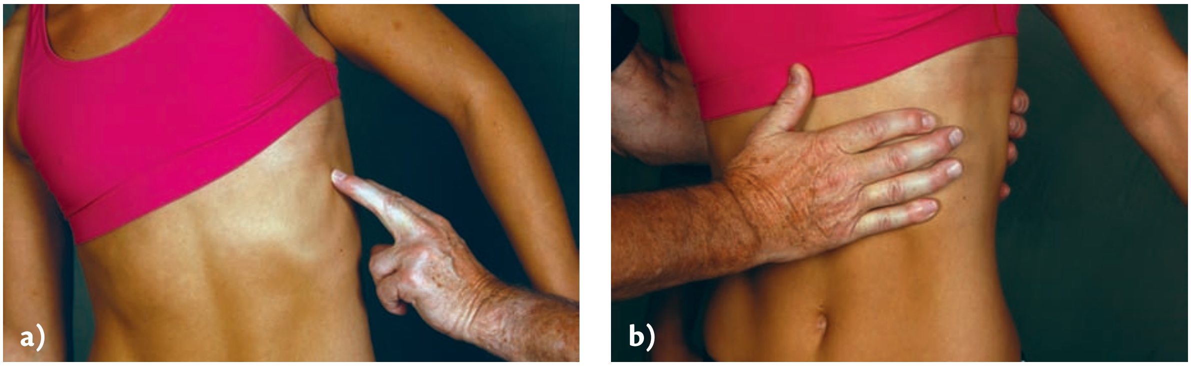

Figure 15.2 Fracture to the ribs. **a)** Common location for pain and direct tenderness with a rib fracture; **b)** when compressing the rib cage indirect pain may be experienced with a rib fracture.

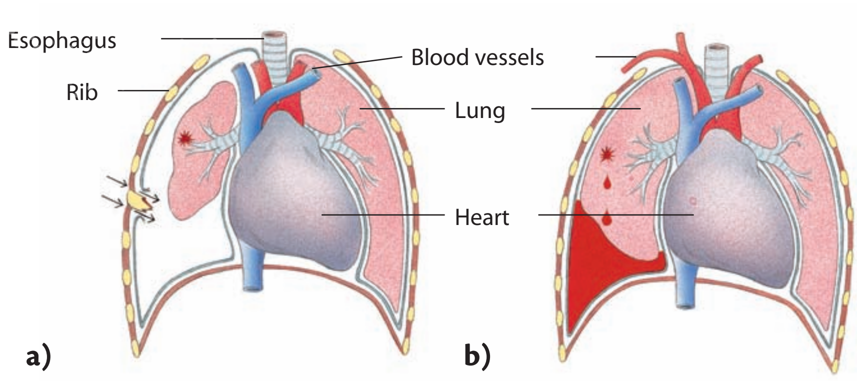

Figure 15.3 Pneomothorax (collapsed lung) and hemothorax. **a)** Pneumothorax: the broken rib's sharp end can cause a hole in the pleural cavity and the lung, which can collapse and the pleural cavity may be filled with air as a result; **b)** hemothorax: bleeding from the damaged lung tissue caused by a broken rib end fills the pleural cavity (the cavity between the two membranes [pleura] surrounding the lung and the inner wall of the thorax) with blood and thereby compresses the lung.

Abdominal injuries

Injuries to the abdomen are rare in sports, but when they occur, they can lead to a catastrophic end (Figs 15.4, 15.5). Such injuries can result from being kicked by a horse, as well as in contact sports, cycling and skiing, etc.

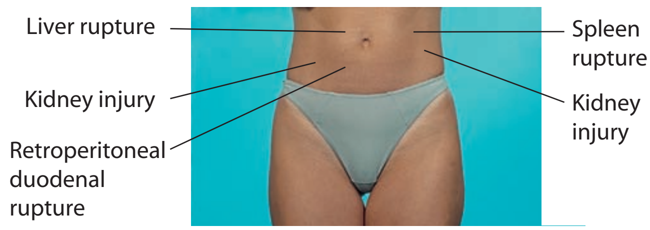

Figure 15.4 Location of injuries to the abdomen.

Rupture of the spleen

The spleen is located in the abdomen, upper left part, under the diaphragm muscle that separates the abdominal cavity from the chest cavity (Fig. 15.5).

The most common cause of death among athletes with abdominal injuries is rupture of the spleen. The injury can occur in direct trauma to the abdomen, such as when a cyclist falls on the handlebar pushing it up into the upper left part of the abdomen, or in tackling and, in rare cases, by way of a rib fracture. It is important to keep in mind that a rupture of the spleen can occur when excessive force occurs to the left side of the abdomen. Athletes who have recently recovered from glandular fever (mononucleosis) are at greater risk of splenic rupture.

Symptoms and diagnosis

Rupture of the spleen and its surrounding capsule causes bleeding into the abdominal cavity with pain, nausea, soreness and increased tension of the abdominal muscles as a result. The injured athlete is initially in pain but after an hour more signs of hypovolemic shock (shock due to severe blood and fluid loss) may appear: rapid and weak pulse, paleness, cold sweats, and sometimes – in major bleeding – increasing sluggishness and loss of consciousness.

Rupture of the spleen with the surrounding capsule intact, causes a hemorrhage, which is limited by the capsule and can swell progressively. The capsule is stretched, weakened and may rupture long after the accident. The hemorrhage can also come to a halt. Risk of rupture for a swollen spleen can be triggered by physical activity 1–2 weeks later, occurring in 10–20% of cases.

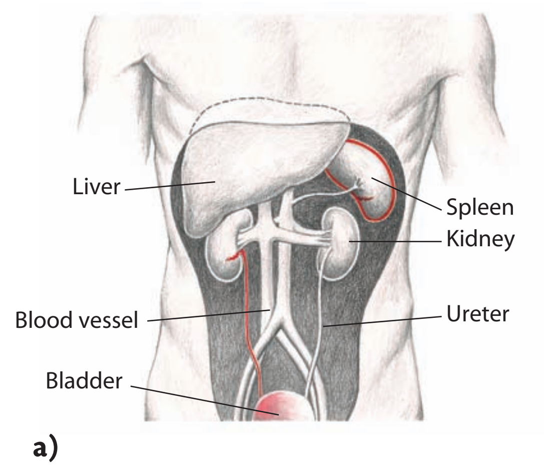

Figure 15.5 Rupture of the spleen. **a)** Overview of the abdomen with liver, kidneys and bladder; **b)** location for injury to the spleen.

If after being subjected to trauma against the abdomen the athlete has residual feeling of sickness: nausea, tiredness, pain in the upper left of the abdomen and sometimes pain in the left shoulder, the athlete should seek medical advice, as an injury to the spleen may exist.

Treatment

The course of events and the results of the physician's examination and investigations will determine the length of stay in hospital. A computed tomography (CT) scan and/or diagnostic peritoneal lavage (DPL) are helpful in confirming the diagnosis. Except in severe cases, attempts are made to preserve the spleen because of its important role in the body's immune system; treatment includes rest, surgical suturing, and local coagulants, depending on the degree of injury. In severe injuries the spleen is removed. Following splenectomy the patient should receive polyvalent pneumococcal vaccine and should continue to be followed up with each new infection because the immune system has been compromised for good.

Rupture of the liver

The liver is located in the upper right-hand part of the abdomen below the rib cage (Fig. 15.6).

Liver tissue is frail and it can rupture as a result of a trauma to the upper right part of the abdomen. The damage occurs only rarely in sports. Most liver injuries that occur are small and self-healing. Sometimes, however, a major rupture may occur, causing generalized condition change and shock, so that the injured athletes suffer from nausea, vomiting, dizziness, fainting and severe pain related to enlarged abdominal circumference. When any of these symptoms appear, the athlete should be immediately transported to hospital for rest and observation. Commonly, surgery is required. A CT scan and/or DPL (rinsing of the abdominal cavity) are useful methods for diagnosis and treatment.

A major rupture in the liver may also result in bile flows out into the abdomen, causing a chemical or bacterial peritonitis. This condition is more serious than the bleeding because the inflammation can damage all abdominal organs. Careful inspections of the abdominal organs are made during surgery when the leaking bile is stopped.

Kidney injuries

Kidney injuries in sports are rare. The kidneys are located behind the peritoneum (the lining of the abdominal cavity) above the pelvic bones on either side of the spine (Fig. 15.7).

As a result of a violent blow to the low back above the pelvis, a kidney can rupture, causing blood to appear in the urine. The bleeding after rupture will often stop and cause no trouble, but a major rupture can cause a life-threatening internal bleeding. The kidney must be surgically removed.

Blood in the urine after trauma to the kidneys should result in the observation of the injured athlete in a hospital. In investigating the extent of the damage a CT

Figure 15.6 Location for an injury to the liver.

Figure 15.7 Location for an injury to the kidney.

scan, ultrasound imaging and contrast radiography of the renal pelvis (pyelography) should be included.

After substantial vigorous physical exertion blood can appear in the urine, causing a faint red discoloration. This does not necessarily indicate a kidney injury but should be investigated by a physician.

Perforation of the duodenum (the first section of the small intestine)

Duodenal perforation in the space behind the peritoneum (retroperitoneal) following a blunt abdominal trauma, such as from the knee of an opponent, in the upper abdomen is rare. The intestines generally are not injured because they are mobile; however, the duodenum is fixed to the retroperitoneum and can be injured.

The injury is characterized by severe upper abdominal pain and vomiting occurring several hours after the injury, due to obstruction of the gastrointestinal tract and retroperitoneal leakage or bleeding from the injury.

If the injury is severe enough, part of the duodenum may go into necrosis several weeks after the injury and leak into the abdomen to cause peritonitis and even death. A CT scan is essential in diagnosing and monitoring the injury. Duodenal drainage and observation in hospital may be necessary. If necrosis of the duodenum is occurring, it must be removed surgically, preferably before rupture, to avoid peritonitis.

Injuries to the lower abdomen

A blow to the testes can cause bleeding and swelling that can disrupt the blood supply to the testes and cause sterility. The injury can be prevented by using a cup, especially for goalkeepers and catchers in ball sports (Fig. 15.8).

Figure 15.8 A suspensor 'jockstrap' is used in many sports such as rugby and by goalkeepers in football/soccer, etc. (see Fig. 4.17 for jockstrap used in ice hockey). (Courtesy of Reebook/CCM.)

Trauma to the penis can cause a painful cramp in the sphincter of the bladder, which can make it difficult to urinate. The pain usually ceases once urination takes place.

Gynecological injuries, such as forced vaginal trauma and hematoma of the vulva, can occur in, for example, water skiers, especially when an inexperienced skier falls in a squatting position. Wearing a wet-suit prevents such problems.

'Winded'

After a blunt forceful trauma to the solar plexus or to the upper part of the abdomen, it is not uncommon for an athlete be 'winded' and to fall and remain lying doubled up on the ground. There can be a temporary loss of muscle function (paralysis) of the diaphragm followed by some breathing difficulties. The athlete will recover more quickly if allowed to crouch, so that the abdominal and respiratory muscles can relax.

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16

Back/Spine Injuries in Sport

Back problems affect 80% of all people at some point in their life. There is no specific category of people who suffer back pain more frequently than others, laborers are affected as often as clerks, men as often as women. Important contributory factors for back pain being triggered are heavy physical work, lifting, static postures and vibration. In spite of the fact that the heaviest industrial tasks are now carried out by machines in many workplaces the number of people seeking advice for back pain does not seem to have decreased. Of all people suffering from back pain, 70% usually return to work within 1 week and 90% within 3 months, regardless of the treatment they receive.

Athletic events normally require a well-functioning and well developed back (Fig. 16.1). Different sport disciplines have different requirements. Athletes in certain disciplines expose themselves to extensive loads in extreme postures and positions, often with many repetitions. In other disciplines, the number of repetitions is very large but the load is low, which can still cause damage.

Many athletes therefore require a back that can handle both extensive basic training and specific discipline training in order to prepare themselves to perform at their maximum in competition.

Overloading of the back should be avoided in both training and competition. Back function needs to be prepared comprehensively long term and discipline specific, to adapt to the demands of competition.

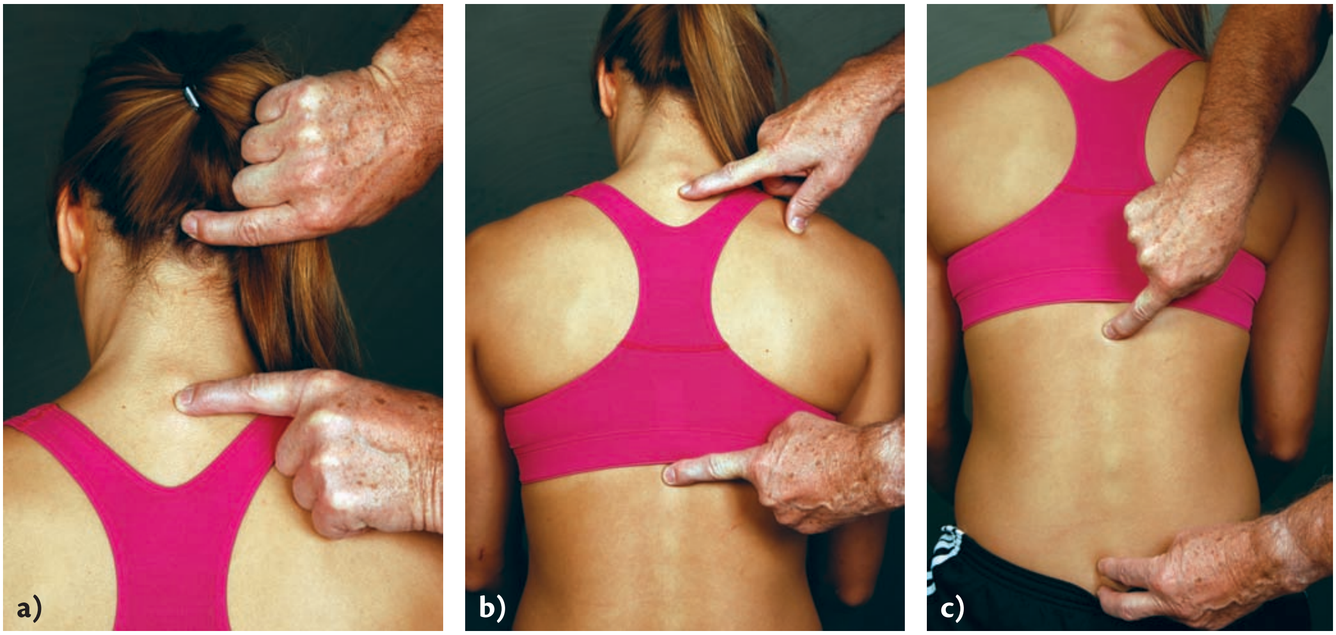


Figure 16.1 The spine is composed of **a)** cervical; **b)** thoracic; **c)** lumbar vertebrae (sacral and coccygeal vertebrae are located below, outside the figure).

Back problems are less common among athletes than in other populations but in some sports the athlete is more vulnerable. Athletes involved in impact sports appear to have risk factors for specific spinal pathologies, that correlate with the loading and repetition demands of specific activities (Fig. 16.2).[1]

In a study of elite youth active in football, tennis, wrestling and gymnastics back pain was present in 50–85% of the athletes. Radiographic changes in the spine that are clearly linked with sports training were prevalent among 36–55% of young people.

Traumatic injuries to the back are common in sports at high speeds, e.g. motor sports, alpine skiing, ski jumping, etc. and in contact sports like hockey, football and rugby (Figs 16.3, 16.4).

The combination of high speed and height can lead to serious back injuries in disciplines such as horse riding and bicycle. Back injuries may be quite severe, for example fractures that cause spinal cord or nerve damage.

Functional anatomy and biomechanics

The spine is composed of 7 cervical (neck) vertebrae, 12 thoracic (chest) vertebrae and 5 lumbar (lower back) vertebrae, plus 5 sacral vertebrae (bone at the base of the spine) fused to form the sacrum and 4–5 separate or fused coccygeal vertebrae forming the tailbone (coccyx) (Fig. 16.1).

Each vertebra consists of a body from which a dorsal arch of bone arises. On each arch there are articular processes that allow limited mobility between adjacent vertebrae. Between the vertebral bodies are flexible plates of fibrocartilage, the discs, which facilitate movements of the spine and act as shock absorbers. Intervertebral discs have no blood or lymph supply and only a limited nerve supply (Fig. 16.5).

The spine has a supporting role, a protective function and a mobility function. The cervical spine is very

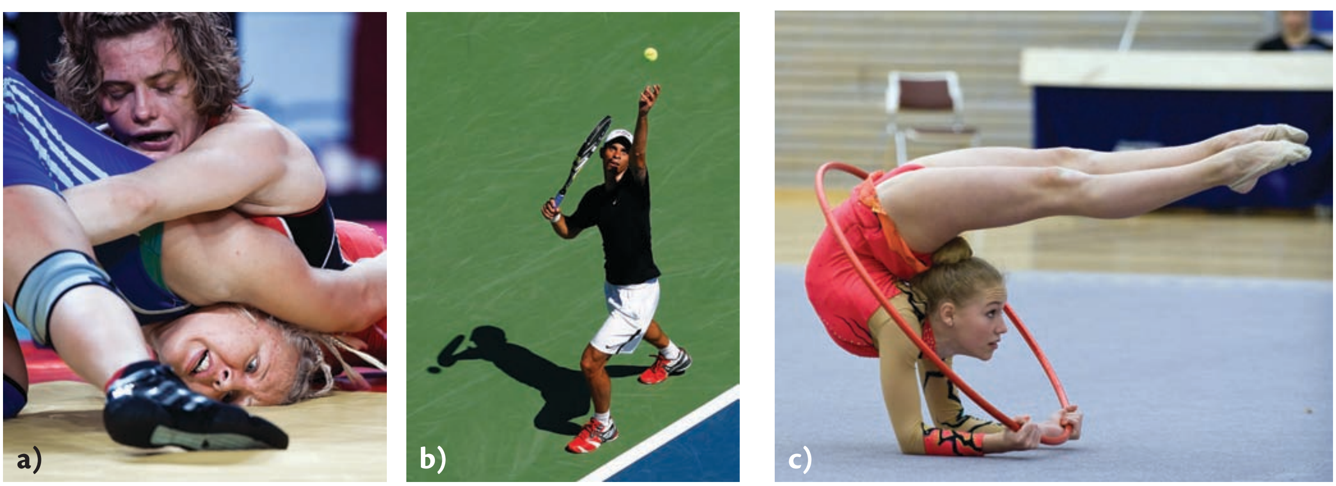


Figure 16.2 a–c) Extreme loads are placed on the spine in certain sports and these participants are more vulnerable than others to back problems, e.g. wrestling, tennis and gymnastics. (With permission, by Bildbyrån, Sweden.)

Figure 16.3 High velocity and hard body contact/tackling contribute to the risk of traumatic injuries to the spine such as in **a)** downhill skiing or **b)** rugby. (With permission, by Bildbyrån, Sweden.)

Figure 16.4 a, b) High speed and falling from a height can increase the risk of back injuries, such as in horseback riding and mountain biking. (With permission, by Bildbyrån, Sweden.)

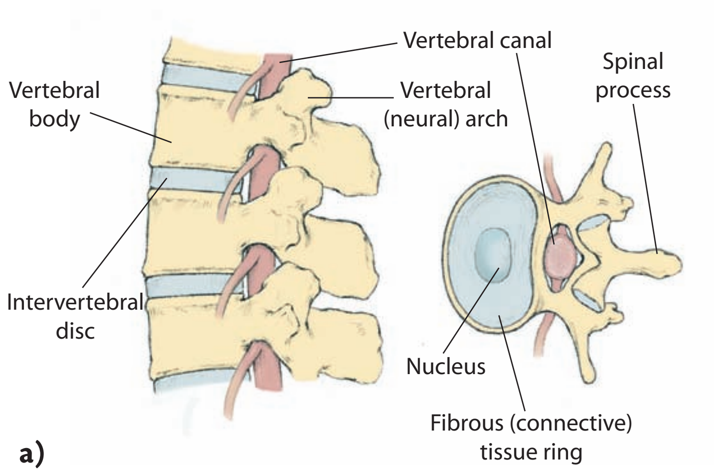


Figure 16.5 a, b) Normal anatomy of the spine.

mobile and the lumbar spine somewhat less mobile. In the lumbar spine, the greatest movement and the largest disc has been found between the fourth and fifth lumbar vertebra. The thoracic spine is more restricted in movement due to fact that the ribs are attached to these vertebrae. The areas of the spine that have the greatest mobility generally give the most trouble.

The spinal column has supportive, protective and locomotive functions. The neck region is very mobile and the lower back region is fairly mobile, with most movement between the fifth lumbar vertebra and the first sacral vertebra. The chest region, on the other hand, is less mobile because the ribs are attached to their corresponding vertebrae. The regions of the spine with the greatest mobility generally give rise to most problems.

The spine is held together with an anterior and a posterior longitudinal ligament system as well as smaller ligaments surrounding the vertebral facet joints and spinous processes. These ligaments that reinforce the joint capsule and the individual geometry of the facet joints, together with the discs, represent the passive stability of the spine. The active stability is entirely dependent on the back and abdominal muscles. These muscles can be divided into the anterior flexor muscle group consisting of the abdominal muscles and psoas muscles, and the posterior extension muscle group, consisting of the deep and superficial muscles (such as the trapezius, the latissimus dorsi, and erector spinae).

The spine is exposed to a heavy load when the body bends forwards or twists. The activity of the back muscles increases markedly when the athlete bends forward to a 30° angle. The vertebral discs are also subjected to more pressure when sitting than standing, since the muscles must work more in sitting than standing. In general, a good rule is to avoid lifting, especially heavy things, when the back is bent forward, turned sideways or the load is applied asymmetrically. When lifting a load it should be as close to the body as possible. Heavy objects should be lifted with the support of the leg muscles.

Examination with back pain present

Diagnosis of back pain requires an expert evaluation of pain, clinical findings, determination of back function, constitutional factors, X-ray findings, etc. The localization, intensity, duration and quality of pain should be assessed, as well as the factors that precipitate or relieve it. The back function analysis should include range of motion (ROM), movement patterns, posture, muscle tone, muscle control, body composition, etc (Fig. 16.6). The overall physique, as well as changes in lumbar form, for example an S-shaped curvature (scoliosis), may be of importance.

A number of skeletal changes, such as slipping of one vertebra on another, stress fractures, bone spurs (osteophytes) along the edges of the vertebral bodies and

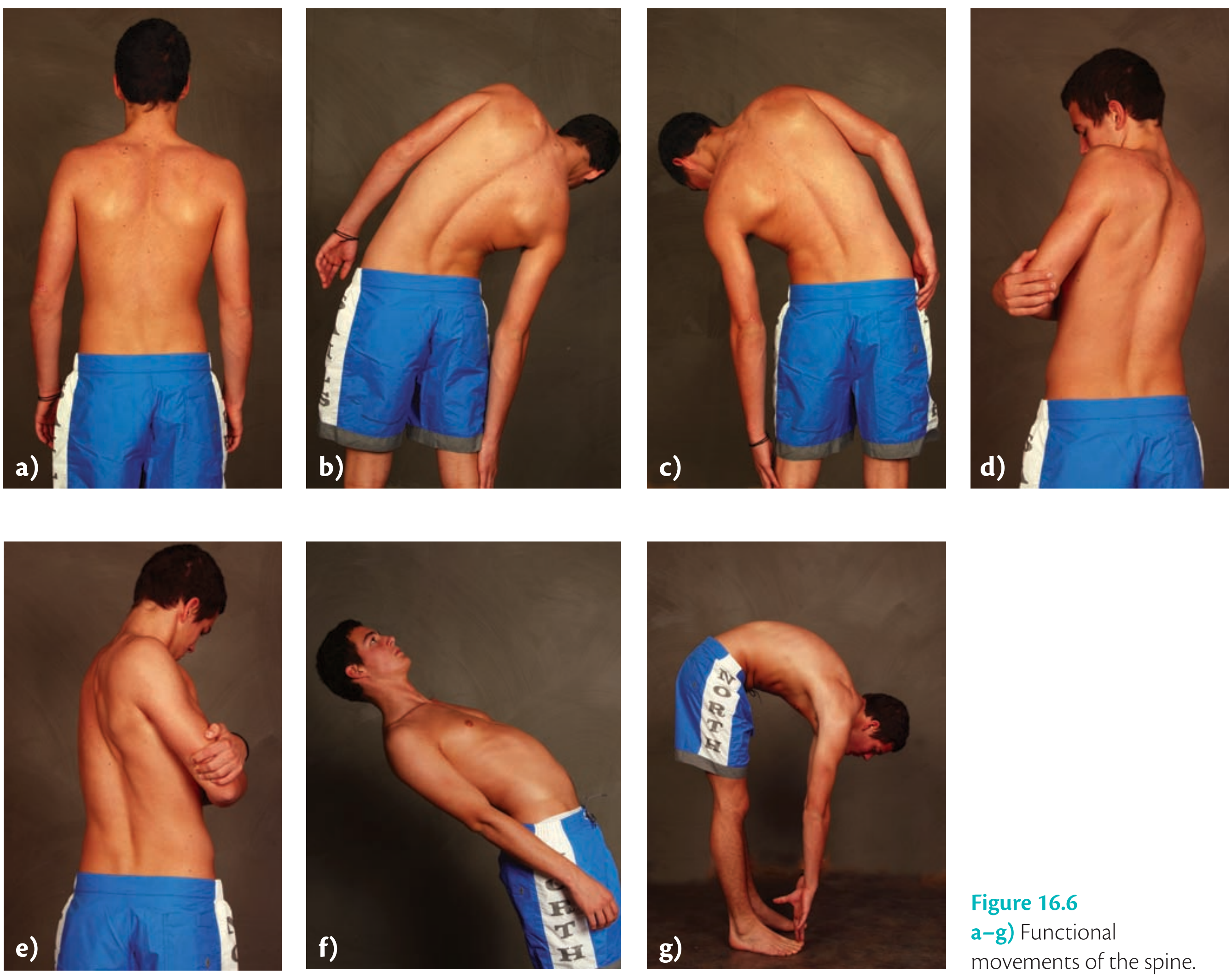


Figure 16.6
a–g) Functional movements of the spine.

degenerative joint changes, can be identified by ordinary X-ray examination or computed tomography (CT) scan, whereas a herniated disc and other soft tissues must be examined with magnetic resonance imaging (MRI). In some cases X-ray examinations can be done in challenging positions that induce pain, such as maximal forward or backward bending, etc.; such an investigation can sometimes reveal that the cause of the pain is due to instability. MRI provides information on both soft tissue and bone, and the results might reveal the cause of the pain as being a herniated disc, osteophytes with pressure to nerve tissue, instability or narrowing of the spinal canal (stenosis), etc.

The injured person's social and psychological situation is valuable information when a history of back problems is given, and the evaluation should encompass family relationships, education, employment, sport and physical activity.

Neck/cervical spine

The cervical spine can rotate with 50% of the rotation taking place between the top two vertebrae, while bending forwards (flexion) and backwards (extension) occurs predominately between the fourth, fifth and sixth vertebrae. The injuries that can occur to the cervical spine include fractures and dislocations that can be a combination of fractures, disc and ligament injuries. Disc degeneration due to age can cause bone spurs (osteophytes) on the edges of the vertebrae bodies and the surface of the facet joints, which can lead to pressure on the nerves with pain as a result. Injuries and diseases of the cervical spine in the neck can cause local pain and pain that radiates to the back of the head, shoulders, arms, hands, and sometimes also to the lower body

Traumatic injuries to the cervical spine

Blunt force to the head and cervical region can fracture the cervical vertebral column and also cause dislocations with simultaneous injuries to the joint capsules, ligaments and discs. The injuries can be either stable or unstable. The most common injury mechanisms are bending backwards (extension) or forwards (flexion), rotating too violently, or hitting the head so that the impact is transmitted to the cervical area (axial compression), for example spearing tackling in American football (Fig. 16.7).

Trauma forcing the neck to bend forward (flexion) can cause a compression fracture to the front (anterior), as well as ligament and disc injuries in the back (posterior) of a vertebral body. Sometimes fractures of the articular processes and damage to the joint capsule may occur; ligament injuries may also be present without any visible skeletal damage to the vertebrae. It is essential to determine if the injury is stable or unstable, which is done with the help of X-ray examination, sometimes done with provocation and MRI (Fig. 16.8).

Trauma forcing the neck to bend back (extension) may cause a corresponding compression fracture to the rear (posterior) as well as ligament and disc injuries in the front (anterior) of a vertebral body.

Trauma forcing the neck to twist (rotation) can occur isolated or in combination with flexion or extension. Unilateral damage to joint processes and ligaments can occur with a dislocation as a result.

Injuries to the cervical spine are common in traffic accidents and accidents at the workplace. In sports, injuries to the cervical area occur in disciplines containing high speeds and high vertical falls, e.g. motor sports, downhill skiing, ski jumping, horseback riding, gymnastics and contact sports.

A fracture and/or ligament injury of the cervical spine resulting from a violent collision with an opponent or with surrounding objects, e.g. a goal post or ice rink boards, can be severe. Within the cervical vertebral column runs the spinal cord, together with its nerve roots through the spinal canal, which can be subjected to pressure and damage by bone and ligament injuries.

Figure 16.7 Certain sports are a risk for serious injuries to the vertebral column.

Figure 16.8 Support for the cervical spine. An adequate supportive neck collar should be used for suspected neck injury.

Whiplash

A whiplash injury occurs when the cervical spine is quickly forcefully extended followed by a sharp forward bending (Fig. 16.9). It is characterized by a collection of symptoms after any kind of injury to the neck, usually caused by sudden stretching and/or bending, associated with contact sports.

Another important cause of cervical spine trauma is the 'whiplash' injury, which occurs when the neck is rapidly extended and then flexed, typically in traffic accidents when one vehicle is run into by another from behind. Ligament, bone (including facet joints), cervical muscle and nerve root injuries may occur, but whiplash usually affects the soft tissue. The damage can result in chronic pain.

Anyone who suffers an injury to the cervical spine or a whiplash injury should be carefully examined clinically and in case of suspicion or evidence of distinct damage, with X-ray and MRI.

Symptoms

- Pain in the cervical spine, especially during moving. This neck pain may continue for several days usually accompanied with stiffness, headache, dizziness and nerve root pain.
- Radiating pain with numbness in the arms.
- Reduced skin sensibility below the level of the injury.
- Weakness or paralysis below the level of the injury.
- Sometimes difficulties with concentration, memory loss, later onset nervousness, insomnia, fatigue and depression, etc. In general there is no correlation

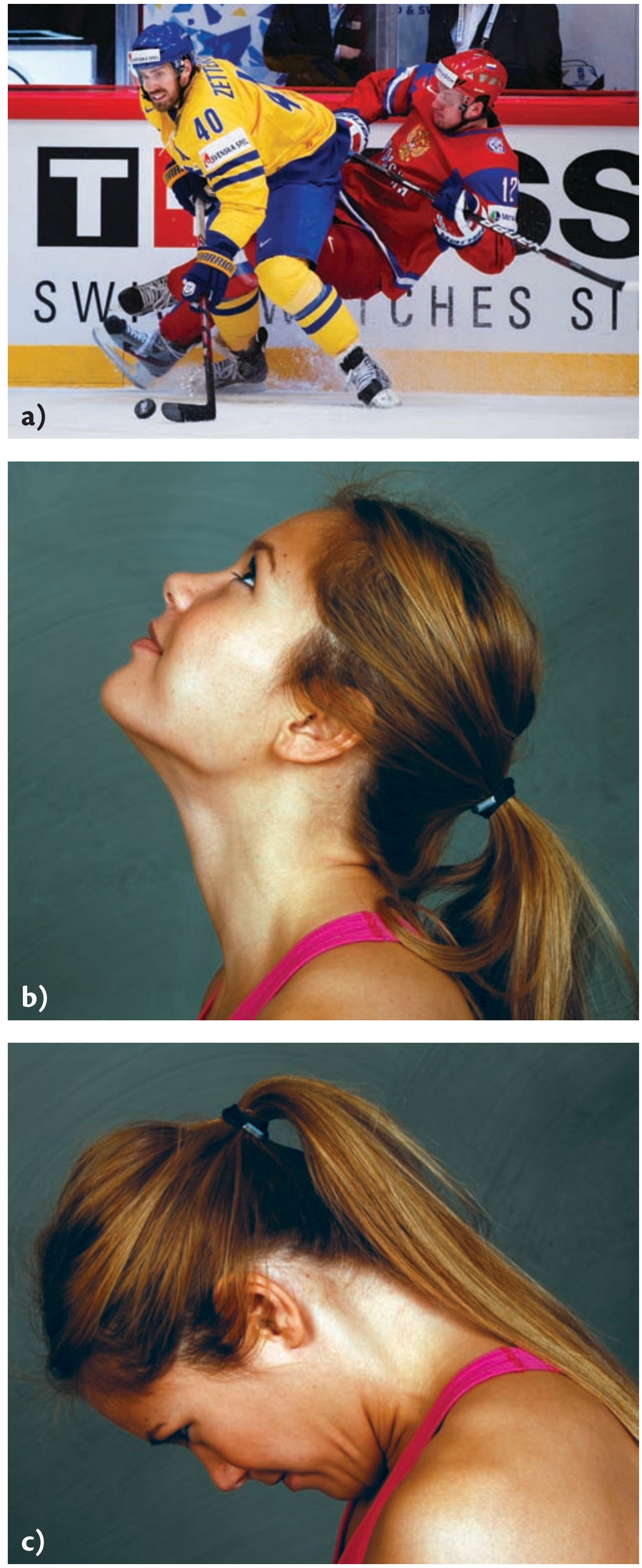


Figure 16.9 Whiplash injury. The injury is most common in car accidents, especially collisions from behind. **a)** Ice hockey player being tackled (with permission, by Bildbyrån, Sweden); **b, c)** the head is thrown backward initially and then forward. In rare cases the opposite occurs.

between perceived discomfort and pathological changes in the soft tissues.

The first responder (coach, athletic trainer, etc.) should:

- Prepare the injured athlete for the transportation to a hospital for examination.
- As soon as medical expertise is available allow them to take over.

The injured athlete needs to be placed carefully on a stretcher so that the head and body are lifted simultaneously. If a neck collar is available it should be carefully placed as support around the cervical spine before the lift so that the position of the cervical vertebrae is not disturbed. If the collar is not available rolled up pieces of clothes, towels, pillows or similar support material are placed on either side of the injured cervical spine to give support during transport to the hospital, to prevent further injury and future invalidity.

The physician may:

- Carry out a careful examination of the nervous system, and arrange for an X-ray (and if needed an MRI or CT scan) of the cervical vertebral column in order to assess its stability and the extent of damage.
- Depending on the grade of injury, treatment may consist of fixation by way of a cervical collar, halo-vest or surgery.
- Treatment may include medication for pain.
- Early physiotherapy treatment plays an important role.

Other injuries to the neck can occur in rare cases such as injuries to the blood vessels, caused in ice hockey or other skating sports where the blade of a skate hits the front part of the neck so forcefully that the blood vessel is cut, with the risk of bleeding to death. The bleeding must be stopped by compression on the area until the medical staff can intervene. Neck protection in the form of a specially developed tear resistant material can prevent these life-threatening accidents (see Fig. 16.8).

Pain radiating from the neck (cervical brachialgia, cervical rhizopathy)

Pain in and radiating outward by way of the peripheral nervous system from the cervical region can be caused by disc degeneration, herniation, or osteophyte formation on the facet joints and /or edges of the vertebrae bodies. These changes affect the nerve roots originating from the central nervous system in the spinal cord to the peripheral nervous system, which can cause radiating pain. Even a temporary strain or entrapment of a nerve can produce similar symptoms. It is customary to distinguish between different types of pain, those concentrated in the neck itself (cervicalgia), those that are diffuse in and around the back of the head and the nape of the neck (cervical brachialgia) and the pain that is well defined (cervical rhizopathy) radiating to the arms (Fig. 16.10).

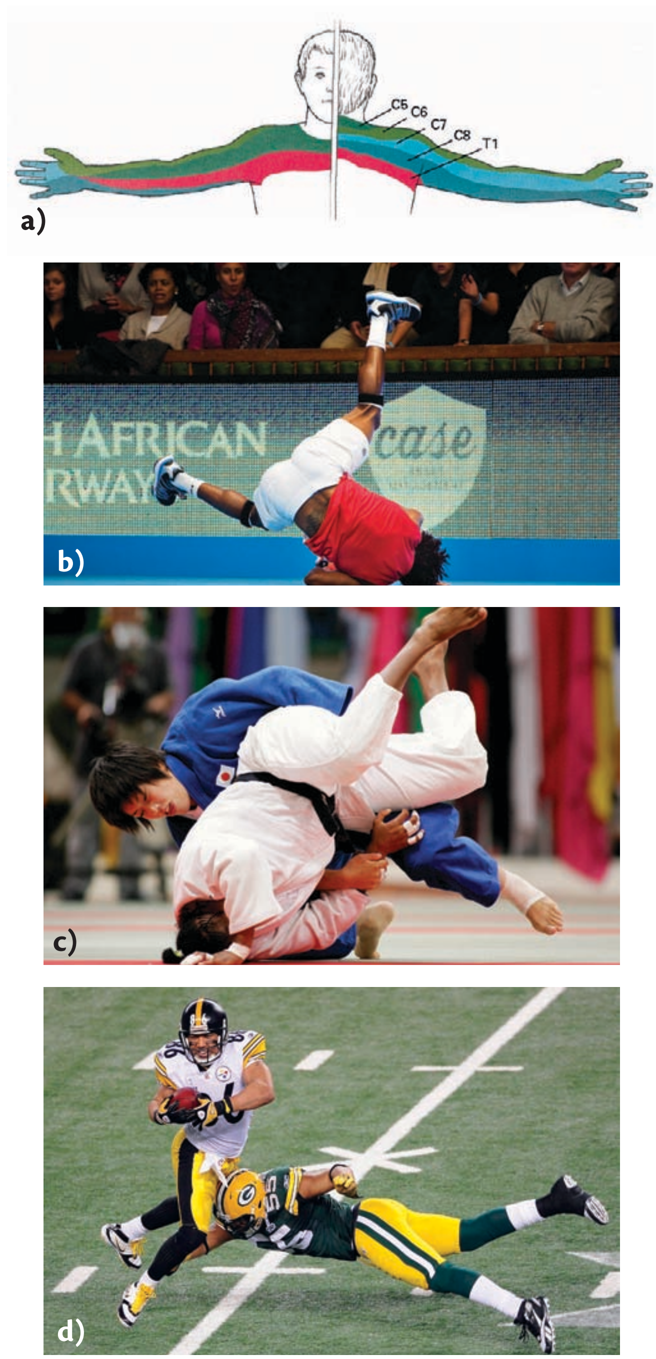


Figure 16.10 a) Illustration of the cervical spine nerve roots and the area of radiating pain that follows when the nerve roots are affected; **b–c)** sports with low to some risk of cervical spine impact; **d)** sport with increased risk of cervical spine impact (with permission, by Bildbyrån, Sweden).

A rhizopathy is a pathologic condition of a nerve root and its specific innervations, which can produce waves of pain along its path.

Symptoms and diagnosis

Pain radiates from the nape of the neck into the shoulder, arm, and/or fingers. The pain is usually deep and widespread (brachialgia), but it can have clearly defined limits with intense, sharp pain following the distribution of the affected nerves (rhizopathy). The pain is felt more acutely during neck movements than during shoulder movements.

The following applies for cervical brachialgia:

- Pain radiating up the neck and into the back of the head can cause headaches, insomnia, and sometimes dizziness.
- Numbness and weakness are felt in the arm and fingers. There may be areas of complete sensory loss (anesthesia).

The common forms of cervical rhizopathy are the following four syndromes:

- **C5 syndrome**, which affects the nerve root coming out between the vertebrae C4–C5. This gives pain radiating from the neck to the top of the inside of the upper arm/forearm to just above the wrist with numbness in the area. The deltoid muscle is sometimes, like the biceps, weakened. The biceps reflex is sometimes impaired.
- **C6 syndrome**, which affects the nerve root coming out between the vertebrae C5–C6. This gives pain radiating from the neck to the top of the arm to the thumb with sensory loss in the area. The biceps muscle and upward bending (dorsiflexion) of the wrist can be weakened. The biceps reflex is affected.
- **C7 syndrome**, which affects the nerve root coming out between the vertebrae C6–C7. This gives pain radiating from the neck over the posterior central arm to the dorsal side of the index, middle and ½ ring finger, with sensory loss in the area (Fig. 16.10). Weakness in the triceps muscle and palmarflexion of the wrist can occur. The triceps reflex is affected.
- **C8 syndrome**, which affects the nerve root that comes out between the vertebrae C7–T1. This gives pain radiating from the neck to the posterior medial underside of the arm to the dorsal side of the fifth and ½ ring finger, with sensory loss in the area. Weakness occurs in the interossei (muscles that have the ability to splay fingers). No reflex is affected (Fig. 16.10).
- The diagnosis of the various syndromes is on the prevalence of pain, muscle weakness and possible reflex effects.
- X-ray examination should be performed, especially if the pain is induced by movement. The examination should be carried out with provocation of pain to detect any abnormal movement.
- MRI can show the lesions to soft tissues. The nerves in the cervical spine can be affected by osteophytes on vertebral bodies, facet joints or herniated discs between the vertebrae; even skeletal changes and disc degeneration, etc. can be found.

Treatment

- Rest.
- Cervical collar and heat retainers.
- Analgesics and anti-inflammatory medication.
- Physical therapy, with or without traction.
- Surgery may be necessary with prolonged rhizopathy.

Pain in the neck (cervicalgia), torticollis (wry neck)

Pain located in the neck that does not radiate into the arms is called cervicalgia (see lumbago, p. 341). Torticollis (wry neck) is a painful condition that can occur in young athletes in connection with violent twisting movements of the cervical spine, such as when diving, wrestling and heading the ball in soccer, causing the head to twist or turn to one side (Fig.16.11).

The probable cause is affected nerve roots from the cervical spinal cord, by way of a quick compression and stretch, causing a reflex spasm in neck muscles.

Symptoms and diagnosis

- A 'vice-like grip' pain felt in the neck and in the angle between the nape of the neck and the shoulder, never extending below the shoulder joint.
- The pain is triggered by neck movements.
- The musculature is tender and tense.
- The neck can be in an unnatural twisted or side position.
- Mobility of the back of the neck is impaired (torticollis) (Figs 16.12, 16.13).

Treatment

- Localized heat treatment.
- Analgesic and anti-inflammatory medication or muscle relaxants.
- Rest to avoid painful movements.
- Traction.
- Cervical collar or heat retainers (Fig. 16.14).
- The condition often improves significantly within 1 week. If this is not the case, a physician should be consulted.

a)

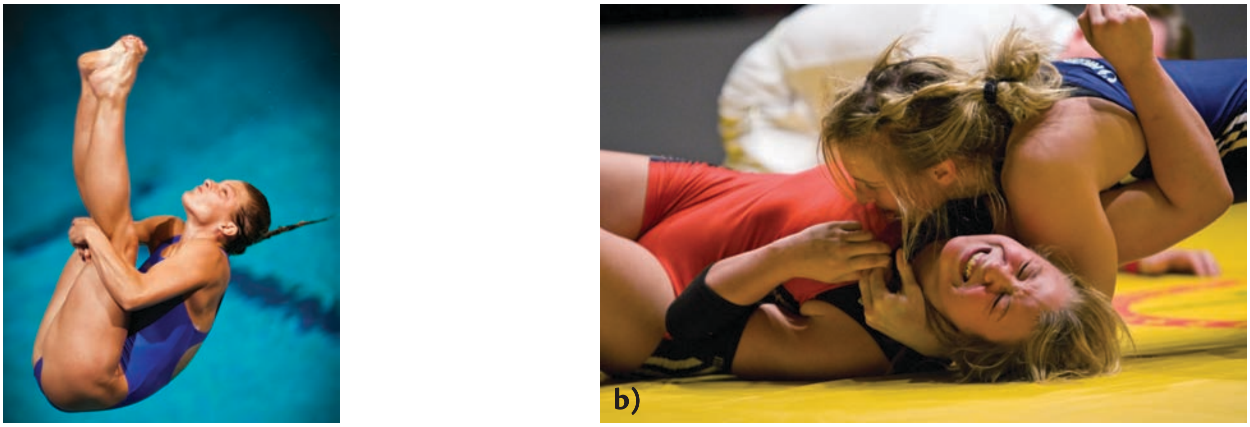


Figure 16.11 Pain in the cervical spine can occur in sports where the neck is very involved, such as **a)** diving and **b)** wrestling. This problem can become chronic in ageing athletes. (With permission, by Bildbyrån, Sweden.)

Figure 16.12 Neck mobility. **a, b)** Examples of active neck mobility in rotation; **c, d)** flexion and extension against resistance.

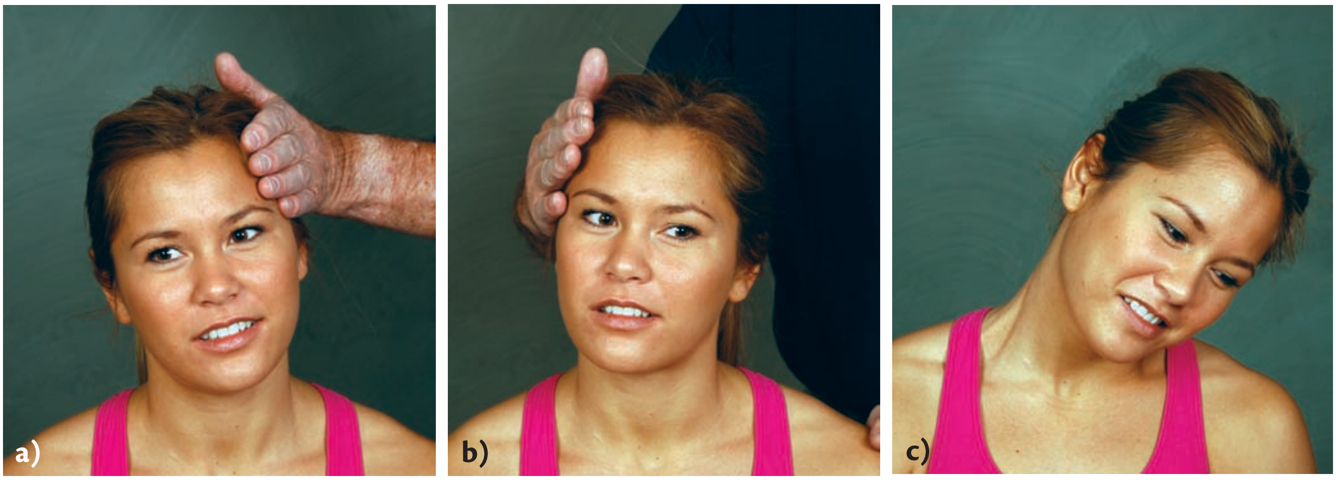


Figure 16.13 a–c) Active lateral flexion with and without resistance.

Figure 16.14 Support measures for the cervical spine. Support collar that relieves and provides warmth to the neck (courtesy of OttoBock Scandinavia/Rehband); kinesio taping techniques for the neck are often perceived as effective by the athlete (one technique is shown in Fig. 5.26B).

Figure 16.15 Skillful treatment often produces good effects. **a)** Manipulation of the cervical spine is often very effective; **b)** a player can often quickly return to their sport after skillful treatment.

Rehabilitation of the neck

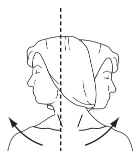
The neck should always be carefully examined by a physician or physical therapist to make a diagnosis before rehabilitation due to the complex anatomy of the neck (Fig. 16.15). Pain distribution and any subsequent neurological symptoms, such as dizziness, numbness, nausea and /or headache, must be examined further.

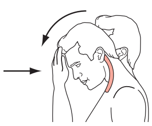
Range of motion training

It is advisable to check with a physical therapist before a training program begins. Position the head so that the ears are directly over the shoulders before the exercises are performed (Start position). All movements should be slow and cautious, without sudden or rocking movements. Do 3–5 repetitions.

Chin tuck

- Pull the chin toward the chest by activating the muscles in the front of the neck. Hold for 5 seconds.





Side bending

- Rotation: turn the head slowly and look over the shoulder; hold for 10–15 seconds. Return to the starting position and repeat the exercise on the other side.
- Flexion: slowly pull the chin towards the chest and then bend the head forward. An elongation of the neck should be felt. Hold for 10–15 seconds. Repeat.

Strength training of neck muscles

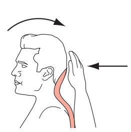
- The athlete's hand is used to provide resistance in performing these exercises. The resistance should be soft and steady without any movement of the head (isometric). Do 5–10 repetitions. Be careful when stretching the neck.

Side bending against resistance

- Sitting down, place the right hand palm just above the right ear. Attempt to tilt the head to the right against the resistance of the hand. Hold for 5–10 seconds. Repeat to the left.

Flexion against resistance

- Sitting down, place the palm of a hand in the middle of the forehead. Attempt to tilt the head forward against the resistance of the hand. Hold for 5–10 seconds.



Extension against resistance

- Sitting down, place the palm of a hand on the back of the head. Attempt to tilt the head back against the resistance of the hand. Hold for 5–10 seconds.

Thoracic and lumbar spine

Fractures of thoracic and lumbar vertebrae

Fractures of vertebrae in the thoracic and lumbar regions are uncommon in sports, but can occur in horseback riding, alpine disciplines, ski jumping, ice-hockey and football/soccer, and in motor sports among others (Fig. 16.16).

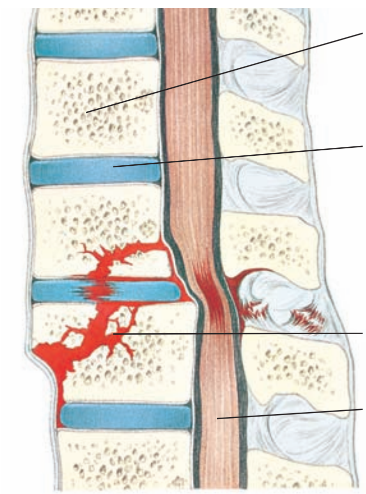


Figure 16.16 Fractures of the vertebrae with displacement and pressure on the spinal cord.

Symptoms and diagnosis

- Severe pain is felt at the site of the fracture.
- Pain is triggered by any back movement.
- If pain radiates into the legs it must be assumed that the spinal cord or its nerve roots have been affected.
- Loss of sensation and paralysis are signs of a serious injury.

Treatment

- The injured person must be taken to hospital for a neurological examination and an X-ray (and if needed a CT or MRI scan) to assess the stability of the vertebral column and other damage.
- When thoracic and lumbar vertebrae have been damaged during sporting activity, the compression damage to the vertebral body is usually only moderate and heals after a period of rest.
- In extreme cases, severe compression of the vertebrae may occur, and injury to the spinal cord and nerve roots may occur. These injuries are treated with bed rest, possibly a stabilizing brace or other type of immobilization, for 2–3 months. If the injury is extensive with instability and neurological damage surgery is necessary.

Fractures of the transverse processes of the lumbar vertebrae

Fractures of the transverse processes of the vertebrae can result from direct violent impact to the side of the vertebral column, or from muscle tear in the muscles attached to the vertebrae, especially in the lumbar region.

Symptoms and diagnosis

- Tenderness is felt over the transverse processes at the side of the vertebral column.
- Pain occurs during movement, especially when the back is bent sideways.
- An X-ray examination confirms the diagnosis.

Treatment

- The athlete should rest until the pain has resolved. The injury has a good prognosis and heals in 6–8 weeks.

Muscle ruptures in the back

Ruptures of the back muscles occur in weightlifters; javelin and discus throwers; pole vaulters; football, handball, basketball and volleyball players; wrestlers and boxers, among others (Fig. 16.17A–C). The injury usually consists of minor tears (grade 1 of 3) and is most often located in the long back extensors (erector spinae) and the large, flat back muscles (latissimus dorsi) (Fig. 16.17D).

Symptoms

- Stabbing pain is felt on flexion, extension and rotation.
- Local tenderness is found over the area of rupture.

The athlete should:

- Begin controlled muscle training after a few days.
- Start active rehabilitation as tolerated with pain as a guide until complete pain-free strength movement is achieved, usually after 3–8 weeks.
- Apply heat locally and use a heat retainer, though not until 2–3 days after the injury has occurred.

The physician may:

- Give analgesic and (perhaps) anti-inflammatory medication.

If training and competition are resumed before the injury has healed completely there is a risk of renewed bleeding and delayed healing.

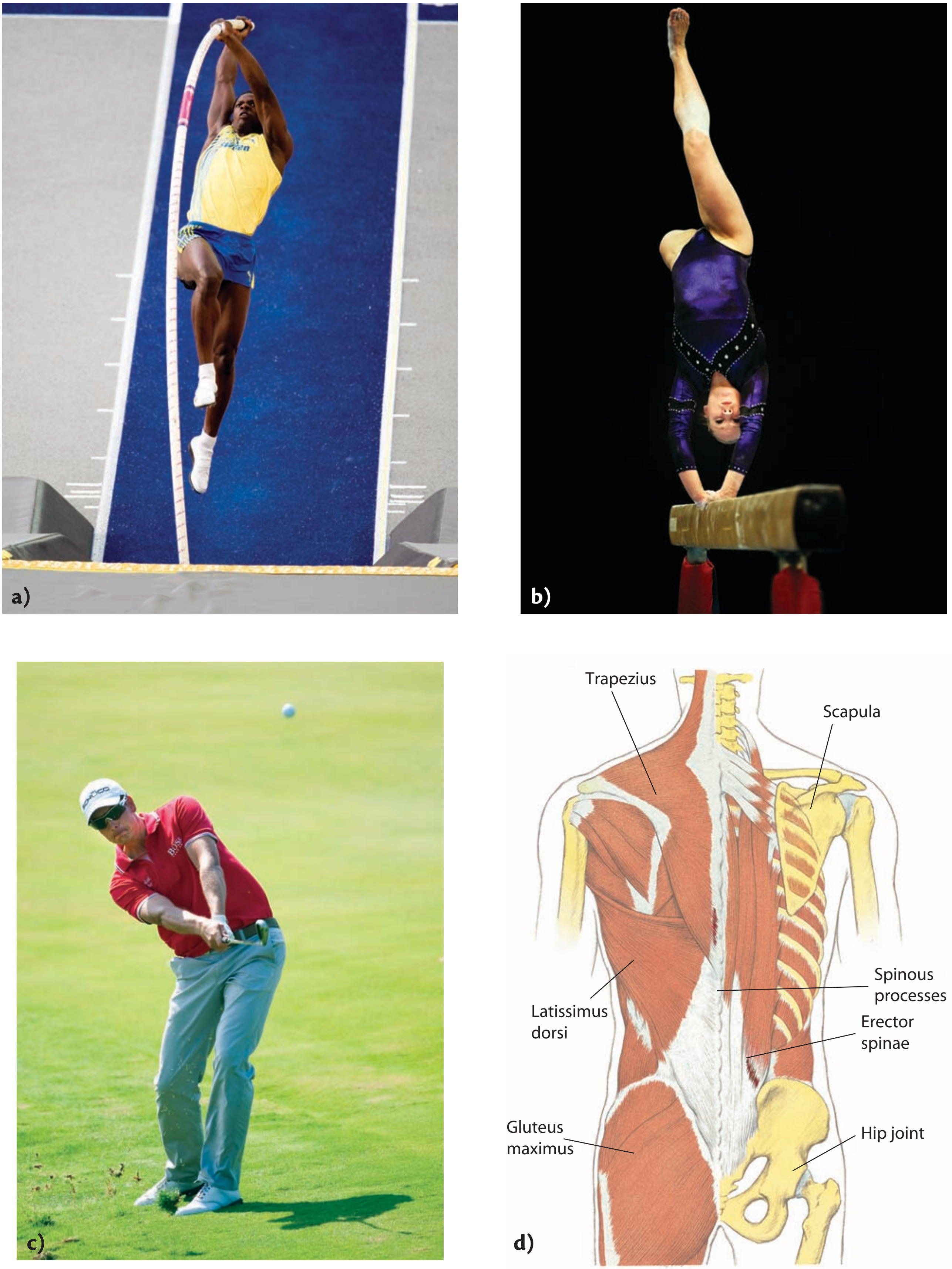
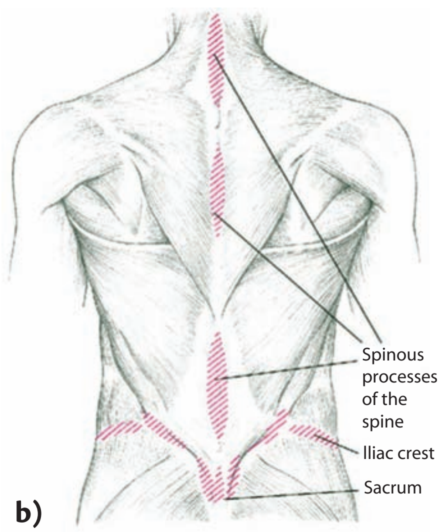


Figure 16.17 a–d) Pain conditions and minor tears in the back muscles are common in sports. (With permission, by Bildbyrån, Sweden.)

Inflammation of muscle attachments in the back

The muscle attachments around the spinous processes of the thoracic and lumbar spine can become inflamed as a result of overuse (Fig. 16.18). Such injuries are most common among cross-country skiers, javelin, discus and hammer throwers, weightlifters and racquet sports participants (Fig. 16.18).



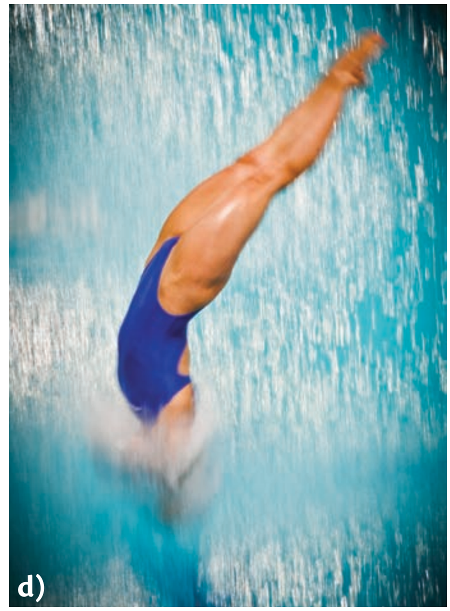


Figure 16.18 The spine is often subjected to overuse in sports. **a)** Monotone weight training can cause overuse injuries and inflammation of the back muscles; the athlete is using a heat retainer; **b)** the red marked zones are possible areas for overload injuries in the spine; **c-e)** throwing and racquet sports with repeated explosive and /or rotational moments such as tennis, diving plus sports with a prolonged exertion like canoeing, can produce overload injuries in the back muscles. (With permission, by Bildbyrån, Sweden.)

Symptoms

- Pain during exertion.
- Aching pain with onset after exertion.
- Tenderness on palpation over the spinous processes and other bony insertions.
- Pain directly on the attachment of the affected muscle, being triggered by its contraction (Fig. 16.19).

Figure 16.19 a, b) The transition between the lumbar and sacral spine is a common location for back pain.

The athlete should:

- Commence active rest (i.e. can be active in activities that do not cause pain but refrain from painful exertion) until pain-free on all exertion.
- Apply heat locally and use a heat retainer.
- Exercise the back with an exercise (e.g. Bobath) ball before returning to sport activity (Fig. 16.20).

The physician may:

- Prescribe anti-inflammatory medication.
- Administer local steroid injections followed by 2 weeks' rest (especially from sports that include explosive and heavy weightlifting activities, etc.).
- Refer to physical therapist.

The inflammation often heals within a few weeks.

Low back pain (lumbago)

Lumbago is a pain in the lumbar region. Lumbago can be acute or chronic and the cause of the problem is still not completely understood, but the pain is often associated with cramps in the back muscles. This condition may in turn be triggered by temporary pressure or a tension stretch to one of the roots of the sciatic nerve. Acute lumbago is very common and mostly affects individuals aged 30–40 years. 80% of all people have at some time suffered lumbago.

Symptoms and diagnosis

- The pain often occurs in connection with heavy lifting or twisting motion, but occasionally can also occur without previous exertion.
- The pain is usually located in the lower back and does not radiate down into the legs, but sometimes it radiates out to the sides and down towards the buttocks (Fig. 16.21).
- Pain is usually experienced when in movement.
- The low back can be a common site for prominent deformity, stiffness and soreness. The doctor during the examination may notice tenderness in the low back when placing finger pressure over the tense muscles.
- Examination by placing finger pressure over the constricted muscles elicits pain in the low back (palpation tenderness).
- The posture may appear asymmetrical, with the back bent to one side (scoliosis) as a result of muscle spasm inhibiting the movements of the back that trigger pain.
- Diagnosis is made on the basis of a typical case history, tenderness and stiffness in the back and postural asymmetry (Fig. 16.22).

The athlete should:

- Adopt the position that causes the least possible pain.
- Apply heat by means of hot baths and locally with, for example, a heat retainer.
- Avoid forward bending and twisting movements and heavy or repetitive lifting.

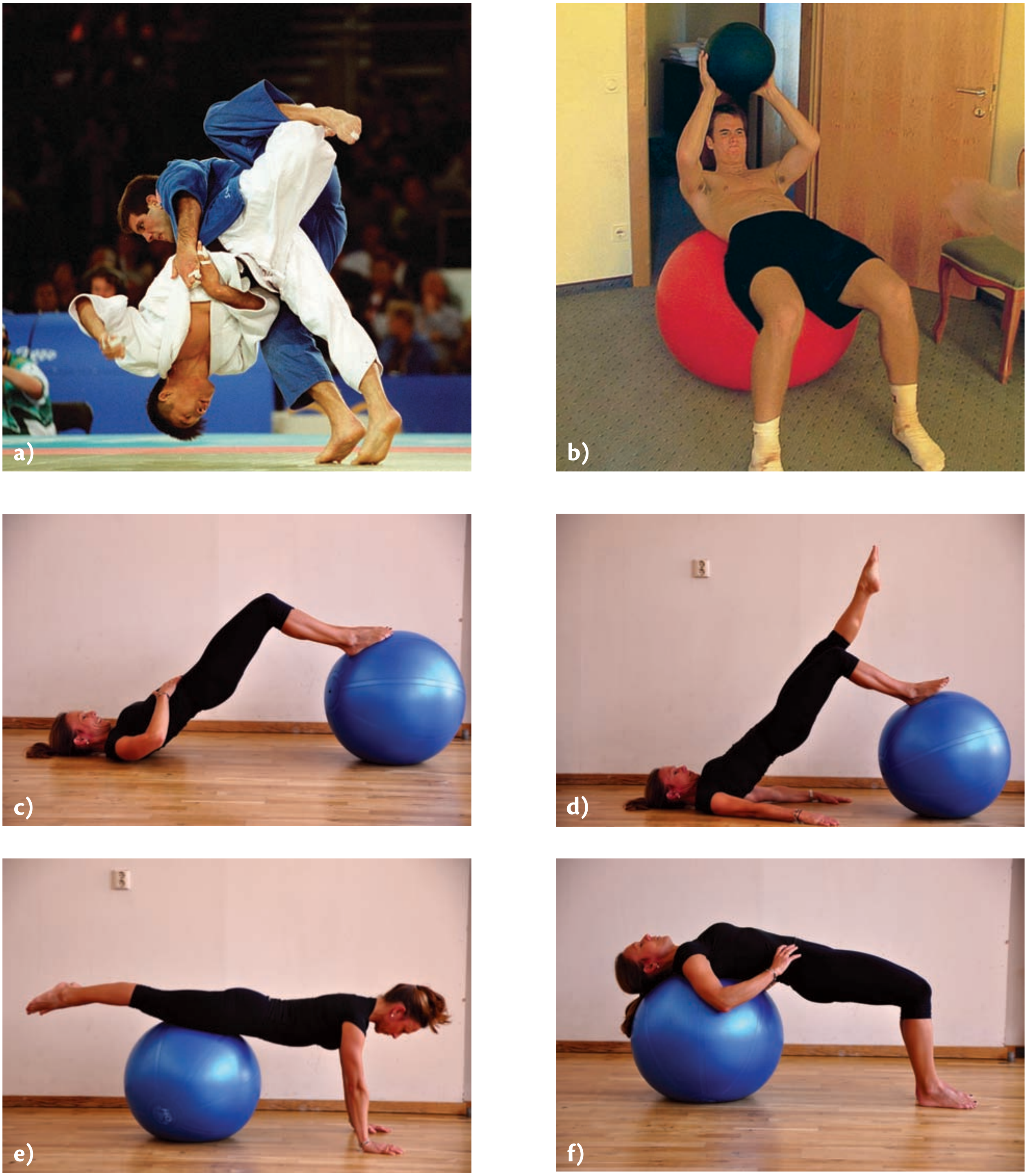


Figure 16.20 Overuse problems of the spine. a) Many sports with throws and lifting can cause back pain (with permission, by Bildbyrån, Sweden); b–f) training with an exercise (e.g. Bobath) ball is very effective for all sorts of problems in the back, including for top athletes (photo, Heijne/Frohm).

The physician may:

- Give ergonomic advice such as lift techniques.
- Prescribe analgesic drugs in order to break the pain cycle that arises from the reflex muscle spasm impairing circulation and causing muscle pain, which in turn precipitates more reflex spasm. Muscle relaxants can sometimes be of value.
- Recommend to rest several times daily in a psoas position (Fig. 16.23) and give other practical advice, such as about ensuring good support when in the

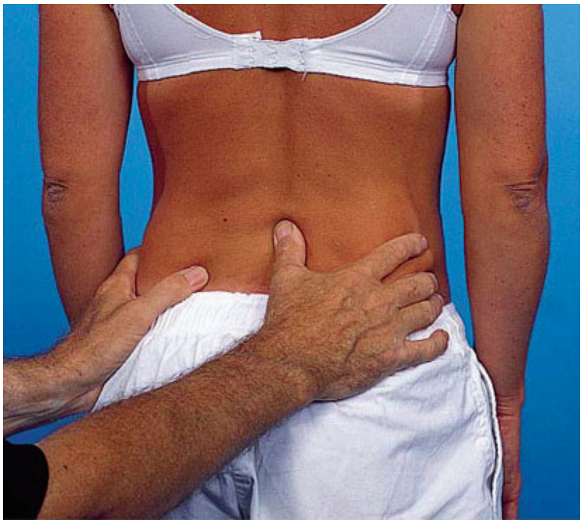


Figure 16.21 Common localization of pain and palpation tenderness with low back pain (lumbago).

sitting position and avoiding positions and movements that cause pain; when rising from lying or sitting the arm's should be used instead of the back muscles.

- Kinesio taping of lower back can provide some pain relief (see Fig. 5.27).

Referal to a physical therapist when symptoms are recurrent (2–4 visits may speed return to work and sport in acute cases).

- Prescribe stretching treatment or manual mobilization for long-term problems.
- Prescribe a correcting corset or weight belt, which gives temporary support and can be worn when the patient carries out activities that usually trigger the problem. A correction corset can be of value in the acute stage of lumbago, but should be used for the shortest possible time to prevent muscle degeneration (hypotrophy) and weakness.
- Arrange X-ray examination of the spine, which, usually however, does not show any changes that explain the problem. There are frequent radiographic findings in the people over 50 years, but these usually have no correlation to the symptoms.
- Arrange a CT or MRI scan of the lumbar spine if pain has been present for more than 2 months or if symptoms are recurrent, and especially when signs of nerve root pain down one or both legs. An elevated erythrocyte sedimentation rate (ESR) may be a sign of infection, tumor or inflammatory disease.
- Prescribe preventive and rehabilitative training (p. 353–5) as early as possible. Jogging has been shown to be beneficial when pain allows.

Figure 16.22 Lifting technique. a) Improper lifting technique with straight legs; b, c) proper lifting techniques using leg strength simultaneously.

Figure 16.23 Psoas positional release technique provides some pain relief. A small cushion in the lumbar region can further relax the muscles, thereby alleviating pain.

Acute low back pain has often a good prognosis, and symptoms resolve spontaneously, usually within the few days of onset, but can sometimes persist for 1 or more weeks. Some individuals can have long-term problems.

Tip

People with back problems should lead a physically active life. However, the activities should be adapted to their current problems until solved.

Sciatica, herniated disc ('slipped disc')

Pain that radiates from the lower back down one or other leg is known as sciatica. The most common causes of problems are osteophyte formation on the vertebral body or facet joints and disc herniation. Less common causes include tumors, defects in the vertebral arch (spondylosis), a forward displacement of a vertebra, especially the fifth lumbar vertebra, commonly occurring after a break or fracture (spondylolisthesis), and infections that can affect the sciatic nerve throughout its course. 95% of all herniated discs occur in the lumbar region, but they can also be localized in the cervical thoracic spine.

When the pain can be felt in the lower back and radiating out down to the leg, the condition is called the lumbago sciatica syndrome. If the pain is only felt in the leg it is called sciatica. The pain usually worsens with exertion, coughing, sneezing or pelvic floor contraction.

The intervertebral discs between adjacent vertebrae consist of an outer fibrous ring (annulus fibrosus), which surrounds a core of a pulpy, semifluid substance (nucleus pulposus). Slipped discs often show signs of degenerative changes, even in relatively young individuals. Cracks may form in the connective tissue ring of a disc, allowing the pulpy substance to seep through and cause pressure on the adjacent nerve roots (Fig. 16.24).

The combination of lumbago sciatica causes pain that is felt not only in the lumbar region, but also radiates downward into one or both legs and is aggravated by exertion and movement. There may be numbness in the area of distribution of the nerve root that is affected as well weakness in the leg and decrease in the reflexes. The pain can be triggered by coughing, sneezing or pelvic floor contraction and can be so severe that the lumbar region becomes locked into a position of lateral flexion (scoliosis).

The primary cause of a slipped disc is bending forwards and/or to the side to lift a heavy object. Athletes who suffer slipped discs have often had previous incidents of acute lumbago. Depending on where the slipped disc is located in relation to the nerve root, different syndromes occur (Fig. 16.25):

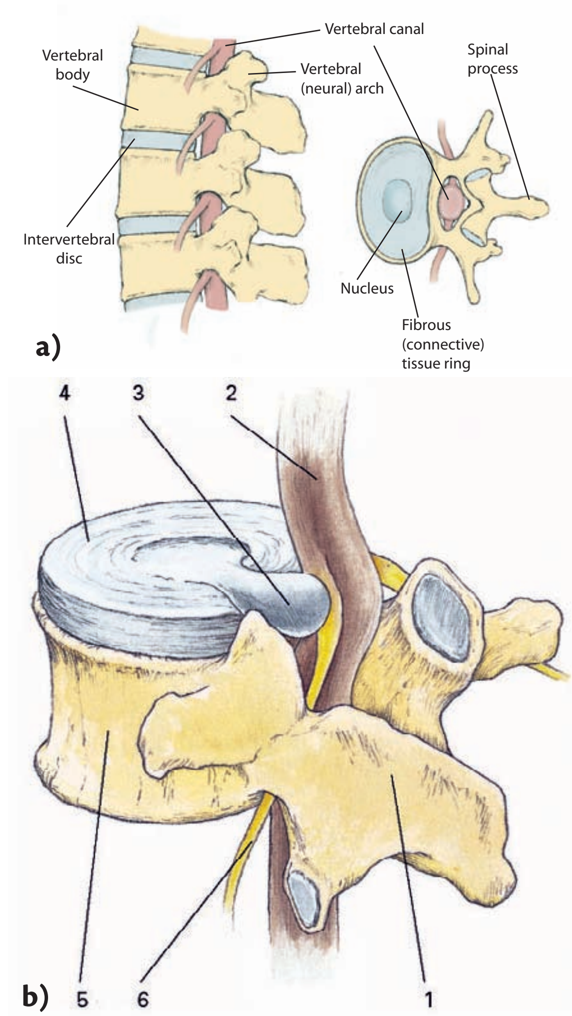


Figure 16.24 Anatomic illustration of the spinal nerves in relation to the vertebrae and discs. **a)** Normal anatomy of the spine viewed from the side and from above; **b)** a herniated disc: the core is pushed out into the vertebral foramen and puts pressure on the nerve root.
1: Vertebral arch; 2: vertebral foramen; 3: herniated disc; 4: connective tissue ring; 5: vertebral body; 6: nerve root.

- **L4 syndrome** affects the nerve root coming out between the vertebrae L3–L4; this gives pain radiating from the lower back, over the buttocks (gluteal muscles), trochanter and down through the groin to the front of the thigh down to the knee, with numbness in the same area. Weakness in the quadriceps muscle may occur as well as impaired patella tendon reflex.
- **L5 syndrome** affects the nerve root coming out between the vertebrae L4–L5; this gives pain radiating from the lumbar region to the outside of the thighs down to the outside of the knee and lower leg, passing to the front of the lower leg and ankle and forward to the big toe and second toe, with numbness in the same area. Reduced strength in bending upward (dorsalflexion) of the ankle and big toe is seen and the person has difficulty walking on the heels.
- **S1 syndrome** affects the nerve root coming out between the L5–S1 (the first sacral vertebrae). The pain radiates from the lower back to the back of the thigh, the back of the lower leg to the outside of the heel and foot to the little toe, with numbness in the same area. Reduced strength in plantar flexion of the ankle and toes is seen and the person has difficulty walking on their toes because of the impact on S1-root. Not infrequently the Achilles reflex is affected (reduced or absent).

Figure 16.25 Illustration of pain radiation from L4, L5 and S1 syndromes. Disc herniation may be the cause.

Slipped discs (herniated disc) can be found in the early teenage years to the elderly. The most common population affected by sciatica are people just over 40 years of age; S1 syndrome is more common in younger individuals while L5 syndrome is more common in older individuals.

Diagnosis and treatment

- The typical history of pain and its area gives a suspicion of the diagnosis.
- Examination of the spine may reveal a scoliosis caused by strong muscular contraction in the lumbar region.
- Mobility is impaired while muscles are sore and tense.
- Straight-leg raise (Lasègue's sign) is positive: in the Lasègues test with the patient lying supine the examiner passively lifts the leg with the knee extended on the affected side, and at some point (degrees) the patient experiences pain radiating down the leg (Fig. 16.26).

Figure 16.26 Lasègue's test for sciatic nerve or disc entrapment. **a)** Lasègue's sign is positive if pain down the leg is triggered when the examiner passively lifts a straight leg; **b)** Lasègue's sign is enhanced by simultaneous dorsiflexion of the foot.

- Neurological examination demonstrates weakened reflexes, signs of weakness or paralysis and loss of sensation (Fig. 16.27).
- In serious cases, disturbance of the innervation to the bladder results in difficulty in urinating. If this occurs, a physician should be consulted immediately.
- Diagnosis is made on the basis of prevalence of pain, loss of sensation and reflexes and impaired muscle power development along the paths and nerve roots. MRI or CT confirms the diagnosis of herniated disc and at which level (Fig. 16.28).

The athlete should:

- Avoid painful movements, relieve tension and pressure on the back by getting into the psoas position (see Fig. 16.23). Rest causes rapid reduction of the muscle mass of the back and special back muscle training should be started as soon as possible.
- Apply heat locally and use heat retainers.

The physician may:

- Prescribe analgesics, anti-inflammatory medication and muscle relaxants.
- Refer to a physiotherapist when the condition is no longer in the acute phase for light traction treatment.
- Prescribe transcutaneous electrical nerve stimulation, (TENS) (see p. 208) for long-term problems.
- Slipped discs (herniated discs) usually heal spontaneously, but this can take anywhere from several weeks to several years.
- Perform emergency spinal surgery in cases of loss of bladder function or rapidly progressive paralysis. These cases are rare.
- Operate when acute pain persists in spite of analgesic drugs, when paralysis occurs, and/or when a disabling postural defect resulting from reflex muscle spasm fails to correct itself or if symptoms worsen. A preoperative CT or MRI scan is needed so that the surgeon can identify and locate the slipped disc.

Please note that only about 20% of all slipped discs (herniated discs) need surgery. Today, there are experts who can perform endoscopic lumbar disc surgery. The other 80% of herniated discs will heal either by itself or with the help of exercise.

Figure 16.27 Functional tests (findings are compared with the healthy side). **a)** Strength test of the big toe by bending upward (extension) against resistance; **b)** strength test of the foot by bending upward (dorsiflexion) against resistance; **c)** strength test of the foot by bending downward (plantar flexion) against resistance.

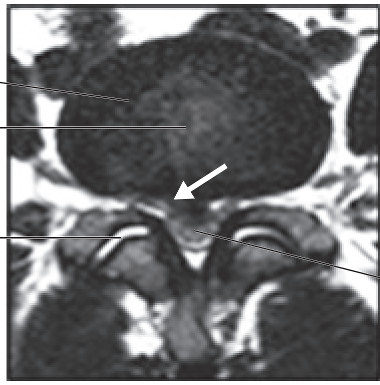


Figure 16.28 Magnetic resonance imaging (MRI) of herniated discs. The picture shows a transverse section at level L4–L5 showing a herniated disc (white arrow).

Results

The result of surgery is good. Between 80 and 90% of patients who undergo surgery for a herniated disc will be satisfied with respect to nerve root syndrome pain. The effect of surgery on back pain is often not as good as the effect on sciatica pain. Persistent back pain in the short- or long term after surgery is not uncommon.

Scientific studies with 1 year follow-up show that the results are equivalent for those operated on at an early stage and those who were treated conservatively with eventual surgery if needed. After 2 years patients who have surgery for disc problems do no better than those treated with pain medication and physical therapy. The degree of pain relief and perceived recovery was, however, much faster for those who had undergone surgery early.

After surgery for a herniated disc the athlete, at best, returns to normal activity or heavy work after 6–10 weeks. A risk of relapse exists, and it is therefore important to commence preventive training of abdominal and back muscles.

Tip

Uncomplicated sciatica has often a good prognosis.

Herniated discs can sometimes heal spontaneously, but this can take a long time.

If the bladder's emptying function is paralyzed, immediate surgery is necessary.

Spinal stenosis

The vertebral column can be affected by narrowing of the vertebral canal (stenosis) for other reasons than a slipped (herniated) and protruding disc. Spinal stenosis is defined as a reduction of the diameter of the spinal canal, nerve root outlet and nerve root canal and may occur locally over a vertebral segment or spread over several. Herniated disc surgery and disc degeneration often cause a lowering of disc height with bone spurs (osteophytes) on the edges of the vertebral body. This in turn presses the vertebral bodies together, squeezing the disc out towards the spinal canal, and in turn reduces the space in nerve root outlets and canals. It can lead to a deterioration of cartilage in the facet joints with osteophytes, that results in even further narrowing. All in all this contributes to a narrowing that often adopts an hourglass like shape.

The condition is not common in people under 50 years, but is the most common cause of back surgery in those who are over 60 years old. Middle-aged former wrestlers and weightlifters with back damage from overload have this condition, particularly in the lower back (Fig. 16.29). Several vertebral levels may suffer simultaneously. Spinal stenosis occurs in the cervical, thoracic and lumbar spine but is most common in the lumbar spine.

Symptoms and diagnosis

- Symptoms almost always occur during different types of physical activity or when the back/trunk is in certain positions.
- Symptoms are uncommon when at rest.
- Pain occurs in the back, especially on extension.
- The pain often radiates out to one or both legs.
- The pain occurs when walking and increases with distance.
- Other symptoms include numbness and muscle weakness with fatigue in the legs. Pain decreases when one stops walking, even more so if sitting down, but will return with continued walking. The symptoms are similar to angina in the legs (claudication) caused by arteriosclerosis; one must distinguish the difference. The prevalence of pain can be diffuse and varies with the extent and vertebral levels involved in the back.
- X-ray examination and MRI (Fig. 16.29) confirms the diagnosis.
- Other possible causes of the pain, for example arteriosclerosis, have to be eliminated.

The physician may:

- Prescribe physical therapy and prescribe analgesics.
- Prescribe a support corset, which can sometimes alleviate the pain especially in the lower back.

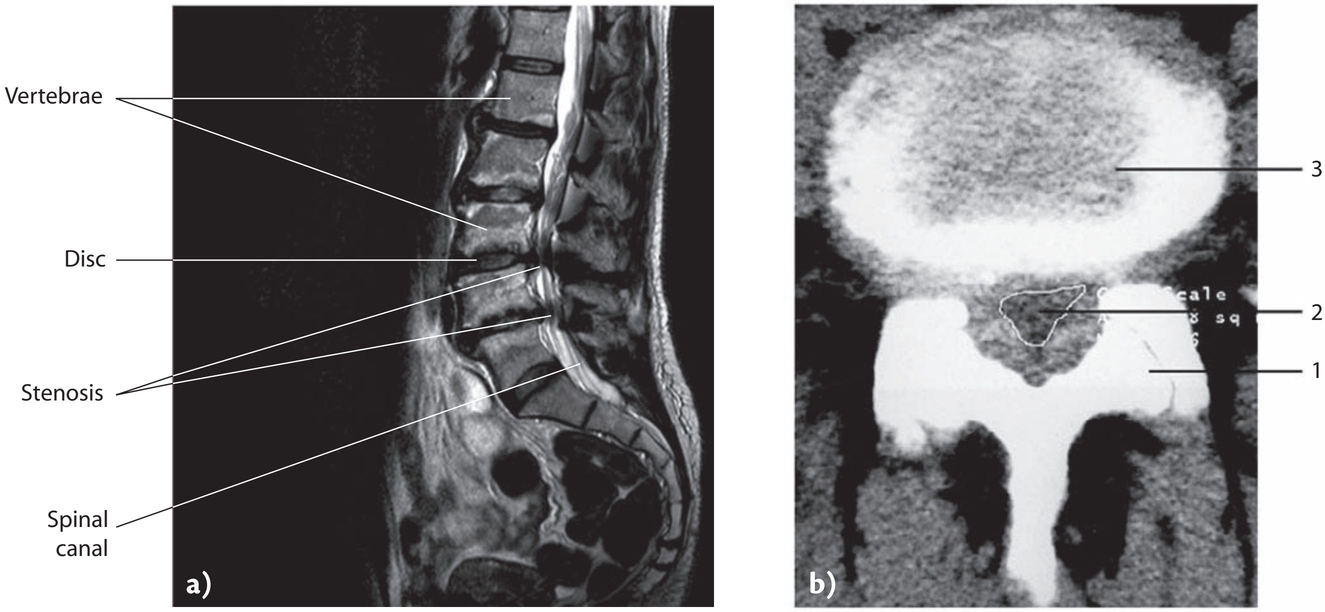


Figure 16.29 Spinal stenosis of the lumbar spine. **a)** Magnetic resonance imaging (MRI) of a lumbar spine from the side displays the stenosis of the spinal canal at several levels; **b)** computed tomography (CT) of the lumbar spine showing the narrowing of the spinal canal. 1: Vertebral arch; 2: remaining space in the spinal canal; 3: disc.

- In cases with severe symptoms operate and remove the causes of stenosis. The surgery is sometimes quite extensive and may require fusion surgery to stabilize the spine. The results are usually very good, but there is a risk of relapse.
- Training under the guidance of a physiotherapist can be combined with appropriate physical exercise if possible. Competitive sports may be selected depending on the athlete's function.

Facet joint syndrome

The joints between the vertebral arches, the intervertebral facet joints, are oriented in such a way that they reduce the rotation capability of the vertebrae. If there were no facet joints the discs would wear out more quickly as a result of rotatory movement in the spine.

When the discs are affected by age-related degenerative changes along with osteoarthritis of the facet joints, the possibility of disc compression is increased as well as spinal and root canal stenosis. This increases the risk for spinal cord and nerve root compression and compression fracture in, and displacement of, the adjacent vertebrae. This can lead to increased load on the joints, causing osteoarthritis. The cartilage of the articular surface is destroyed, and the resulting osteophytes then press on the nerves so that radiating pain is experienced without a disc having slipped. Often both sides of the facet joints are involved.

Symptoms and diagnosis

- Facet joint syndrome affects those aged 40 years and over and manifests itself as a sudden pain in the lumbar region.
- Rest makes the pain worse, and is helped by movement and training, which distinguishes this type of osteoarthritis from others.
- Stiffness and a limited ROM are found in the back.
- Tenderness occurs beside or along the spinous processes and pain is experienced when extending the back.
- Pain in the back and buttock is felt on lifting an extended leg.
- An X-ray and a CT or MRI scan confirms the diagnosis.

The physician may:

- Prescribe physiotherapy.
- Prescribe analgesic medication.
- Prescribe a lumbar heat retainer.
- Inject local anesthetics into the area of the affected joint (should be done under fluoroscopic control).
- Surgery can be necessary in some cases, where a small nerve to the facet is severed and osteophytes are removed. Sometimes a fusion must be performed.

Lumbar insufficiency ('weak back')

Some people have a 'weak back', which means that they show symptoms such as fatigue, stiffness and weakness, accompanied by aching, during or after slight loading of the back.

The athlete should:

- Improve technique or change working posture in order to relieve the symptoms.
- Strengthen the back muscles by extensive training (p. 353–5) which should be a part of all training programs.

The physician may:

- Prescribe physiotherapy with a back muscle program and give advice on lifting technique.

Roundback, juvenile kyphosis (Scheuermann's disease)

Scheuermann's disease is a hereditary condition that produces progressive hunching of the back (kyphosis) and can uncommonly prevent sporting activity (Fig. 16.30).

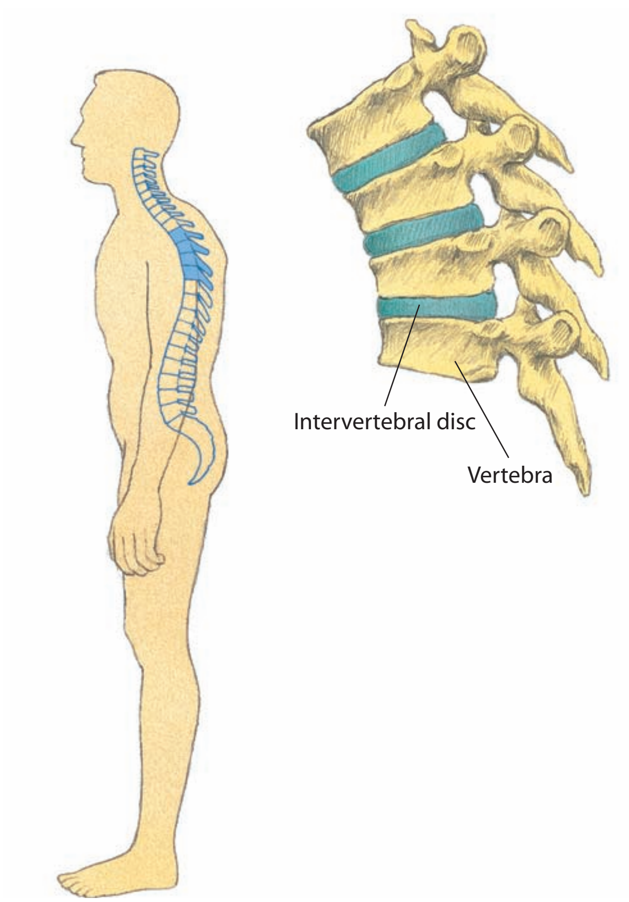


Figure 16.30 Roundback (thoracic kyphosis, Scheuermann's disease). Wedge-shaped vertebrae in the thoracic spine causing a kyphosis.

The condition affects mainly boys in puberty. There are usually 3–5 thoracic vertebrae that are involved, that become wedge-shaped.

Symptoms and diagnosis

- This disease usually provides no major problems.
- Fatigue is felt in the thoracic spine during exertion or by the athlete having to sit in school all day.
- Weakness and pain are associated with the exertion of the back.
- The condition is often brought to medical attention by parents, coaches or trainers when they notice changes in the shape of the child's back.
- Increased lung capacity is found in, for example, swimmers and skaters.
- X-ray, CT or MRI provides the diagnosis. Adolescents having this condition may be X-rayed so that infectious diseases and tumors of the vertebral column can be ruled out.

Treatment

- If back weakness is found, physical therapy with strength training of the muscles can be prescribed, which can be helpful.
- The condition progresses relatively slowly until bone growth is complete. Occasionally, when growth is rapid and the curvature increases, a corrective corset or plaster cast support is prescribed.

Healing and complications

- The condition rarely gives any symptoms once bone growth is complete.
- Individuals who have this back deformity, as adults, have a lower rate of absenteeism from work due to back problems than other people.

Scoliosis (S-form curvature of the spine)

In scoliosis, abnormal lateral curvature to the left or right of part of the spine renders the vertebral column S-shaped (Fig. 16.31). The spine is also abnormally rotated and may have one, two, three or more bends of various degrees. It affects mainly growing children and the cause is unknown (idiopathic). It is often discovered by the child's school nurse, physical education teacher, coach or parents, and should lead to a visit to the physician.

Scoliosis occurs in about 5% of all children in a normal population, but a mild form is more common than that among some athletes engaged in extreme one-sided sporting events, e.g. tennis player and javelin thrower.

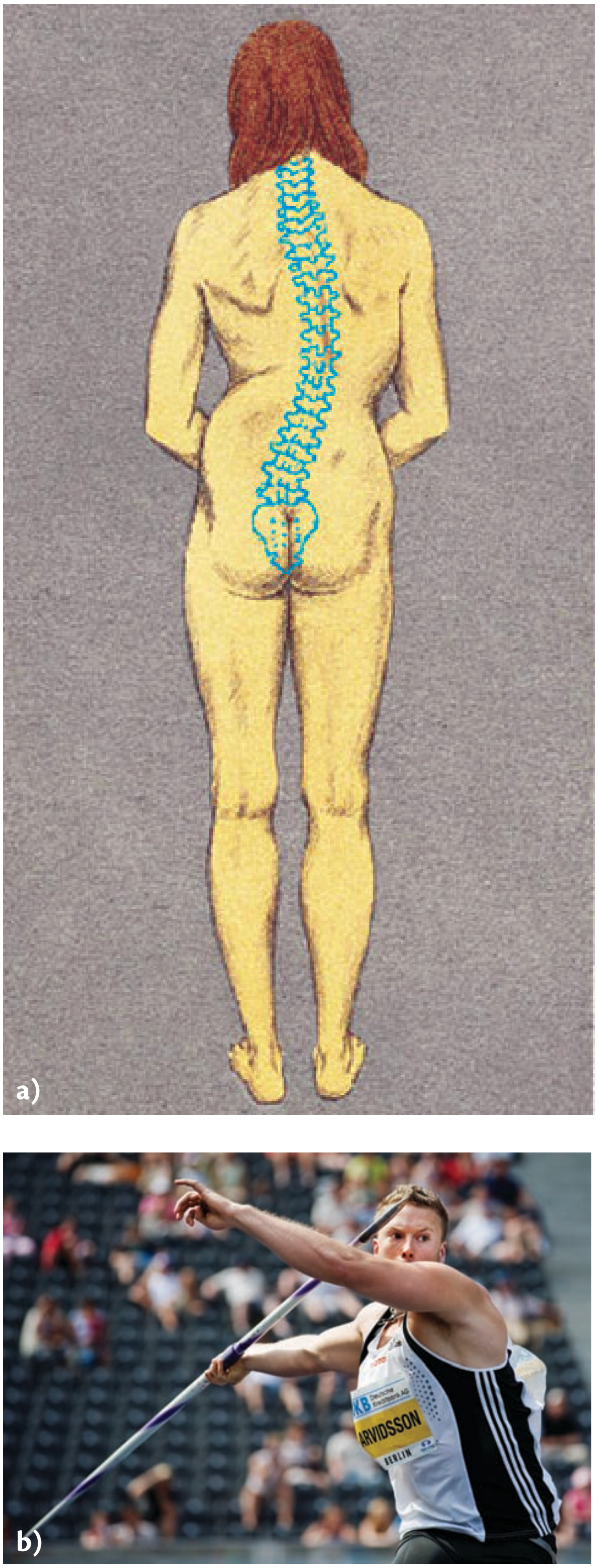


Figure 16.31 a) Scoliosis; **b)** javelin throwers and tennis players, among others, after 8–10 years of hard training may acquire a permanent moderate scoliosis. (With permission, by Bildbyrån, Sweden.)

Javelin throwers who have trained for more than 8 years can develop a type of scoliosis that appears to cause them no problems in the short term. The explanation could lie in the throwing mechanism: during the throw the body is bent and twisted towards the throwing arm at the same time as the lower back becomes more swaybacked (lordotic). Repeated training with this style of throwing movements results in the upper back muscles becoming more highly developed on one side of the body.

Symptoms

Scoliosis hardly ever causes discomfort or pain and does not preclude physical activity. The most important sign is the curvature of the spine, as determined by X-ray. The curvature is measured by the Cobb angle, which measures the sagittal plane deformity. These measurements give somewhat questionable results since they do not take the lumbar and thoracic rotation into account.

Treatment

- All children and adolescents with scoliosis should be assessed by an orthopedic physician.
- In mild cases the patient is kept under observation and receives treatment from a physiotherapist.
- Brace treatment can be tried in severe cases. In many countries the most often used type of brace is the Boston or Milwaukee brace.
- Moderate scoliosis is present when the Cobb angle is 20°. This condition affects 5 times more women than men.
- Severe scoliosis is present when the Cobb angle is greater than 30°, which affects 10 times more women than men.
- For Cobb angles greater than 40–50°, surgery is often recommended. In this extensive curvature cardiac and pulmonary difficulties may be present, especially when the patient has reached middle age.

Defective vertebral arch (spondylolysis) and forward displacement of a vertebra (spondylolisthesis)

A defect in the vertebral arch is called spondylolysis. The defect can be congenital or may be caused by injury or overloading, resulting in stress fracture. Spondylolysis is the prerequisite for a forward displacement of one vertebra in relation to the vertebrae below it if the defect is found on both sides. Once this has occurred the condition is called spondylolisthesis (Fig.16.32).

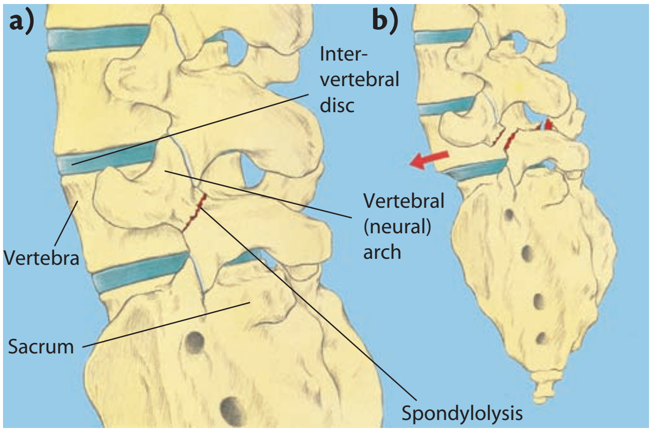


Figure 16.32 Spondylolysis and spondylolisthesis. **a)** Spondylolysis (defect through the vertebral arch) is a serious condition that can worsen and lead to instability and forward glide of the vertebral body; **b)** spondylolysis with a forward glide of the vertebral body (spondylolisthesis) is a serious condition that can affect nerve function to the pelvis and lower extremities.

The younger the individual is at the time the defect occurs, the greater the risk of the vertebral body sliding forward. The risk of the vertebrae body sliding forward is very small in young adults who have stopped growing, i.e. around 20 years of age.

The degree of symptoms depends in part on the speed of the onset of the slippage and partly by its extent. Spondylolysis can in itself cause problems, including back pain and sciatica due to the local changes around the defect, i.e. without any slippage having occurred. The symptoms of spondylolisthesis begin as the vertebral body slips forwards and exerts a traction and compression on the nerve roots. In growing adolescents the symptoms often appear after physical exertion.

Spondylolisthesis occurs in approximately 3–7% of the population, and the fifth lumbar vertebra (L5) is usually involved. Studies have shown that the condition is up to 6 times more common in women than in men. Research has not been able to identify an explanation for the increased incidence in women, but the role of hormones is discussed.

In sports where the back is exposed to heavy loads, such as gymnastics, diving, javelin throwing, wrestling, weightlifting, tennis and golf, a comparatively larger proportion of participants is affected. The injury occurs primarily in sports where extreme backward bending of the spine is often performed by growing youth such as gymnastics

Symptoms and diagnosis

- Lower back pain followed by fatigue in adolescents, usually after physical exertion.
- Sometimes sciatica symptoms occur in both legs; even though the unilateral Lasègue's test (see p. 345 Fig. 16.26) is usually negative, it may be positive when both sides are tested.
- Sometimes a step-off notch can be felt in the spine during examination.
- An X-ray examination should be done with the athlete in a position that triggers pain.
- An early bone scan (isotope scan) may show signs of tissue damage such as a stress fracture.
- CT or MRI scan (Fig. 16.33) confirms the diagnosis.

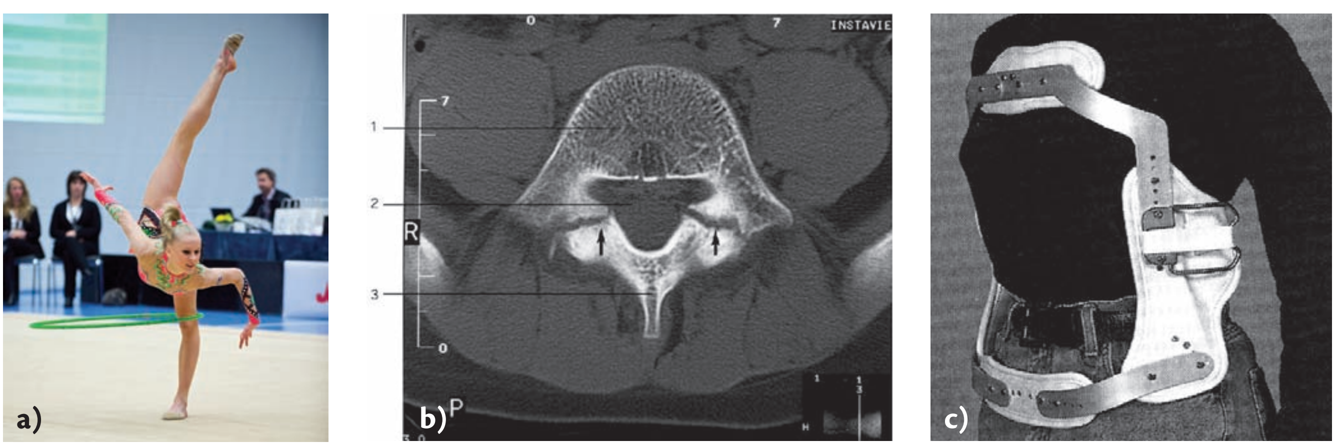


Figure 16.33 Defective vertebral arches – spondylolysis may occur as a stress fracture. **a)** Gymnast in extreme positions, such as backward bending of the spine, are at risk of overloading the vertebral column with stress fractures as a result; **b)** spondylolysis of the fifth lumbar vertebra (L5) verified with computed tomography (CT) caused by fatigue of the skeleton, i.e. stress fracture in the vertebral arch (see arrows). 1: Vertebral arch; 2: vertebral foramen; 3: transverse processes; **c)** a Boston brace used for fixation of stress fractures of the lumbar spine. (Courtesy of Prof. Tommy Hansson, Sahlgren Academy, Gotheburg University, Göteborg, Sweden.)

The athlete can:

- Rest from painful activities until symptoms have resolved.
- Consult a physician for an opinion.
- In general continue training in most instances, provided that the back is protected from overexertion, sciatic symptoms are absent and the symptoms do not worsen. Exercises emphasizing flexion like sit-ups should be prescribed; weight lifting and other strenuous back weight training should be avoided. Adolescents below 16–18 years of age should avoid extreme movements and loading in the lumbar spine.

The physician may:

- Recommend a change of sport.
- Prescribe rest when the damage is in the acute phase.
- Prescribe physiotherapy with a back muscle program, give advice on lifting technique.
- Prescribe a soft brace and a lumbar heat retainer (see Fig. 16.18A).
- Prescribe a rigid lumbar support such as the Boston brace (Fig. 16.33C) when stress fractures are present.
- Operate when other treatment has not been successful.
- Keep growing adolescents who have had this condition under observation with annual X-ray examinations.

Ankylosing spondylitis (Bechterew's disease)

Ankylosing spondylitis, also known as Bechterew's disease or pelvospondylitis ossificans, mainly affects the sacroiliac joint, the joints between the vertebral arches and the anterior long ligament of the spine, which may gradually ossify. The disease is characterized by inflammation of the synovial membranes, fibrous joint capsule, ligaments and cartilage effects and is similar in this respect to arthritis. Typically the affected joints and ligaments plates fuse. It usually afflicts young and middle-aged men and should be suspected in cases of chronic, but not severe, pain in the lumbar region. The condition is usually associated with other disorders.

Later in the course of the disease changes may arise also in other joints, such as in the joint between the breastbone (sternum) and collarbone (clavicle), as well as in the hip, shoulder and toe joints. At this stage, an increasing hunch back (kyphosis) is also common. Of the men who have ankylosing spondylitis, approximately 75% have also a chronic inflammation of the prostate gland (chronic prostatitis), 20% have intestinal inflammation and 5% psoriasis. In women ankylosing spondylitis is linked in 80% of cases to intestinal diseases, 15% have recurrent urinary tract infections and 5% have psoriasis. A third of those affected may at some time during the course of disease have an inflammation of the eye's iris (iritis). This eye infection is often recurrent.

Symptoms and diagnosis

- The onset is gradual, and the first symptoms are dull ache and stiffness, especially in the lower back in the morning.
- Pain in the lumbar area disrupts sleeping. Typically, the affected person wakes up in the night because of the dull ache and then gets up, for pain relief.
- Pain can radiate to the groin as well as down the legs. The symptoms can sometimes mimic those of sciatica.
- Other joints can also be affected, e.g. hip, shoulder and toe joints. Increasing kyphosis may appear.
- Diagnosis is difficult in the early stages, but the person has the symptoms described above as well as tenderness over the sacroiliac joint. In men signs of inflammation in the prostate gland (prostatitis) often provides support for the diagnosis. Many who have Bechterew's have had an episode of prostatitis. The relationship is not fully understood.
- ESR is often elevated, and special blood tests (HLA-B 27) support the diagnosis.
- A bone scan (isotope scan) is valuable and supports the diagnosis.
- X-rays of the sacroiliac joint may show ragged edges along the joint. An X-ray examination of the thoracic and lumbar spine can show an incipient ossification of the anterior longitudinal ligament and bone spurs on the anterior front of the vertebral bodies.
- MRI provides additional information on soft tissue and bone deformation.
- Ankylosing spondylitis often intensifies periodically at irregular intervals and results in varying degrees of increased stiffness in the back along with ossification of the ligaments in the back. Women often have a milder form of the disease than men.

The athlete can:

- Relieve stress on the affected joints.
- Avoid rapid twisting movements.
- Avoid cold and drafty conditions.
- Use a heat retainer.
- Consult a physician.

The physician may:

- Prescribe 'Bechterew gymnastics', a special type of physical therapy, that aims to prevent deformities and increase mobility in the spine, shoulders and hips.
- Perform movement training, if possible, in hot water.
- Practise thoracic breathing exercises.
- Prescribe anti-inflammatory medication.
- Treat other associated diseases.

Active mobility training should be commenced at an early stage, but the disease the person is suffering from other than ankylosing spondylitis should be treated before returning to training and competition. Sports activity can be undertaken during symptom-free periods without major limitations, though a physician should be consulted. During intensified active periods of the disease, sporting activity should be limited.

Tip

Rehabilitation programs for the lumbar spine must always be based on the findings at the examination of the injured individual to meet their specific needs.

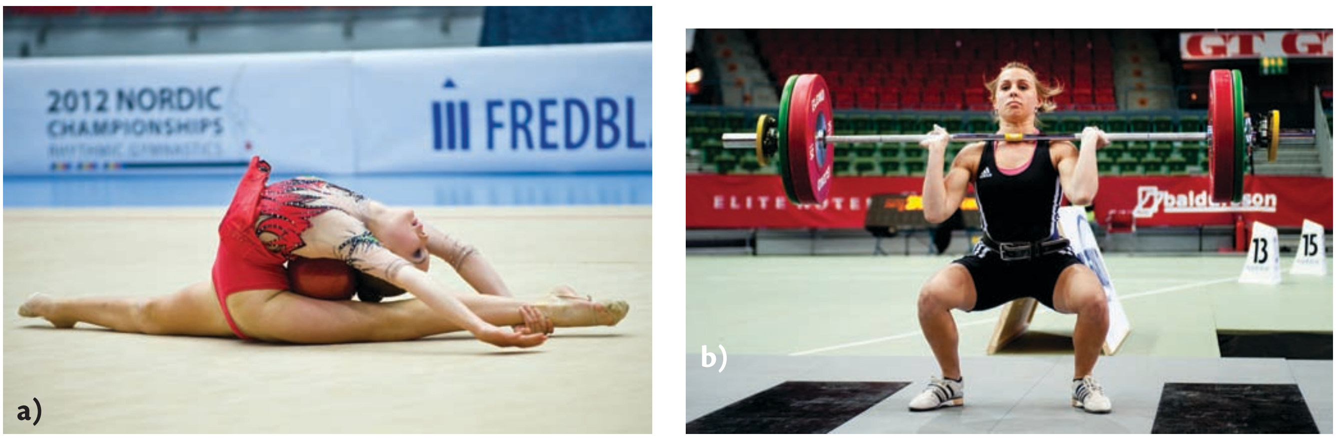


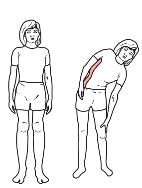
Figure 16.34 a, b) Elite athletes who train intensively for long periods of time have an increased risk of degenerative problems of the spine. (With permission, by Bildbyrån, Sweden.)

Rehabilitation of lumbar spine diseases

Athletes who engage in activities with high loads to the back have an increased risk of back problems that correlate to the load and number of repetitions of a specific activity. Elite athletes, who train intensively and for long periods of time, are at increased risk for degenerative back problems compared with inactive persons (Fig. 16.34).

A systematic study of the medical condition's progress, a physical examination and diagnosis and specific treatment reduces the athlete's symptoms and accelerates the return to sports. Rehabilitation programs for lumbar spine should be based on an individual assessment and to strengthen the weak links of the individual athlete. The examination should be both functional and level specific to the spine. Based on the findings a rehabilitation program should be designed based on the local core stability and global core mobility.

- Stabilization training of the trunk exercises the deep stabilizing muscles.
- Research has shown that deep-seated abdominal and back muscles, which normally are reflex activated, become inactive after a period of back pain. Good core stability can basically prevent this and lead to good pain control in the lower back.

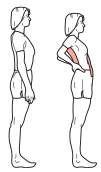


Range of motion training for the lumbar spine

Standing side bends (lumbar thoracic lateral flexion)

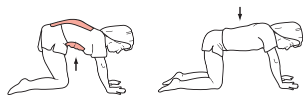
- Standing straight, feet slightly apart, bend torso to one side and allow hand to slide down the leg as far as it feels comfortable.

- Repeat on the other side, 10 times in each direction.



Standing backward flexion (lumbar/thoracic extension)

- Standing straight with hands placed in the lower back, bend slowly backwards as far as it feels comfortable.
- Hold for 5 seconds and relax. Repeat 10 times.

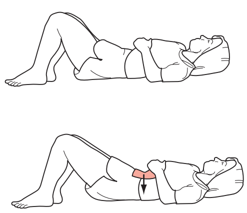


Cat exercise – arching the back (lumbar/thoracic flexion and extension)

- Kneel on all fours, arch back upwards as high as comfortable, and then release the arch going slowly down dropping the belly towards the floor.
- Repeat 10 times.

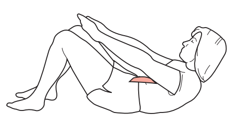
Strength of lumbar muscles

Strength training of the lower back is best done with professional help. A properly designed program is essential for safety and efficiency. The exercises may be performed to the edge of the muscular fatigue, as long as the proper alignment can be maintained. Good balance between abdominal and back muscles is recommended. Bobath balls are good aids in strength training of the trunk (see Fig. 16.20b).



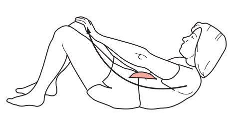
Pelvic lift (muscles involved: multifidus, rotators, transversus abdominis)

- Lie on back with knees bent and feet on the floor.
- Activate the core by drawing the navel towards the spine by tightening abdominal muscles then lift the buttocks slightly off the floor.
- Hold for 10 seconds. Repeat 10 times.



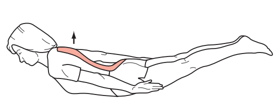
Low sit-ups (muscles involved: upper rectus abdominis)

- Lie on back with knees bent and feet on the floor.
- Activate the core by pushing the back down into the floor.
- Reach with hands toward knees, pull in chin towards chest and roll up the upper body so that shoulder blades lift off the floor.
- Hold for 10 seconds, breathing normally, then relax.
- Repeat 10 times.



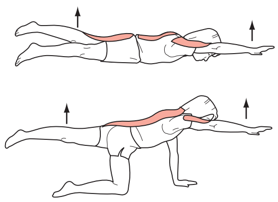
Diagonal sit-ups (muscles involved: rectus abdominis, external and internal oblique muscles)

- Lie on back with knees bent and feet on the floor.
- Activate the core by pushing the back down into the floor.
- Make a low sit-up and let the left hand reach forward towards the right knee.
- Hold for 10 seconds, breathing normally, then relax.
- Repeat in the opposite direction. Do 10 repetitions in each direction.



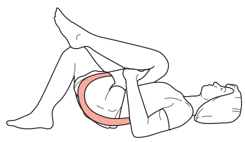
Back raises, thoracic extension (muscles involved: erector spinae)

- Lie on stomach with arms to the side.
- Lift the upper body off the floor using the back muscles, hold chin to chest.
- Hold for 5 seconds, breathing normally, then relax.
- Repeat 10 times. This exercise should be recommended with caution depending on the medical condition.



Diagonal arm/leg lifts (muscles involved: lumbar stabilizers)

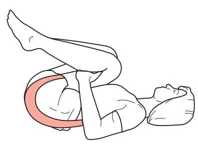
- Lie on stomach with arms stretched upwards over the head, straight legs.
- Lift left arm and right leg at the same time.
- Hold for 3 seconds and then relax, switching sides. Repeat 10 times.
- Progression of this exercise is done by doing the same exercise kneeling on all fours. Repeat 10 times.



Stretching of the lumbar muscles

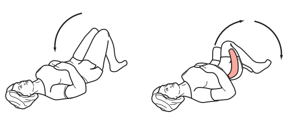
Knee to chest (lumbar flexion)

- Lie on back with knees bent and feet on the floor.
- Using both hands to first pull up one knee to chest and then the other.
- Hold both legs to chest for 10 seconds, then lower one leg at a time. Be sure to push the lower back against the floor when the legs are lowered.
- Repeat 10 times.



Lying twist (lumbar rotation)

- Lie on back with knees bent and feet on the floor and arms straight out.
- Gently let both legs fall to one side for 10 seconds and return to starting position, then do the same on the opposite side.
- Hold for 10 seconds. Repeat 10 times in each direction.



Piriformis stretch (muscles involved: piriformis and gluteal muscles)

- Lie on back with knees bent and feet on the floor.
- Grasp the left lower leg with right hand, left hand at the knee.
- Pull the leg diagonally upwards diagonally across the chest, toward the opposite shoulder. Hold for 20 seconds, then relax. Repeat with the other leg three times.

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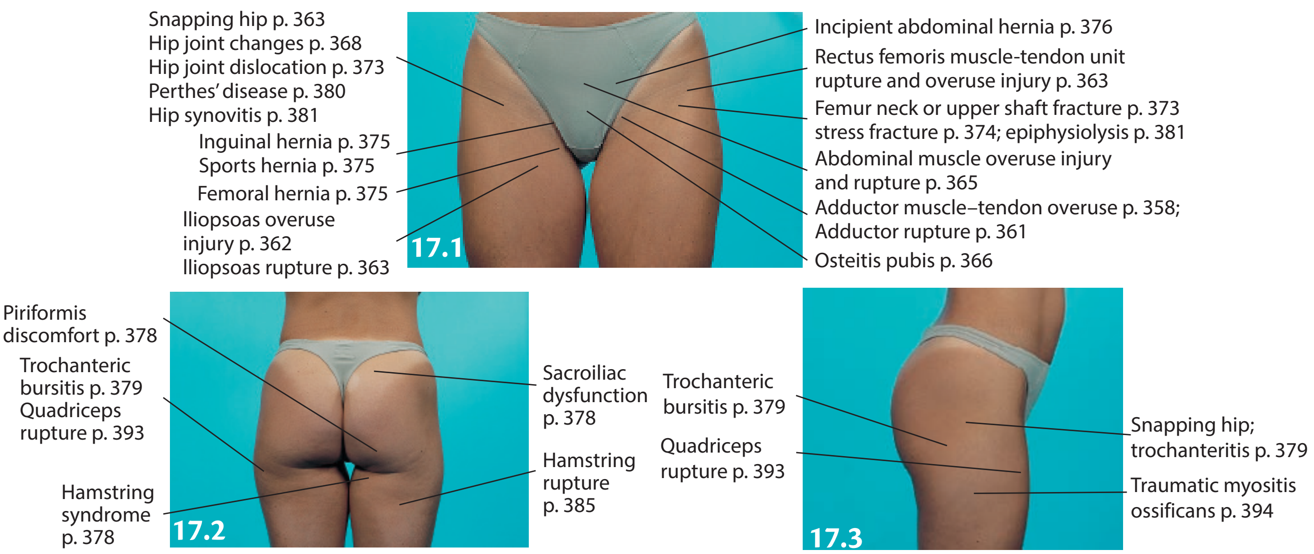
17 Groin, Pelvis and Hip Joint Injuries in Sport



Figures 17.1–17.3 Localization of injuries in the groin, pelvis and hip joint.

Pain occurring around the hip and in the groin is common in sports (Figs 17.1–17.3). Injuries to the hip and groin region occur about 0.69 times per 1000 hours of activity. 5–15% male and 4–8% female football/ soccer players have injuries originating in the hip/groin region.

These injuries constitute a major Sports Medicine challenge because the symptoms are often diffuse, vague and uncharacteristic. Injuries *can* occur acutely, but often the athlete has had chronic pain with vague symptoms that are difficult to deduce and diagnose. It is therefore essential to understand that there are many different possible differential diagnoses in this region. Teamwork is often necessary for a successful outcome: ideally this team should include not only an orthopedic surgeon and a primary physician, but also an experienced radiologist, a general surgeon, a gynecologist and a neurologist. An experienced physiotherapist and/or athletic trainer should also be included.

The most common location for groin pain is the adductor muscle–tendon complex (muscles that pulls the leg inward), with the pain usually being caused by overuse injuries involving the adductor longus muscle–tendon junction. These injuries occur mostly in football/ soccer and ice hockey players (Fig. 17.4).

Another common cause of groin pain is a hernia. Diffuse pain in the groin, which is difficult to diagnose can be a minor hernia. Hernia-related pain is usually centered in the groin and spreads proximally along the muscles outward to the inguinal ligament and over to the opposite side. The pain can be both considerable and long term. 30% of these painful conditions are attributed to peripheral nerve entrapments or nerve root problems. Patients who have pain in the groin that is difficult to assess should be sent to a general surgeon who has experience of this type of damage.

Physicians are increasingly facing long-term pain caused by weakness in the abdominal muscles in the posterior inguinal wall without clinical evidence of an inguinal hernia. Other conditions that can cause problems is an inflammation at the pubic symphysis on the pubic bone, different types of hip pain, bursa inflammation, 'snapping hip', nerve compression (entrapment) syndromes, stress fractures, infections such as prostatitis and urinary tract as well as tumors. If the athlete indicates a problem and pain when testing rotation of the hip joint, an orthopedic surgeon should examine the patient and an X-ray examination should be initiated to identify any damage to the hip joint.

The research and science available concerning long-term problems in the hip and groin area is still limited and mainly based on case studies. An injury in the groin area may perhaps not be so serious, but improper or no treatment can lead to a chronic pain condition that reduces the athlete's performance. An injury of the hip joint may require arthroscopy or major surgery to alleviate the problem.

Figure 17.4 Groin injury is common in many sports, including **a)** ice hockey and **b)** football/soccer. (With permission, by Bildbyrån, Sweden.)

Tip

Successful treatment requires a proper diagnosis.

Functional anatomy

The anatomy of the hip and groin is complex (Fig. 17.5). Besides a large number of muscles and tendons, there are also glands, bursae and other soft tissues that can be inflamed and injured.

The skeleton in the groin /pelvic area consists of the pelvis, comprised of the two hip bones (each hip bone consisting of three fused sections, ilium, ischium and pubis), sacrum, coccyx,and the fifth lumbar vertebrae (L5). There is minimal movement across the joints of the pelvis (the left and right sacroiliac joints and the symphysis) and no muscles act on these joints. The pelvis serves as a weight-bearing connection between the lower extremities and the trunk. The hip joint is very stable. The force transmitted across the pelvis is 2.6 times body weight. Running increases that force to 5 times body weight during the stance phase and 3 times body weight during the swing phase.

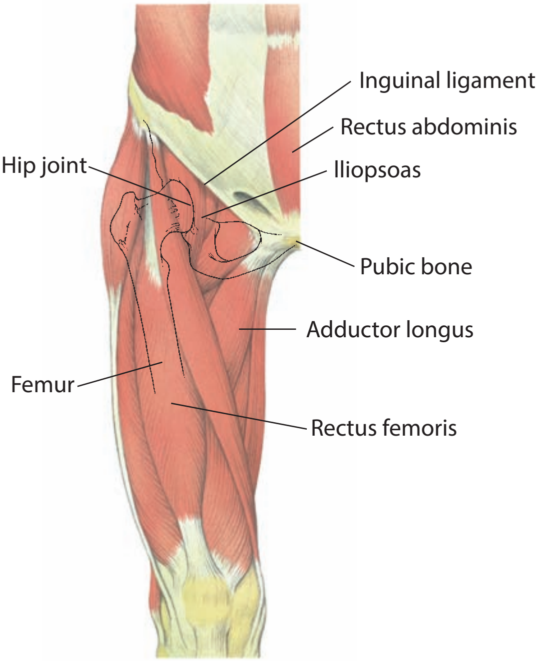


Figure 17.5 Overview of the muscles in the groin.

Groin injuries

Groin pain and tendinopathy in tendons/muscles in the adductor muscle group

The muscles that draw the leg inwards (adduction at the hip joint) are primarily the adductor longus, adductor magnus, adductor brevis and pectineus. The gracilis muscle and the lower fibers of the gluteus maximus also work as adductors. However, it is usually the adductor longus that is injured in sports.

The adductor longus muscle originates from the pubic bone (pubis) and has its insertion on the middle third of the medial side of linea aspera, which is located on the posterior midline of the femur shaft (Fig. 17.6).

The injury can be caused by a combination of stretching the abdominal muscles (hyperextension), extreme outward movement of the femur from the midline (hyperabduction) and a rotational movement at the pubic symphysis. Overloading can be caused by kicking with the inside of the foot (push pass) in football/soccer, especially meeting resistance from an opponent kicking the ball at the same time, hard running and pulling the free leg inwards while skating. It is also common in team handball and ice hockey players, bandy players, skiers, weightlifters, hurdlers and high-jumpers. The specific adductor longus injury has been estimated to have an incidence of 0.25 per 1000 hours. Complete ruptures are uncommon, but

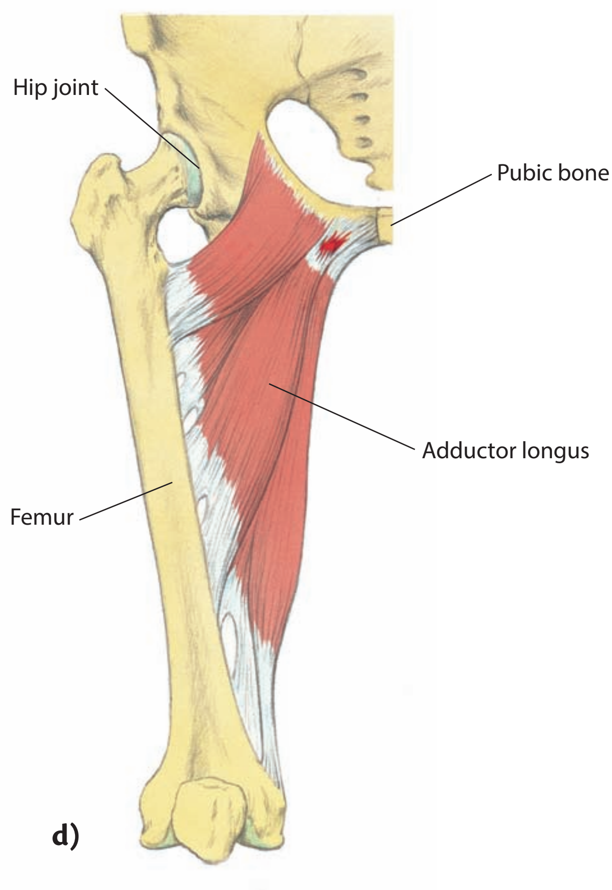


Figure 17.6 a–d) A common injury of the adductor longus muscle/tendon that moves the leg inwards (adduction) occurs in many sports. (With permission, by Bildbyrån, Sweden.)

partial ruptures may occur and should be suspected in minor traumas.

Symptoms and diagnosis

- Symptoms often have gradual progression and have a connection with the start of a season with a training camp or intensive training periods.
- Pain can often be located in the origin or at the junction of the muscle–tendon unit and may radiate downwards into the medial thigh. The pain often decreases after initial exertion and can disappear completely, only to return after training with even greater intensity. There is a risk that athletes will enter a persistent pain cycle that is difficult to treat.
- Tenderness is often felt over the origin of the muscle/tendon on the pubic bone. This tenderness is distinct (Fig. 17.7A).
- The pain can be triggered by activating the muscle, by pressing the leg towards the other against resistance (Fig. 17.7B–E).
- Functional impairment is common. Sometimes the athlete cannot run but can manage to bicycle. The

Figure 17.7 Tests for tenderness and pain in the adductor longus muscle/tendon. **a)** Localization for point tenderness over the muscle/tendon insertion on the pubic bone; **b, c)** pain can be elicited in the injured area by pressing the legs inwards against resistance; **d, e)** alternative techniques to test if pain can be elicited in the injured area by pressing the legs inwards against resistance.

athlete should restrain from participation in sports that include explosive movements.
- An X-ray examination may show calcification around the origin of the muscle on the pubic bone.
- A magnetic resonance imaging (MRI) or ultrasound examination can be helpful to diagnose partial ruptures or other tendinopathies.

The distance between the origin of adductor muscles and rectus abdominis muscle is very short. The pathological changes are likely to involve both tendons of these muscles at the same time.

Preventive training with specially designed strength and flexibility exercises (p. 381–3) is essential and should be included in every training program as an integral part of the warm-up and cool-down. The staff should be aware of the diverse training levels of the athletes and should, if possible, vary the training individually with this in mind. Athletes who undergo a good basic fitness training have fewer injuries than others; this is especially true of muscle injuries.

Treatment

The athlete should:

- Rest from discomforting activities as soon as pain in the groin is felt; the condition usually resolves itself relatively quickly without any other treatment (this is based on the assumption that the injured athlete does not return to training and competition until there is no functional pain).
- Use general heat treatment in the form of hot baths, hydrocollators, etc.
- Maintain basic fitness by cycling (preferably on an exercise bicycle) or swimming, using the crawl stroke, but only if these activities are pain-free.
- Apply local heat and use a heat retainer in chronic conditions (Fig. 17.8).

Figure 17.8 Heat retaining shorts of neoprene-like material can be of value when treating groin pain. (Courtesy of Otto Bock/Rehband, Sweden.)

The physician may:

- Prescribe a few days of anti-inflammatory medication.
- Prescribe a specific strength training program. This program should include functional activities such as closed chain and cross-over exercises, preferably under the supervision of a physical therapist or athletic trainer (see below).
- Prescribe deep friction massage, which has sometimes been shown to be effective.
- Administer a steroid injection in exceptional cases around the muscle or tendon attachment, while prescribing a 1–2 weeks' rest from excessive exercise after the injection (the injection should only be given when there is distinct tenderness over the attachment into the bone).
- Prescribe local heat treatment.
- Consider operating in chronic cases that haven't responded to treatment. Surgery often consists of a tendon release and eventual removal of damaged tendon tissue.

A training and/or rehabilitation program for those with an injured adductor longus muscle is as follows (for basic principles see p. 381–3); a well-executed training program has proven to be effective:

- Warm up: a light dynamic training program, such as using an exercise bicycle, for 5–10 minutes.
- Activate the adductor muscle without movement of the hip (isometric training) without resistance, use several different joint angles up to the pain threshold.
- Dynamic training without resistance.
- Isometric training, with gradual increase of the external load.
- Stretching according to the technique described (p. 382).
- Dynamic training with gradually increasing load.
- Technique-specific coordination or proprioceptive training.
- Sport-specific training.

The training elements that have caused pain in the groin adductors should not be resumed until the pain and tenderness have completely disappeared. It has been shown that if the injured athlete rests immediately upon the debut of symptoms, the injury normally heals quickly within 1–2 weeks, but if the training is started too early (before all the symptoms have completely disappeared) the injury can be hard to treat. If the condition is not treated at all, however, there is a high risk that it will be long term or chronic. A return to training is often possible within 1–3 months for long-term or chronic problems; if after surgery rehabilitation is not done correctly it may take considerably longer, i.e. 3–5 months.

Rupture of the adductor longus muscle

Ruptures of the adductor longus can be partial or complete. Complete ruptures are usually located at the muscle's insertion into the femur, but can also occur at its origin on the pubic bone. Partial ruptures usually occur in the muscle–tendon junction (Fig. 17.7). A rupture of the adductor longus muscle can occur when the muscles of the adductor group are tense and overused, for example in soccer, a player kicks the ball with the inside of the foot at the same time as an opponent blocks the ball with his foot, or when making a quick change in direction, a slide tackle or an explosive acceleration/deceleration is made.

Symptoms and diagnosis

- Sudden momentary stabbing pain in the groin is experienced. When attempts are made to re-start activity, the pain resumes.
- Localized internal bleeding can cause swelling and bruising, which may not appear until a few days after the injury has occurred.
- If the muscle cannot contract at all there is reason to suspect a total rupture.
- When the rupture is in the muscle belly a tissue defect can be felt at the site of injury, and the muscle is most tender there.
- A clinical examination should be performed when the muscle is in a relaxed state as well as in a contracted state against resistance.
- An X-ray should always be taken in athletes with groin pain. If swelling is present, as in complete rupture, an MRI or ultrasound scan should be performed.

The athlete should:

- Treat the injury immediately with ice, compression and elevation.
- Rest initially (crutches may be used).
- Avoid activities causing pain.
- Start rehabilitation with careful exercises and gradually increase function and try to maintain range of motion (ROM).

The physician may:

- Treat a partial rupture as described on p. 170. A partial rupture will heal with scar tissue and a subsequent inflammatory reaction after the acute stage.
- Operate in cases of complete rupture; it should be noted that this is uncommon.
- Operate in cases of a partial rupture after unsuccessful conservative treatment and there is chronic pain present.

During the rehabilitation period the injured athlete should continue strength training (p. 383), maintain and gradually increase their fitness by cycling, light jogging, swimming, etc. Not until the athlete is completely free from discomfort from the injured muscle group while exercising can regular training be resumed. The intensity of the return to training should at first be limited and increased gradually. Matches and competition should be avoided until recovery from the injury is complete and the fully trained athlete has been tested under competition-like conditions.

Complete rupture of the adductor longus muscle can occur without causing the athlete great discomfort after initial healing. It can, however, make the athlete suspect a tumor, as the belly of the muscle may turn out to be of unnatural size and shape. The increase in size is likely due to compensatory growth (Fig. 17.9).

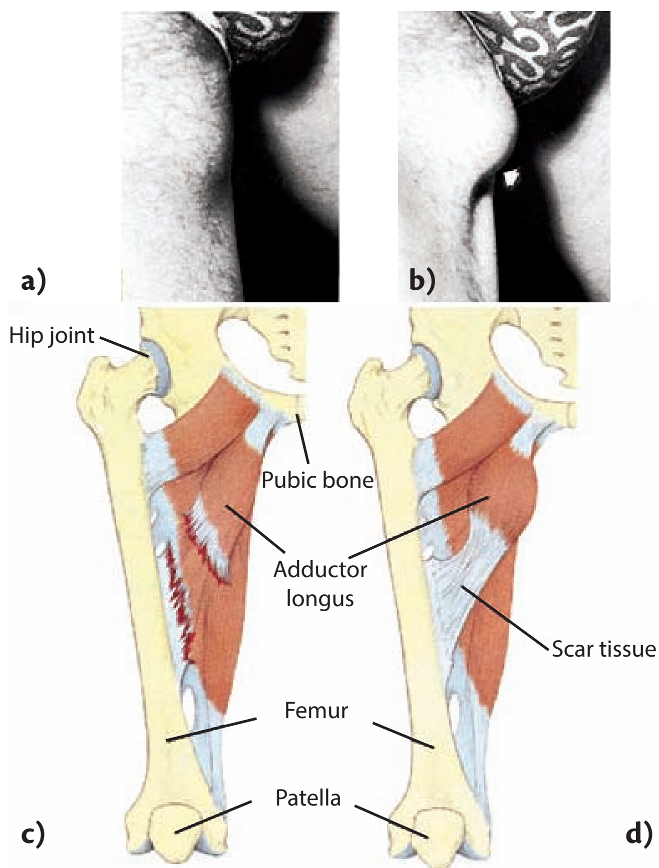


Figure 17.9 Example of a complete rupture at the insertion site for the muscle that brings the leg inwards (adductor longus). **a)** Muscle relaxed; **b)** muscle contracted; **c)** rupture in the insertion of the thigh bone (femur); **d)** healing with scar tissue, which results in a shortened muscle that looks enlarged when contracted.

Overuse injuries to the iliopsoas muscle

The iliopsoas muscle is by far the strongest flexor of the hip joint. It arises from the lumbar vertebrae (psoas major) and the inner aspect of the hip bone (iliacus) and inserts into the bony prominence at the top medial part of the femoral shaft (lesser trochanter). Load on the muscle essentially means load on the insertion. Overuse injury of the iliopsoas muscle can occur during weight training with a loaded barbell while simultaneously doing knee-bends, sit-ups, rowing; running with high knees against resistance, i.e. snow or water at shore line for conditioning; running uphill; intensive shooting practice in football; badminton; long and high jump; hurdling; steeplechase; rowing, etc (Fig. 17.10).

Between the iliopsoas muscle tendon and the external surface of the hip joint capsule lies a large bursa (iliopectineal bursa), which semicircles the tendon and can become the location for an inflammation, either isolated or simultaneously with a tendinopathy of the iliopsoas muscle (Fig. 17.11). These conditions can be difficult to distinguish, and in the following section are therefore treated together.

Symptoms and diagnosis

- As a result of this injury the athlete can enter a cycle of pain.
- Tenderness at the insertion of the tendon into the femur may be present but can be difficult to demonstrate in a highly muscular individual.
- Pain in the groin may be present when flexing the hip joint against resistance (Fig. 17.11).

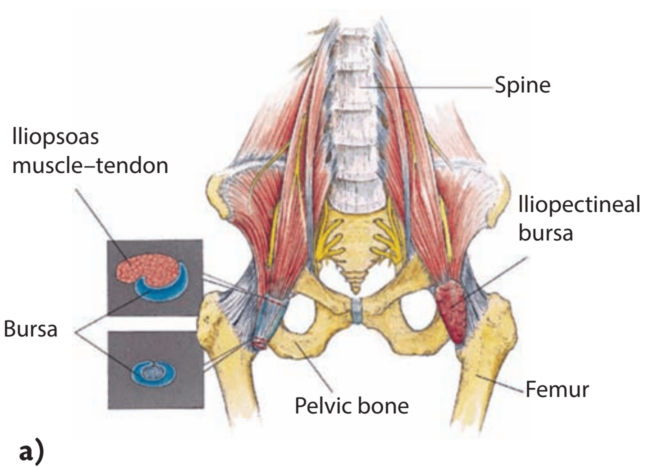


Figure 17.10 Rupture or tendinopathy in the hip joint's main flexor (iliopsoas muscle/tendon). **a)** The ilipsoas origin and course to the insertion on the inside of femur. Around the tendon there is the iliopectineal bursa; **b)** rowers use their iliopsoas muscle a lot with many repetitions of flexion and extension of the hip joint. The muscle/tendon of the iliopsoas may then become overloaded (with permission, by Bildbyrån, Sweden).

Figure 17.11 Rupture and/or tendinopathy in the hip joints flexor (iliopsoas). **a)** The finger points to the location for possible deep pain when testing for pain on flexion of the hip joint against resistance; the technique shown in figure 17.12 c) can be used; **b)** Thomas test (iliopsoas test). The athlete lies supine at the very edge of the table, with both legs hanging freely. Thereafter the athlete flexes one knee and pulls it back to the chest. The lumbar spine must remain flat. The examiner controls the opposite leg to make sure that it maintains full contact with the table. If the athlete is not able to maintain their lower back against the table the test is considered positive, indicating injury to the iliopsoas. It may also be a sign of impingement (conflict, collision) of the hip joint.

The athlete should:

- Initially rest until pain free, then gradually increase activity as tolerated.
- Apply local heat treatment and use a heat retainer.

The physician may:

- Prescribe a few days of anti-inflammatory medication.
- Prescribe a specialized muscle training program (see p. 383).
- Prescribe MRI to confirm the diagnosis.
- In cases of a suspected bursitis aspirate the bursa to confirm the diagnosis. This may be difficult and should therefore be done under fluoroscopic control. After the bursa has been drained a small amount of a steroid preparation can be injected into it.

When there are signs of recurring injury in the groin muscles the athlete should rest and avoid painful activities, otherwise the condition can easily become prolonged and chronic.

Ruptures of the hip flexor muscle (iliopsoas)

Rupture of the iliopsoas muscle is uncommon; it occurs usually in the muscle–tendon junction or at the insertion at the lesser trochanter. An avulsion fracture of a bony fragment can occur especially in growing athletes.

Symptoms and diagnosis

- Pain occurs suddenly, like a stab in the groin, and returns as soon as the injured athlete tries to flex the hip joint.
- When the rupture is partial, deep pain is felt at the iliopsoas insertion into the inner aspect of the femur (lesser trochanter) when the hip joint is flexed against resistance.
- Swelling and local tenderness may be present at the iliopsoas insertion.
- Total rupture gives an extreme weakness in flexion of the hip joint.
- Sometimes a bone fragment may be torn away at the insertion (avulsion fracture); an X-ray examination is required to confirm, particularly in a growing individual.

Treatment

- A partial rupture of the muscle–tendon should be treated in the same way as a rupture of the adductor muscles (see p. 360).
- Complete rupture of the iliopsoas muscle requires surgery.

'Snapping hip' (coxa saltans)

'Snapping hip' syndrome can be caused by injuries both within the joint and outside the joint. The condition is not well defined. The athlete/examiner feels or maybe even hears a 'click' in the hip at the following locations:

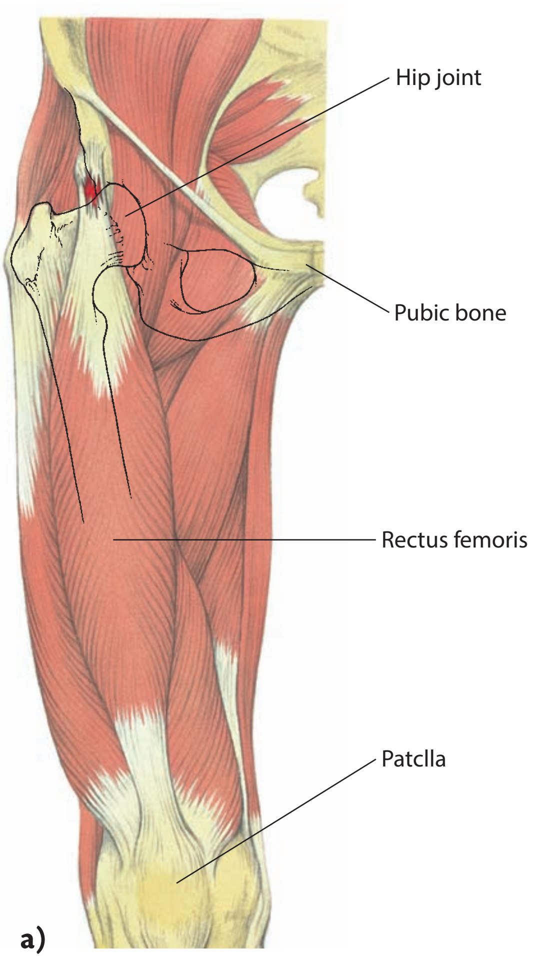
- Lateral, snapping occurs at point of the greater trochanter where the thickened iliotibial band that runs from the pelvic arch down the lateral side of the leg to the tibia slides back and forth over a thickened bursa.
- Anterior deep hip snapping, where the sensation can occur due to:
  - ✓ the iliopsoas tendon passing over the anterior aspect of the hip joint (the iliopectineal eminence) with the iliopectineal bursa, which may be inflamed and thickened;
  - ✓ the iliofemoral ligament passing the head of the femur;
  - ✓ inside the joint (intra-articular) pathology: loose bodies, cartilage fragments, labrum tears, etc.

When an athlete feels or hears a 'snapping' in the hip area it is usually perceived as unpleasant. Occasionally pain is associated with this syndrome, which is predominantly seen in women. Tenderness and pain indicate treatment. The biomechanical reasons for the snapping should be investigated. Occasionally surgical treatment is indicated in patients with prolonged symptoms.

The snapping caused by the iliopsoas tendon, when it rides over the iliopectineal eminence and bursa, occurs when the hip is abducted (away from the body) and externally rotated. Iliopsoas bursography can be carried out to demonstrate bursitis. An MRI scan can confirm this finding. Surgical treatment in these cases includes lengthening or sectioning of the iliopsoas tendon with reasonably good effects, and/or excision of the thickened bursa.

Tendinopathy of the upper part of the rectus femoris muscle

The rectus femoris muscle, which is one of the four muscle heads of the quadriceps, originates from the anterior inferior iliac spine of the pelvis (straight origin) and just above the articular cavity of the hip joint (oblique origin at ilium above acetabulum). The muscle flexes the hip and extends the knee joint (Fig. 17.12). Pathological changes in the muscle causing pain just above the hip joint can be from overuse such as intensive shooting practice in football/soccer, repeated fast starts, strength training, etc.



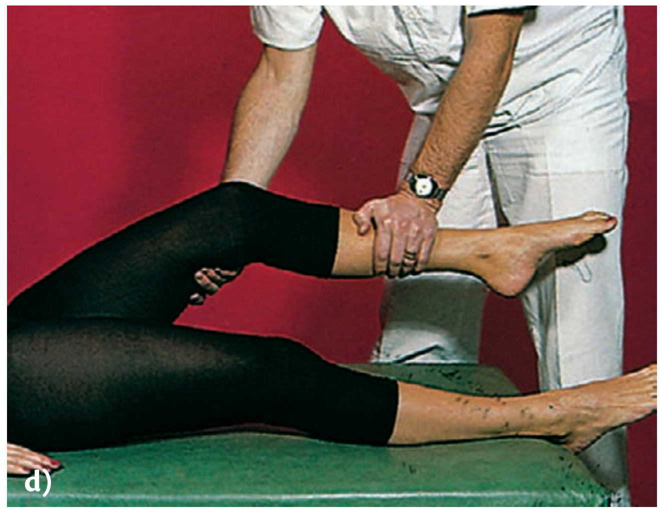


Figure 17.12 Partial rupture or tendinopathy in the upper part of the rectus femoris muscle. **a)** Anatomical overview of the muscle–tendon complex, showing a common location of a rupture or a tendinopathy in the rectus femoris origin; **b)** localized tenderness over the muscle origin; **c)** pain on flexion of the hip joint against resistance; **d)** pain on extension of the knee joint against resistance.

Symptoms and diagnosis

- Pain occurs during and after exercise.
- Pain is triggered by flexing the hip joint or extending the knee joint against resistance (Fig. 17.12).
- Local tenderness is felt at the origin of the muscle above and anterior to the hip joint.

Treatment

The treatment is in principle the same as that for overuse injuries of the adductor muscles (see p. 360).

Rupture of the upper part of the rectus femoris muscle

A rupture at the origin or the upper third of the rectus femoris muscle can cause pain in the groin. This rupture is usually partial, but complete ruptures can occur. The rupture can occur during shooting and tackling in ice hockey, football/soccer as well as executing fast forward accelerations in many sports.

Symptoms and diagnosis

- A sudden stabbing pain is felt in the groin while doing strong dynamic flexing of the hip joint or extension of the knee joint, i.e. shooting a soccer ball.
- In the case of a complete rupture it is impossible to contract the muscle.
- A defect and tenderness can often be felt in the belly of the muscle or tendon.
- An X-ray should be taken since a fragment of bone may have been torn away from the origin, especially in growing adolescents. At a later stage there may be residual calcification following hemorrhage.

Treatment

- Partial rupture: see p. 360.
- If the rupture is complete, surgery is probably preferable, especially if the origin of the muscle has been torn away from the skeleton near the joint, taking with it a fragment of bone.

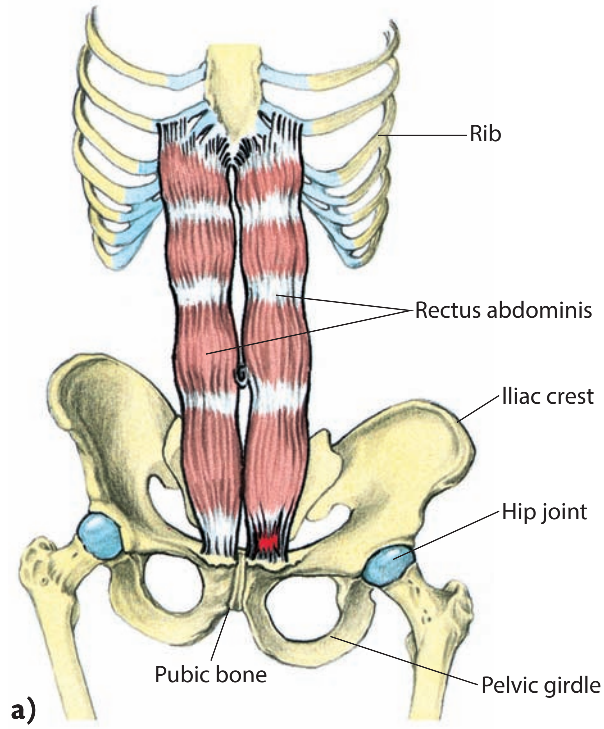
Ruptures of the abdominal muscles

Ruptures of the abdominal muscles usually occur to the straight abdominal muscle (rectus abdominis, 'lower abdominals'), but the oblique and transverse abdominal muscles (external oblique muscle, internal oblique muscle and transverse abdominis) can also be affected. The rectus abdominis muscle comprises two parallel muscles separated by a midline band, and originates from sternum, the fifth, sixth and seventh costal cartilages and xiphoid process and inserts on the upper part of the pubic bone (pubis) at the symphysis. Overuse injury and partial rupture of the rectus abdominis muscle is usually localized to the top of the pubis (Fig. 17.13). Ruptures can also appear in the transverse (oblique) muscles towards the sides of the abdomen and can confuse the diagnosis if they are located over the appendix.

Ruptures of the abdominal muscles occur in weightlifters, throwers, gymnasts, rowers, wrestlers and pole-vaulters among others. Degenerative changes in the muscle/tendon tissue (tendinopathy) are often triggered by exertion, such as strength training, sit-ups, shooting practice in soccer, as well as serving and smashing in tennis and badminton.

Symptoms and diagnosis

- A sudden stabbing pain may indicate that a rupture has occurred upon forceful exertion of the abdominal muscles.
- There may be tenderness and/or inflammation over the area in which the rupture has occurred. (Fig. 17.14).



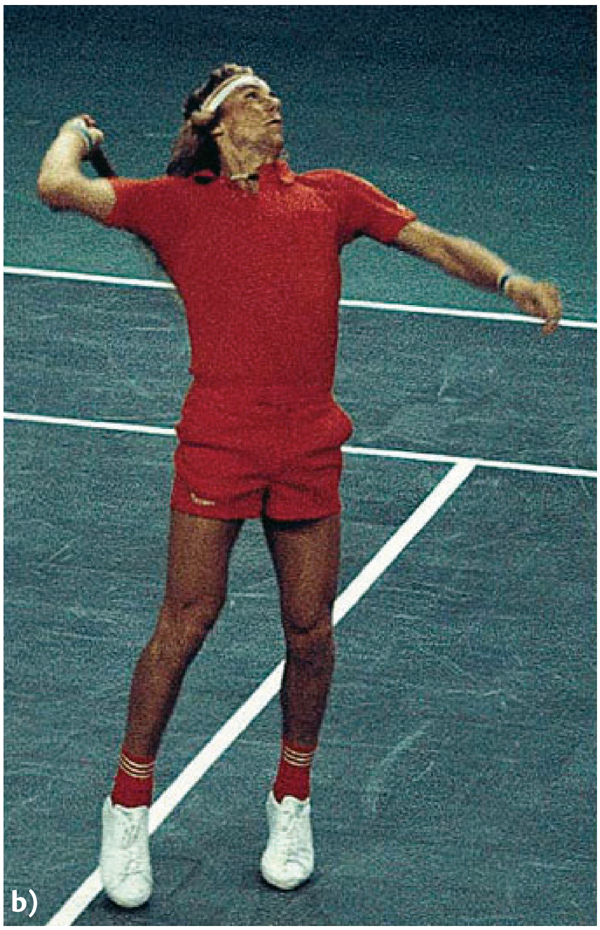


Figure 17.13 **a)** Tear of the rectus abdominis insertion on the upper part (symphysis) of the pubic bone (os pubis); **b)** a tennis player may have discomfort from this injury during the serve.

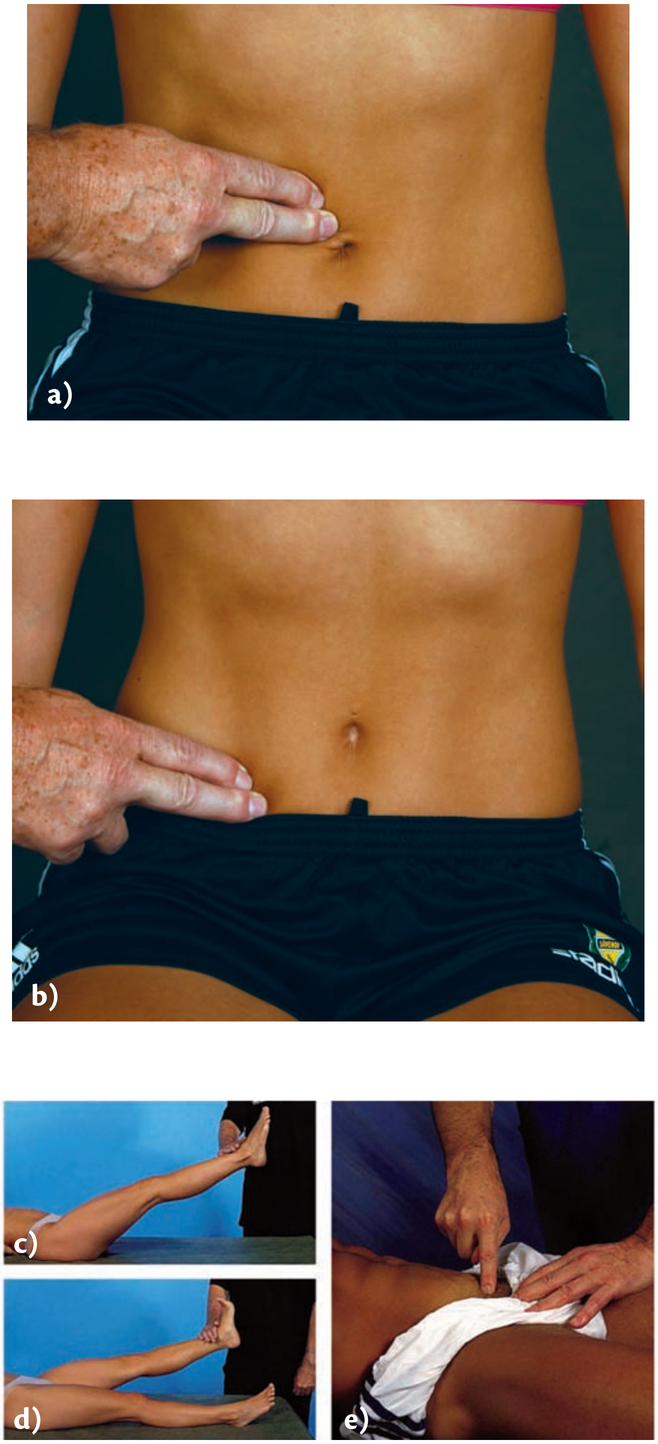


Figure 17.14 Location of tenderness and pain when there is a rupture and/or an inflammation in the rectus abdominis. **a)** Tenderness in the rectus abdominis at the level of the navel; **b)** tenderness over the transverse or oblique abdominals in the right part of the abdomen; **c)** straight lifting of both legs at the same time against resistance will elicit pain; **d)** a leg can be lifted against resistance and pain is elicited; **e)** tenderness may also be localized to the insertion of the pubic bone (os pubis).

- Impaired ability when attempting, for example, quick starts or running.
- A rupture of the abdominal muscles can be difficult to distinguish from inflammation of the internal organs such as appendicitis. It is typical of a rupture that the tenderness and the pain are more pronounced when the abdominal muscles are contracted than when they are relaxed.
- Pain can be elicited if the injured athlete lies flat and lifts legs against resistance (Fig. 17.14D,E).
- Overuse injuries of the abdominal muscles often demonstrate tenderness and pain over the insertion of the rectus abdominis muscle into the pubic bone. The symptoms are triggered by contraction of the abdominal muscles.

Treatment

The athlete should:

- Initially rest; gradually increase activity as tolerated.
- Apply local heat and use a heat retainer.

The physician may:

- Prescribe anti-inflammatory medication.
- Prescribe a suitable exercise program (p. 381–3).
- Administer a local steroid injection followed by 2 weeks' rest. The injured athlete should avoid strenuous activities as long as there are signs of inflammation of the tendon attachment.
- Operate when there is prolonged pain.

If the athlete rests immediately when the first signs of overuse of the abdominal muscles appear, healing takes only 1–2 weeks. If there is a muscle rupture the healing time varies according to the extent of the injury. The injured athlete should not return to training and competition until healing is complete, otherwise new ruptures may ensue and delay the healing process. Large muscle ruptures can lead to hernia formation in the abdominal wall.

Most athletes train their abdominal muscles by sit-ups. In order to protect the iliopsoas muscle during the rehabilitation period, the hip joint should be held bent so that this muscle does not contract. The best method of training the rectus abdominis muscle is half sit-ups, done slowly with bent knees and feet in the air.

Osteitis pubis – inflammation at the pubic symphysis

Osteitis pubis is noninfectious inflammation of the pubic symphysis, which may cause pelvic and abdominal pain. This painful condition is common in football/soccer, ice hockey, skaters, dancers, American football players, as well as in long-distance runners and weightlifters. The incidence of osteitis pubis seems to have increased in the past few years. The reasons for this increase may be the change in physical demands of high intensity training, running faster and more jumping and tackling, for example in sports such as Australian football, among others. Other factors that can influence this injury are increased hardness of the natural playing surfaces, due to better drainage, stadium roofs limiting sunlight and rainfall, as well as artificial surface shock absorption characteristics. There is also an increasing tendency to recruit players of increased body size in sports such as handball, volleyball, American football, rugby etc., where higher demand on strength of the abdominal muscles can lead to increased stress in the area.

There is usually no trauma involved, instead there is a gradual onset with pain localized in the cartilaginous joint between the pubic bones (pubic symphysis), often radiating either up to the abdomen or down into the groin. The precise cause of this injury is unclear, but muscle strain or stress fractures have been suggested. Pubic instability secondary to hip adductor imbalance, trauma or overuse may contribute to osteitis pubis. Ruling out disease of the bladder or prostate gland is important.

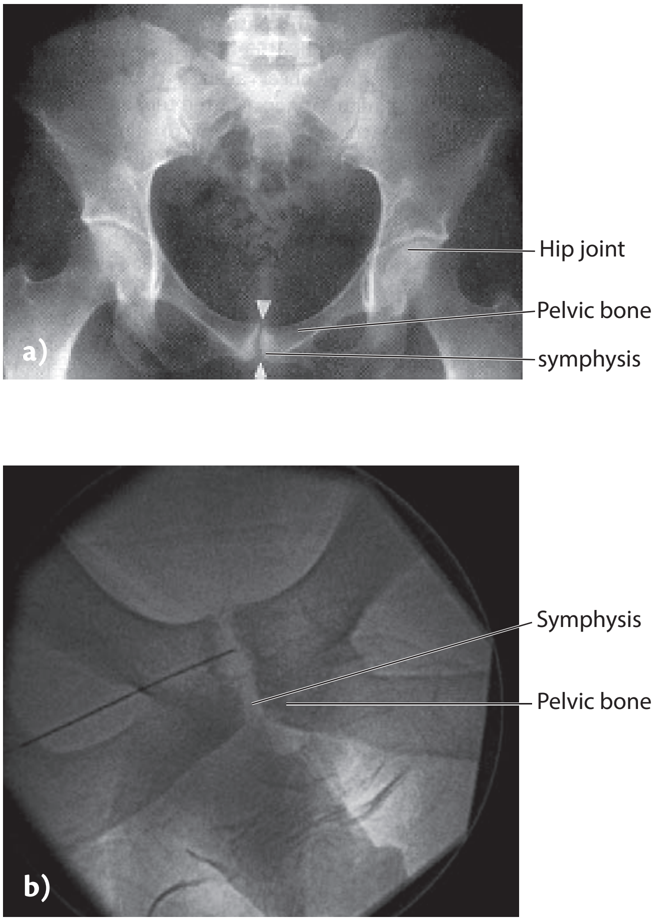


Figure 17.15 Changes may be seen in the skeleton around the symphysis (osteitis symphysis pubis). **a)** X-ray picture of the pelvis. The arrows show changes in the symphysis on the pubic bone, i.e. the point where the left and right pubic bones meet at the front of the pelvic girdle; **b)** if needed a corticosteroid injection can be given into the space between the symphysis; fluoroscopy (use X-ray to obtain images of internal structures through the use of a fluoroscope) should then be used to check that the injection is given in the correct place. Notice the bony changes (erosion).

Symptoms and diagnosis

- Gradual onset of pain, centrally localized in the pubic symphysis with radiation to the sides and distally, is typical.
- Tenderness is felt over the pubic symphysis.
- Passive abduction (away from the body) and active adduction (toward the body) and internal rotation of the hip are painful.
- Pain may often be more intense the morning after a training event, or when turning in bed at night.
- A bone scan may show an increased uptake early in the course of the disorder.
- Typical X-ray findings such as erosion or hardened bone (sclerosis) of the symphyseal junction, may be present after 2–3 weeks (Fig. 17.15).
- MRI and CT scans can give valuable information.
- It should be pointed out that X-ray changes resembling those of osteitis pubis can sometimes be incidental findings, causing the athlete no problems whatsoever.

Treatment

- The condition self-heals, and the athlete should be informed of this. The problem is that the condition is sometimes persistent and difficult to manage
- Activity causing pain should be avoided.
- Anti-inflammatory treatment and physical therapy may help.
- Heat retaining shorts may help.
- A corticosteroid injection may be given under fluoroscopic control (Fig. 17.15B).
- Surgery is rarely indicated; when there is chronic instability or other treatments have had no effect it may be tried, but results are debatable.
- Return to sport is on average possible after 9 months of conservative treatment. Occasionally symptoms may last more than 2 years.

Tip

This painful condition heals by itself, but it can take time. Conservative treatment is recommended.

Overuse injury or rupture of other groin muscles

A number of other muscles and tendons in the groin region can be injured during sporting activity, including the gracilis pectineus, sartorius, tensor fasciae latae and gluteus medius. The precise location of the pain, together with an assessment of muscle function, can clarify the diagnosis. Symptoms and treatment are in principle the same as those described for overuse injuries of the adductor muscles (p. 360).

Other causes of pain in and around the hip

Hip joint changes – labrum and cartilage damage

Groin pain may be triggered by changes within the hip joint itself and be early signs of wear and tear changes (osteoarthritis, see p. 165) or inflammation (arthritis, see p. 166). Loose bodies can occur in the joint, formed by a release of fragments of bone and cartilage (osteochondritis dissecans, see p. 164) (Fig. 17.16). Other painful injuries within the joint (intra-articular injury) include cartilage injuries with fragmentation, and bone spurs (osteophytes) on the joint edges of the femur head and the joint socket, not uncommon in ice hockey and soccer players among others. Another occurring problem for athletes is a labrum injury. The labrum is a ring of cartilage that surrounds the acetabulum (the socket of the hip joint). The labrum is most vulnerable for tears anteriorly and can loosen completely and lodge itself in the joint.

Symptoms and diagnosis

- This injury can cause a sharp pain in the hip joint.
- It can cause pain on exertion and strain and may include snapping and locking of the hip joint. Prolonged and persistent aching may also occur often after exertion.
- Flexion and rotational movements of the hip joint can cause pain (Fig. 17.17).
- MRI with contrast (MRI arthrogram) has a reliability of 91% in terms of imaging labrum tears, i.e. it is a very good method to determine this diagnosis.
- Arthroscopy can be considered (Fig. 17.18).
- Arthroscopy of labrum injuries is advantageous where fragments can be removed or attached with anchors (Fig. 17.19).

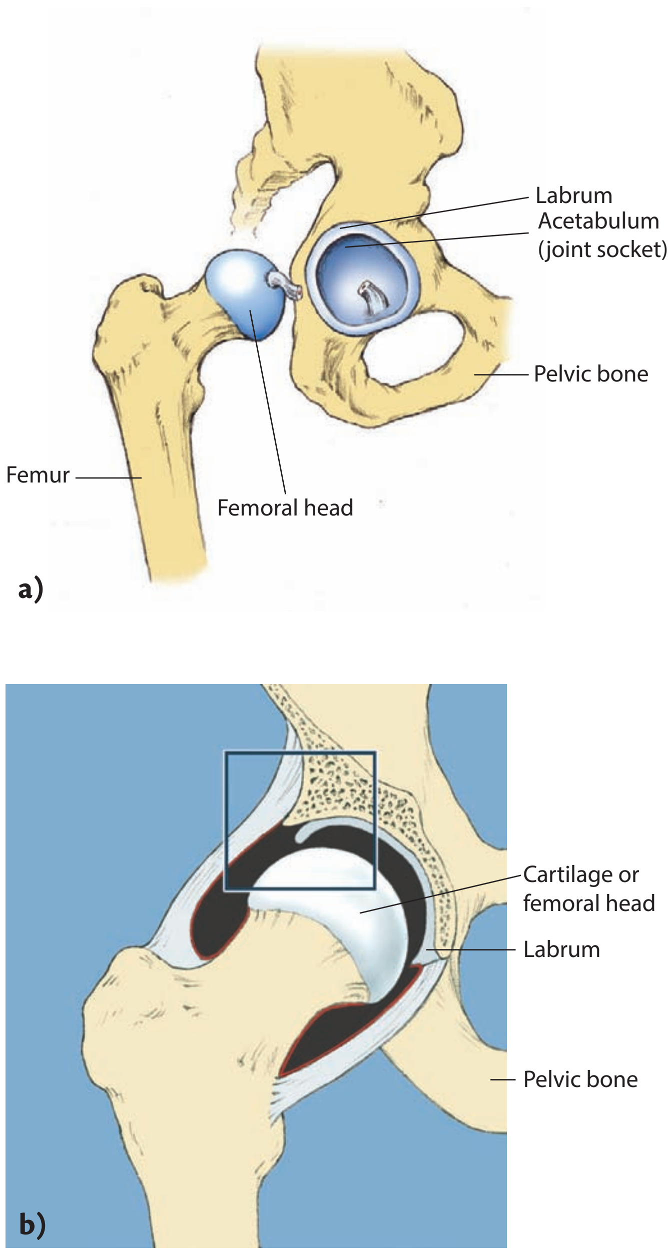


Figure 17.16 Anatomical picture of the hip joint. **a)** The femoral head of the hip joint (caput femoris) is luxated out of the socket of the hip joint (acetabulum). **b)** injury with avulsion of the labrum at the edge of the joint cavity (acetabulum) (see square).

Figure 17.17 The motions of the hip joint can be tested both passively and actively and the pain recorded. **a)** Flexion: in supine position the hip joint is passively flexed with the knee joint flexed; **b)** extension: in prone position the hip joint is passively extended posteriorly; **c)** internal rotation: in supine position the hip joint and the knee joint are flexed to 90° and the hip joint is then internally rotated 90° as the lower leg is moved outwards to the side (abducted); **d)** external rotation: in the same original position as C, the hip joint is rotated externally by moving the lower leg inwards to the side (adduction); **e)** internal rotation in prone position: the knee joints are bent 90° and the lower legs moved outwards; **f)** external rotation in prone position: the knee joints are bent 90° and the lower legs are crossed.

Figure 17.18 Arthroscopy of the hip joint. **a)** Patient positioning: the procedure is performed on an extension table, where the hip joint can be extended and the joint be widened; **b)** monitoring of the hip joint can be performed using X-rays and arthroscope TV monitor and fluoroscopy (this is an imaging technique that allows the physician to see the internal structure and function of a patient); **c)** a labrum injury can be diagnosed and treated with the aid of arthroscopy (courtesy of Prof. Marc Safran, Stanford University, California, USA).

- Damaged cartilage surfaces can be evened out. These surfaces can also be treated with microfracture surgery. Results are good in 70% if the cartilage damage is less than 1 cm^2 and 40% if the damage is larger than 1 cm^2.

Femoroacetabular impingement (hip impingement syndrome)

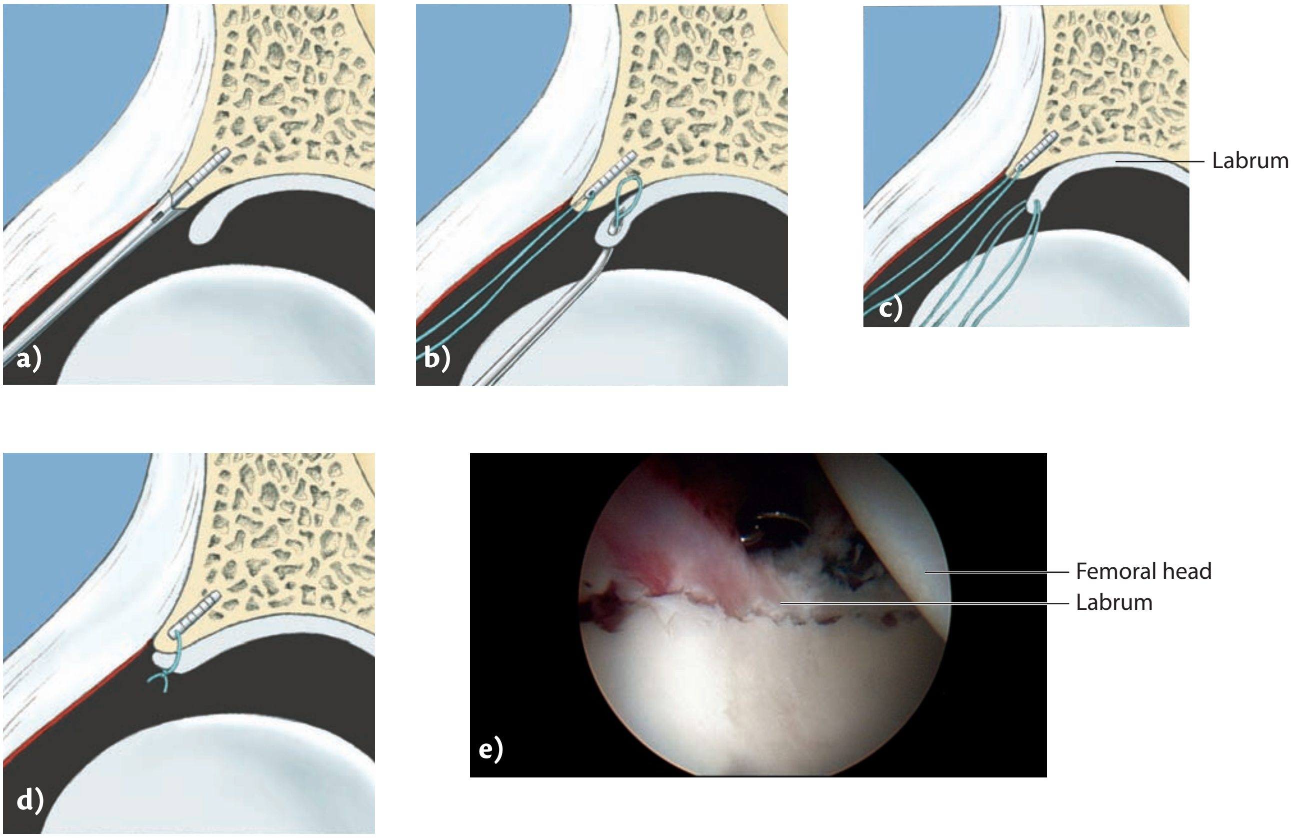
Femoroacetabular impingement (FAI) is a condition characterized by abnormal conformation between the hip joint socket (acetabulum) and the femoral neck near the head, causing too much friction in the hip joint (Fig. 17.21). Pain is a sign of this injury, and 85% have moderate or high levels of pain.

In principle, the femoral neck near the femoral head is too thick and comes often in contact/conflict with the edge of the acetabulum, in which the hip joint, the labrum or cartilage on the joint surface may be damaged and bone spurs (osteophytes) form on the femoral neck adjacent to the femoral head and joint edges, both on the front-top (anterior proximal) and rear-bottom (posterior distal). FAI can be divided into two categories, cam impingement and pincer impingement. In many sports the normal ROM is repeatedly exceeded, as in the hip joint, where a conflict between the neck of femur close to the head and the rim of the acetabulum may occur. The bone in the contact area reacts with bone formation, osteophytes, according to Wolff's law and the joint motion will be restricted by the bone formation, e.g. in rotation.

Sometimes it starts on the neck (cam) and most of the time it also involves the acetabulum (pincer). The head becomes gradually more oval from being spheric and the acetabulum becomes larger and encloses more of the head. Both types of change deform the joint and may cause cartilage damage and progress over time to osteoarthritis.

Cam impingement

- Cam comes from the Dutch word meaning cog.
- It describes a condition where femoral head joint to the femoral neck is anatomically altered by the femoral head not being perfectly round.



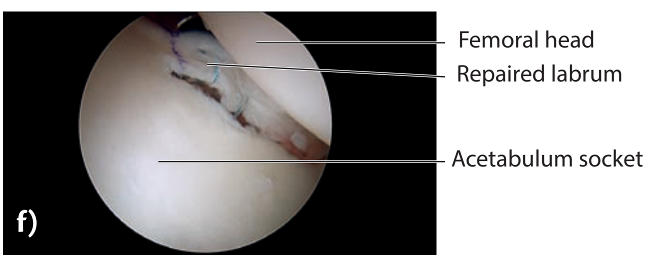


Figure 17.19 Arthroscopic repair of labrum. **a)** One suture anchor or more can be fixed to the bone edge of the acetabulum; **a+c)** sutures are put through the edge of the labrum; **d)** sutures are tied fixing the labrum to the edge of the acetabulum; **e)** arthroscopic picture with detachment of the labrum; **f)** labrum fixed in place by arthroscopic surgery (**e, f)** courtesy of Prof. Marc Safran, Stanford University, California, USA).

- This loss of roundness contributes to abnormal contact between femoral head and joint socket (acetabulum) (Fig. 17.21).
- The typical profile of an athlete with this condition is a male between 20 and 30 years old.

Pincer impingement

- Pincer comes from the French word meaning pinch.
- The acetabulum, i.e. joint socket, covers too much of the femoral head and restricts movement.
- The pincer formation may be due to so called retroversion, i.e. the acetabulum is angled backward or is too deep (Fig. 17.21).
- Cam and pincer often exist simultaneously as they affect each other through movement of the hip joint.
- The typical profile of an athlete with this condition is a female between 30 and 40 years old.

Symptoms and diagnosis

- Pain, especially during activity.
- Front (anterior) impingement test is positive in 99% of cases. Performed with internal rotation adduction in 90° of flexion (Fig. 17.22A).
- Rear (posterior) impingement test. Performed with external rotation of the hip joint in hyperextension (Fig. 17.22B).

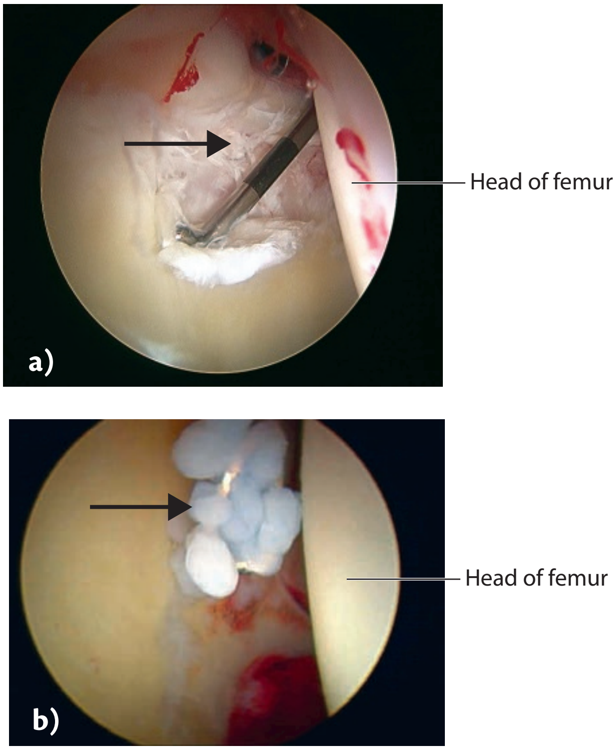


Figure 17.20 Injured articular cartilage in the hip joint. **a)** Injury to the articular cartilage seen via arthroscopy; **b)** free bodies in the hip joint, which can be removed via arthroscopy. (Courtesy of Prof. Marc Safran, Stanford University, California, USA.)

- Significant reduction in ROM, especially internal rotation and abduction.

Treatment

- Non-surgical treatment of FAI is possible. It includes, however, a change of life style for the athlete, a decrease in activity and a commitment to maintain hip strength. Non-operative treatment does not change the underlying biomechanics of FAI.
- X-rays provide support for the diagnosis as well as MRI (Fig. 17.23).
- Surgical treatment may be performed using hip arthroscopy or open surgery where excess bone causing the impingent is removed (Fig. 17.24).

There are a number of associated conditions with pincer-cam injuries such as labrum injuries, cartilage damage and incomplete ossification of bone junctions in the hip joint socket (os acetabuli).

The post-operative after-treatment for FAI surgery includes:

- 1 week with a maximum of 20 kg weight bearing and free movement.
- 12 weeks without excessive loads or athletic endeavors.

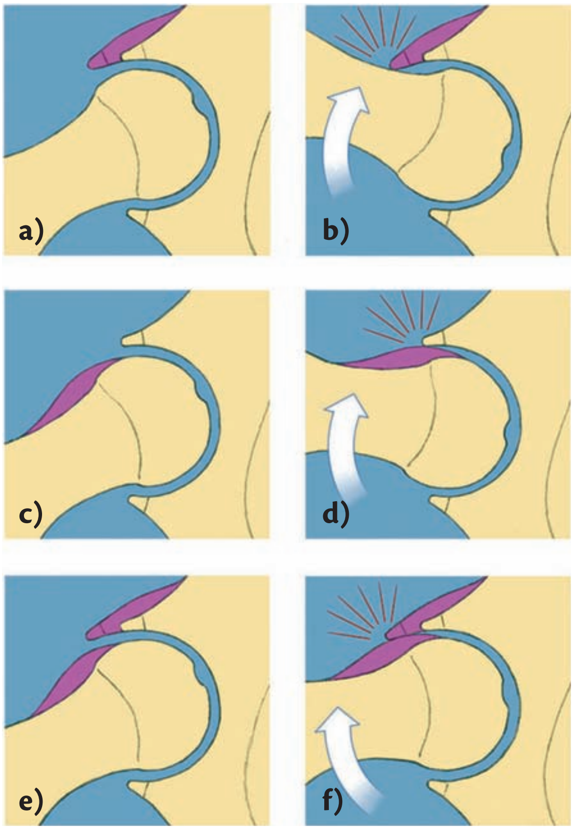


Figure 17.21 A–F show femoroacetabular impingement and the edge of the acetabulum caused by bony formations (osteophytes). **a)** Pincer impingement: osteophytes are formed on the acetabular edge caused by repeated contacts with the upper part of the femoral neck by the joint surface of the femoral head; **b)** pincer impingement: during repeated flexion and rotational motions in extreme positions the osteophytes grow and cause a pincer impingement with increased pain and decreased movement; **c)** cam impingement: in the conflict between the edge of the acetabulum and the upper part of the femoral neck close to the edge of the femoral head a reaction can occur in the femoral neck with osteophytes as a result, a so-called cam impingement with increased pain and decreased motion as a consequence; **d)** cam impingement: during repeated contact there is a reactive build-up of bone causing increased pain and decreased motion as a consequence; **d)** pincer–cam impingement: continued contact between the edge of the acetabulum and the neck of the femur can result in osteophytes on both locations; **f)** pincer–cam impingement: with continued contact this can result in increasing pain and decreased ROM, especially internal rotation, flexion and abduction. All the three conditions can lead to osteoarthritis in the hip joint.

In one study most athletes were relieved of their cam impingement symptoms and satisfied with their results. 88% were able to return to their respective sport.[1] FAI is a possible cause of hip osteoarthritis, but good clinical studies do not yet exist.

Figure 17.22 Clinical tests for anterior and posterior impingement in the hip joint (femoroacetabular impingement [FAI]). **a)** Anterior impingement test: an apprehension test can be done with the hip joint flexed to 90° and somewhat internally rotated (adduction). In this position the hip joint is passively internally rotated to an extreme position with collision of the osteophytes in the anterior-upper part of the hip joint. The test is positive if pain is elicited; **b)** posterior impingement test: an apprehension test is carried out with the hip joint extended and then the hip joint externally rotated to its extreme position. Collision will then occur due to osteophytes in the posterior-inferior aspect of the hip joint. The test is positive if pain is elicited. (Courtesy of Dr. Abellán Guillén, Murcia, Spain.)

Dislocation of the hip joint

The hip joint is extremely stable under normal circumstances, but can be dislocated (usually backwards) by very violent impact (e.g. in American football, downhill skiing and motorsport). The injury is serious because the femoral head can be damaged permanently through impairment of its circulation. Dislocations of

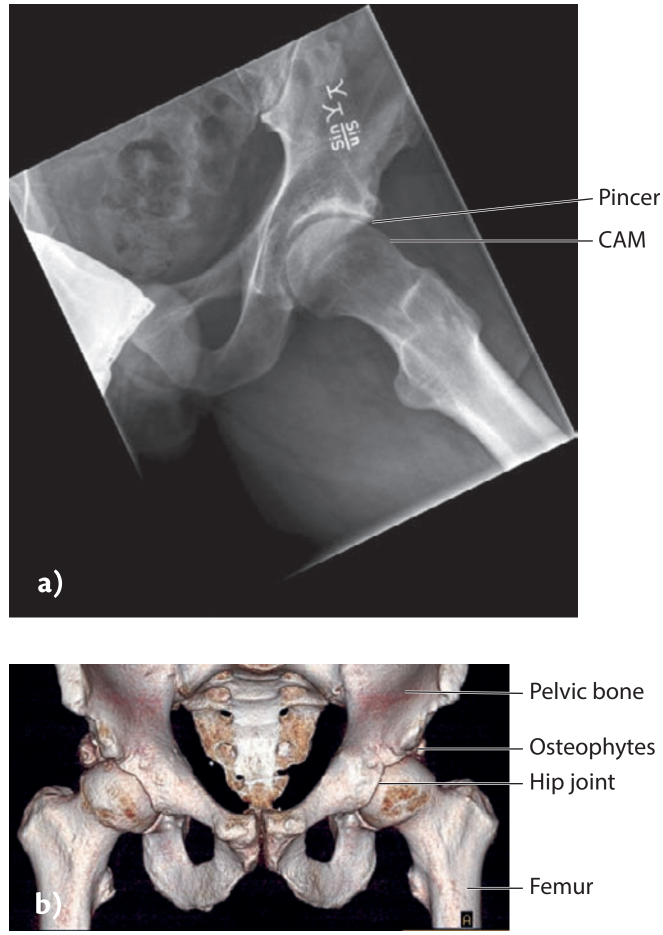
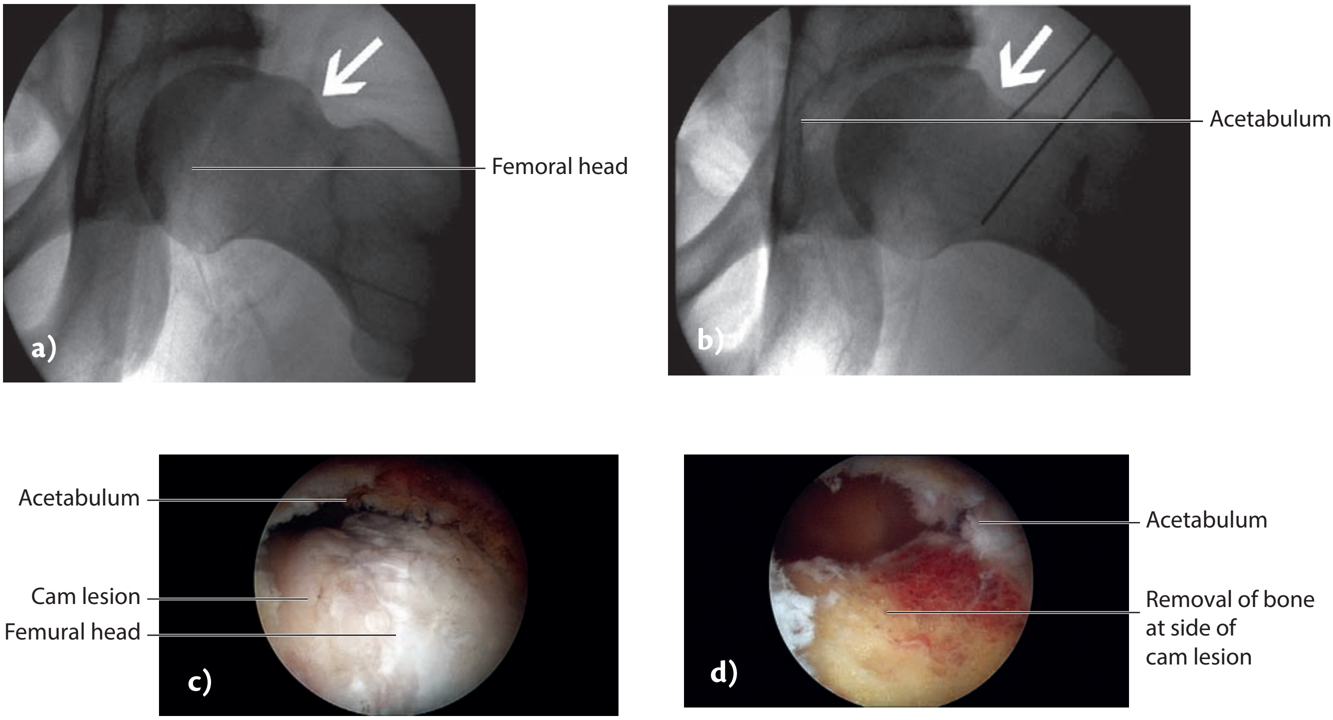


Figure 17.23 Femoroacetabular impingement (FAI) in the hip joint. **a)** X-rays in the frog position show changes corresponding to pincer at the edge of the acetabulum and cam on the femoral neck; **b)** CT scan reconstruction shows pronounced bone formation (osteophytes) on top of the acetabulum causing FAI.

the hip joint rarely occur without simultaneous skeletal injuries, and prolonged follow-up treatment is needed before a return to sport can be made. This injury may result in tissue death (necrosis) of the femoral head, which may cause permanent dysfunction.

Fracture of the neck or upper shaft of the femur

Fractures of the neck of the femur and of the upper part of its shaft are comparatively common injuries in the elderly. However, fracture also occurs in younger individuals who have fallen directly on the hip while skating or skiing, for example. A typical symptom for fractures of the neck of the femur is that the injured leg is shortened and rotated outwards (externally) after the injury. These fractures are nearly always operated on and



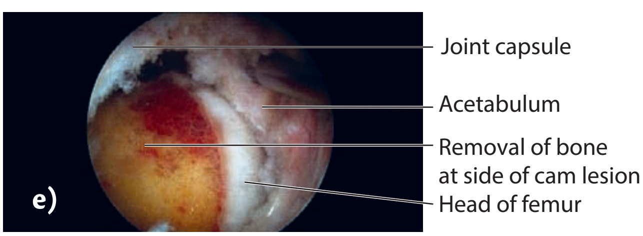


Figure 17.24 Femoroacetabular impingement (FAI) seen on X-rays and via arthroscopy before and after surgery with resection of the osteophyte. **a)** X-ray with the leg in frog position (Lauenstein position) before arthroscopic surgery; **b)** X-ray with the leg in frog position (Lauenstein position) after arthroscopic surgery; **c)** osteophyte on the femoral neck seen via arthroscopy,cam impingement; **d)** bone removed during surgery; **e)** end result after surgery. (Courtesy of Prof. Marc Safran, Stanford Universiy, California, USA.)

healing and rehabilitation are slow processes. Return to former activity level is often possible.

Stress fracture of the neck of the femur

Stress fractures (see p. 150) can occur in the upper part of the femur, neck of the femur or pelvis/pubic bone, typically in long-distance runners, as a result of prolonged and repeated load. Women that have an eating disorder, amenorrhea or osteoporosis (p. 22) are especially susceptible to this type of injury.

Symptoms and diagnosis

- Pain occurs while straining the hip joint and also aching in the joint after exertion.
- Pain upon movement of the hip joint.
- X-ray examination should be carried out when there is persistent pain in the hip region.
- A bone scan or an MRI can be useful, particularly in cases where there is a high risk of stress fractures.

Treatment

- Rest the leg until the fracture has healed, which usually takes 5–8 weeks, depending on the location of the fracture and the age of the injured athlete. Crutches may be necessary to reduce weight bearing.
- Return to sport is not considered until a complete healing is verified.
- If the fracture is located on the upper, outer part of the femoral neck, surgery should be performed. Stabilization with a nail or plate with screws, to

prevent malalignment at the site and the increased risk of necrosis of the femoral head.

Hernia

Inguinal and femoral hernias are relatively common ailments and can cause radiating pain diffusely in the groin area. An especially bothersome condition among some athletes is the so-called 'sports hernia'. This syndrome is characterized by a weakness in the back wall of the abdominal muscles (posterior inguinal wall) of the inguinal ring causing persistent groin pain. However, it is not a hernia in the clinical sense.

Inguinal hernia

An inguinal hernia is a protrusion that occurs in the peritoneum as a result of a weakening of the abdominal wall musculature and connective tissue layer in the openings of the inguinal canal where the spermatic cord passes through to the testicle (Fig. 17.25). This protrusion most often contains intestines and fat tissue, which produces a rounded bulge in the groin.

80% of hernias are inguinal. These are more common in men. An inguinal hernia can protrude at some point along the inner half of a line between the pelvis (pubic tubercle) and the forward bony projection of the iliac crest (anterior superior iliac spine). In some cases, the contents of the hernia become entrapped and cannot be pushed back and intense pain occurs. This is called a strangulated or incarcerated inguinal hernia and usually requires surgery as soon as possible.

Symptoms may include pain and discomfort in the groin associated with activity and when coughing, sneezing or straining. When a doctor examines an athlete for diffuse pain in the groin the inguinal hernia examination is included.

Inguinal hernia is normally treated with surgery, sometimes via an endoscope. The athlete can often resume their rehabilitative strength training 1–2 weeks after surgery but should not return to full strength training until at least 8–10 weeks afterwards, depending on the results.

Femoral hernia

Nearly 10% of all hernias are femoral hernias, which is a protrusion on the front of the upper thigh below the groin fold. The treatment is similar to that of inguinal hernia.

Sports hernia

Hernias are increasingly recognized as a cause of persistent groin pain, in the absence of other pathological findings. Sports hernia syndrome is assumed to be caused by a congenital weakness of the posterior wall of the inguinal channel, causing chronic groin pain, but without a clinically recognizable hernia.

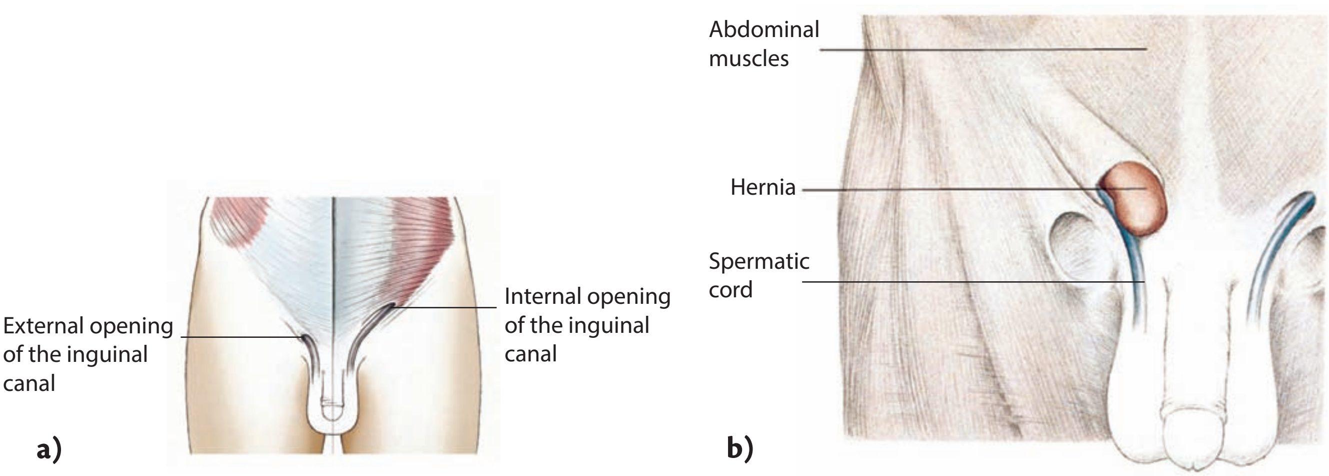


Figure 17.25 Inguinal hernia (hernia inguinalis). Hernia may result from a weakness in the abdominal muscles, which form the inguinal canal through which the spermatic cord passes from the abdomen down to the testis. **a)** The spermatic duct leaves the inguinal canal through the outer opening; to the right the anterior abdominal wall is removed and the inner opening of the canal is shown; **b)** a bulging hernia (inguinal hernia) can be seen by the outer opening of the inguinal canal; sometimes the hernia can extend down into the scrotum (scrotal hernia).

Symptoms and diagnosis

- The athlete experiences pain in the area while playing football/soccer, American football, hockey, team handball, etc. Long-range free kicks can cause discomfort as well as sprinting.
- Discomfort and pain increases gradually during activity.
- The pain is located deep in the groin region and may worsen. Symptoms may become so severe that ordinary running becomes impossible because of the pain, which can be sharp when doing quick changes of direction.
- The pain is usually worse on one side, but can sometimes radiate out to the sides or over the midline into the thigh along groin muscles and to the scrotum and testicles.
- Among the affected athletes 50% describe pain when coughing.
- Medical examination demonstrates tenderness especially over the pubic tubercle of the affected side.
- The scrotum is then invaginated and the inguinal rings palpated from the inside. The area around the external ring is tender but a protrusion can be felt in less than 10%.
- Since this condition is difficult to detect by clinical examination, a herniogram or a modified CT herniogram may be used for diagnosis.
- MRI is positive in 10–20%; however, with increasing experience, this figure is expected to increase.
- Dynamic ultrasound has been reported to be useful.

Treatment

- Operation, whereby the inguinal canal back wall is reinforced. This is done sometimes with the addition of an artificial net and in some cases with the help of laparoscopic surgery. These interventions have now become very common. The indications for these procedures vary, but some are performed for prevention.
- Reported results are excellent: 85–90% of athletes are considered able to return to their regular activity level within 3–8 weeks and for the remaining 10% their symptoms have improved. It should be noted that the follow-up of these operations is very poor and some decisive scientific studies are not available.

Incipient abdominal hernia

Groin pain with no clinical findings showing signs of hernias are usually associated with incipient hernias, which sometimes correspond to 'sports hernias'. These are hernias (plus the not fully developed hernias) within the abdominal wall that can cause pain radiating towards the groin. Soccer players can develop these incipient hernias on the side of the dominant leg. Herniography, in which contrast medium is injected into the abdomen and allowed to sink down into the hernia, may reveal this lesion. Herniography is very sensitive and the results must be carefully correlated with present symptoms. Operative treatment of these incipient hernias gives excellent results, with an early return to sports.

Hydrocele testis – accumulation of fluid around a testicle

A hydrocele is an accumulation of watery fluid around the testicle. It does not usually cause serious problems and is treated by draining the fluid. Large hydroceles may sometimes need surgical treatment.

Other testicular conditions that can cause symptoms in the groin area include tumors in the testicle, inflammation of the surrounding tissues, varicose veins in the scrotum and testicular torsion; this is more common in adolescents and is caused by the rotation of the testicle causing a strangulation of the circulation and needs surgery acutely.

Inflammation of internal organs

Appendicitis

Appendicitis is characterized by pain in the lower right-hand side of the abdomen and mild fever. Nausea and vomiting often occur and lifting the right leg exacerbates the pain. Symptoms that persist for more than a few hours should lead to urgent consultation with a physician. Return to sport is possible 3–8 weeks after surgery.

Gynecological disorders

Gynecological disorders can cause pain radiating to the groin area. They may include inflammatory conditions, infections and tumors.

Urinary tract infection

Such infections can cause pain radiating into the groin region. Urinary tract infections are characterized by a burning sensation during urination and frequent, urgent passage of urine that may smell unpleasant. The infection can cause pain that radiates to the groin region. Urinary tract infections should be evaluated by a doctor and treated with different antibiotics, active against the particular types of bacteria present in the urine. In general, the athlete should reduce his/her level of physical activity in the acute stage of the infection.

Prostate inflammation (prostatitis)

Inflammation of the prostate gland can cause pain radiating towards the groin. Difficulty in passing urine is common and is worse during cold weather. The condition must be examined by a physician and treated with drugs. Upon medical examination of athletes with groin problems rectal palpation should be routinely done (with a finger in the rectum).

Prostate cancer

During the last decades, the number of diagnosed cases has increased sharply. According to the World Cancer Report 2014 (World Health Organization) prostate cancer is globally the second most common cause of cancer and the fifth leading cause of cancer-related death in men. Prostate cancer mainly affects older men; in 99% of cases the patient is over the age of 50 years. One problem may be that this disease often grows slowly and it may take years before the first symptoms appear. However, there are some that grow relatively fast.

In the early stages prostate cancer does not usually show any symptoms. In later stages, the man can get a weak urine stream and more frequently feels the need to urinate. Blood in the urine may occur and should prompt further investigation. Sometimes, unfortunately, prostate cancer doesn't show any symptoms until it has spread outside the prostate gland to the bone, with pain in the back or hips. Weight loss, fatigue, anemia and the like may be early signs of prostate cancer.

Diagnosis is by rectal examination, with a finger in the rectum to feel (palpate) if the prostate is harder and bumpier. An elevated prostate-specific antigen (PSA) may indicate disease but is not definitive. The diagnosis can be confirmed with a biopsy using ultrasound imaging.

Treatment should be initiated promptly and can include surgery to remove the prostate gland, radiotherapy and/or hormone treatment or postpone treatment and keep it under observation. The treatment should be discussed with a specialist. In general, physical activity and sport can be conducted in parallel with treatment. The prognosis is usually good compared with other cancer types.

Other tumors

Tumors are not uncommon in the groin region and can cause pain and aching that may first appear during sporting activity. Other symptoms are similar to those caused by overuse injuries and ruptures of muscles and tendons, and when they are persistent examination sometimes reveals a tumor as the cause. The rectum should also be examined thoroughly.

Sciatica

Pain radiating to the groin and down the thigh may be caused by the L4 syndrome of sciatica (p. 345).

Nerve entrapment, nerve compression syndrome

Compression of the nerves in the groin is usually due to local anatomical conditions. The nerves in question are primarily the ilioinguinal and iliohypogastric nerves, the genitofemoral nerve and the lateral cutaneous femoral nerve of the thigh, which all supply skin areas around the groin folds, and also the anterior cutaneous femoral nerves of the thigh and the obturator nerve (Fig.17.26).

The ilioinguinal and iliohypogastric nerves run zigzag through the three layers of the lower abdominal wall muscles. They supply the lower abdomen and the skin

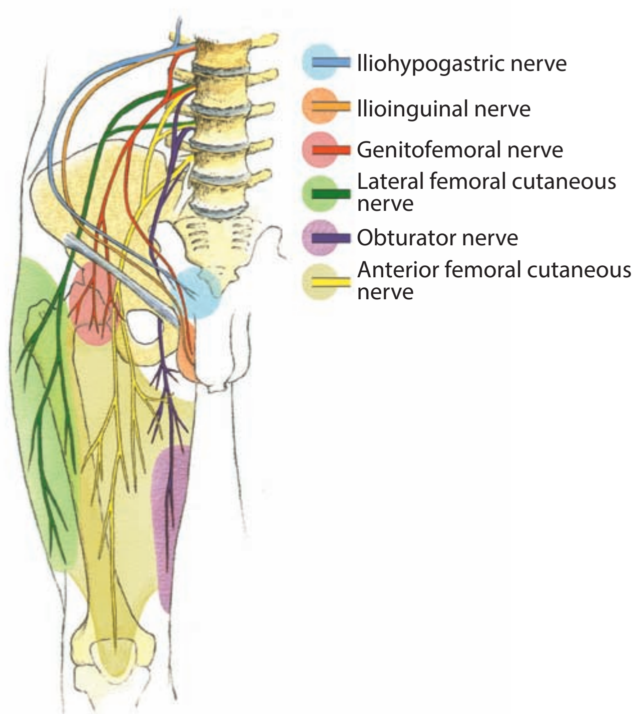


Figure 17.26 Direct pressure on nerves (compression, entrapment) in the groin area is common.

just above the penis and scrotum or labia, and the inside of the thigh. The intensity and character of the pain varies. Numbness or increased sensitivity in the area can be demonstrated by scratching a needle lightly over the skin from a painless to a painful area, and the diagnosis can be confirmed by injecting local anesthetic solution around the nerve. When symptoms are severe and persistent, a local cortisone injection and then surgery such as neurolysis (relief of tension/compression upon a nerve) are sometimes resorted to.

Symptoms and diagnosis

- Pain in these areas should lead to suspicion of pressure on the nerve. Pain intensity and character varies.
- Pain after activity is characteristic.
- Weakness in the groin muscles (adductors) can be experienced.
- Increased sensitivity of the area is demonstrated by pulling a needle over the skin of a pain-free to painful area.
- Diagnosis can be confirmed by:
  - ✓ injecting local anesthetic over the nerve;
  - ✓ electromyography (EMG) can be positive.

Treatment

In case of severe, long-term pain, surgery may sometimes be resorted to, in which the nerve is released after local cortisone injection. The genitofemoral nerve supplies a skin area just below the groin fold and also parts of the external sexual organs, while the lateral cutaneous femoral nerve of the thigh, as its name suggests, supplies the anterior lateral part of the thigh. Symptoms and treatment in cases of pressure on these nerves are the same as those outlined above for pressure on the ilioinguinal nerve. The rehabilitation time is 3–4 weeks.

Piriformis syndrome

Pain around the back of the pelvis and in the piriformis muscle may be a consequence of piriformis syndrome. Compression of the sciatic nerve as it passes through the piriformis muscle has been suggested as a cause of groin pain. The patient feels pain in a sitting position and then rotates the hip inward. Pain is experienced when the examiner internally rotates and extends the thigh forcefully (Pace sign). In MRI a thickened and inflamed nerve is seen. Treatment consists of anti-inflammatory medicine and possibly a cortisone injection.

Physical therapy is usually necessary. When there is long-term pain and conservative treatment has not given a good result, an operation separating the piriformis muscle can give acceptable results. This method of operation may be resorted to even if the nerve and muscle have not shown any major deviations.

Hamstring syndrome

Pain localized to the distal part of the buttocks at the hamstring origin can be caused by compression of the sciatic nerve by the hamstring muscles (hamstring syndrome). The characteristic complaint is pain in the sitting position. This syndrome has been found among runners, especially sprinters and hurdlers, while long-distance runners seem to have no problems from this injury. Soccer players and active athletes in other explosive sports may have this syndrome.

The clinical findings include:

- Pain in the buttock, sometimes radiating down the leg, which is aggravated with activity.
- Hamstring contraction against resistance will cause pain in the buttock.
- Sometimes tenderness is present.

The treatment is conservative as long as possible, using functional movements and stretching. Surgical excision of damaged tissue and freeing of the nerve may occasionally be indicated. For hamstring ruptures, see p. 385.

Sacroiliac dysfunction (inflammation of the sacroiliac joint)

Inflammation of the joint joining the pelvis and the sacrum (sacroiliac joint) is not uncommon as an isolated condition among athletes participating in winter sports. It can also be part of generalized disease, such as Bechterew's disease. In sports, sudden violent contractions of the hamstrings or abdominal muscles with severe direct load to the buttocks or forceful straightening from a crouched position, can generate forces to the sacroiliac joints that may cause injury and pain at a later stage. The main symptom of this syndrome is pain and tenderness in the region.

Symptoms and diagnosis

There are several ways to examine the status of the sacroiliac joint. One way is the three-step examination. With the patient lying face down (prone position), the examiner works upwards and examines first the hip and iliopsoas muscle, then the sacroiliac joint and finally the low back.

1. The first step consists of the hip joint stretched in extension with the knee bent and pressure placed on the buttocks.

2. The second step is the same for the hip but the examiner places pressure on the sacrum, so that a further extension of the hip will increase the effect on the sacroiliac joint.
3. In the third step the examiner places pressure in the junction between the sacrum and low back with the hip again in extension. If the patient feels discomfort or pressure over the pelvic ring it may indicate that there are pathological changes in the sacroiliac joint.

- Vague symptoms include aching and stiffness in the lower part of the lumbar region. These are most pronounced in the morning and after periods of inactivity. The symptoms can come and go, with long periods free from problems being typical.
- The aching can radiate towards the back of the thigh, the hip joint or the groin. Changes in the sacroiliac joint can, however, be painless.
- Inflammation of the sacroiliac joint can sometimes be combined with inflammation of other joints, e.g. the knee and ankle.
- A raised erythrocyte sedimentation rate (ESR) occurs along with other blood level changes typical of inflammatory disorders.
- An X-ray or CT scan may show osteophytes, which can be a sign of pathologic changes.

Treatment

Many different treatments have been tried, but the success rate depends on whether the diagnosis is accurate or not. Anti-inflammatory medication and occasionally steroid injections may help. Bechterew's disease (ankylosing spondylitis) can also affect the sacroiliac joint causing vague and diffuse symptoms.

The physician may:

- Prescribe anti-inflammatory medication.
- Prescribe physiotherapy.
- Recommend a lumbar heat retainer.

It should be noted that home training is crucial for the future outcome. In order for the training to be effective, the athlete must know how to exercise. The symptoms are prolonged, but the condition is considerably more benign in women than in men.

Lateral hip discomfort, trochanteritis (inflammation and calcification of the greater trochanter)

Some of the large muscle groups of the buttocks have their attachments to the greater trochanter of the femur in the upper, outer (lateral) part of the thigh. An irritant inflammatory condition can be found in the muscle attachment of the gluteal muscles in cross-country running and orienteering, for example.

Symptoms and diagnosis

- Pain occurs over the upper part of the femur on the lateral aspect of the hip.
- Tenderness occurs when applying pressure over a small area around the greater trochanter.
- Pain is elicited by actively pressing the leg outwards (abduction) against resistance.
- An X-ray examination sometimes reveals calcification in the area.
- Ultrasound or MRI scans may show soft tissue pathological changes.

Treatment

The athlete should:

- Rest initially until pain free, then gradually return to activity as tolerated.
- Apply local heat and use a heat retainer.

The physician may:

- Prescribe anti-inflammatory medication.
- Prescribe an exercise program (p. 383).
- Administer a steroid injection combined with prescribed rest.

Trochanter bursitis

Over the upper lateral part of the femur, beneath the fascia latae, lies a superficial bursa, with a deeper one between the tendon of the gluteus medius muscle and the posterior surface of the greater trochanter (Fig. 17.27).

The injury mechanism is often a fall or blow to the hip; bleeding can occur in the superficial bursa (hemobursa, p. 185). A small quantity of blood in the bursa will self-absorb but a large amount tends to become blood clots. These clots gradually transformed into loose bodies or adhesions that give rise to inflammation and accumulation of fluid. Inflammation caused by friction and overuse can affect either bursa, and is a more common cause of pain than hemorrhagic bursitis. An excessive pronation of the foot and other malalignments (pronation, p. 540) can contribute to overuse in this region.

Symptoms and diagnosis

- Functional pain is prominent while running.
- Intense pain is caused by swelling and inflammation, which rarely resolves spontaneously, so medical attention should be sought.
- Local tenderness occurs over the upper, lateral part of the thigh.

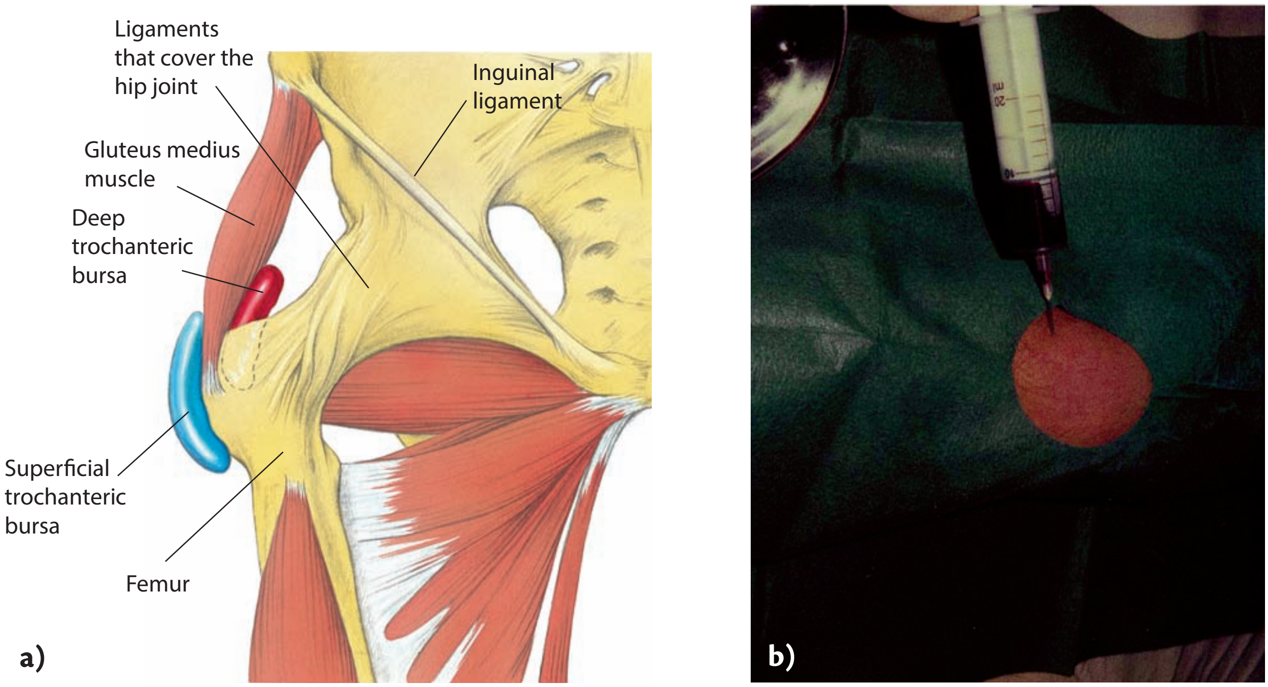


Figure 17.27 **a)** Anatomy at the upper lateral part of the femur (trochanter region); **b)** puncture of the superficial bursa located at the upper lateral (trochanter), which is aspirated for blood (hematoma) after an acute trauma towards this part. An untreated hematoma can result in a chronic inflammation (chronic bursitis).

- Pain can be elicited by passive adduction (of the leg) at 90° of hip flexion.
- Pain and discomfort cause impaired function and limping. Sometimes snapping can be felt.
- Pain can radiate down the thigh at night.
- Loose bodies and adhesions in the bursa can give rise to crepitus (crunching sensation) during hip movements and can sometimes be felt as small, mobile hard beads when the skin overlying the bursa is palpated.
- To confirm the diagnosis the physician may ask the athlete to lie down on their healthy side and raise the leg (abduct) on the tender side. This compresses the bursa, resulting in severe pain. If the same movement is carried out against resistance, the pain increases.

Treatment

The athlete should:

- Rest the injured area.
- Perform ice therapy on the hip for several days.
- Run on even surfaces.

The physician may:

- Prescribe foot orthotics if, for example, excessive foot pronation is present.
- Prescribe anti-inflammatory medication.
- Aspirate and drain the bursa in cases of bleeding or extensive accumulation of fluid (Fig. 17.27B).
- Administer a steroid injection.
- In cases of prolonged problems not responding to conservative therapy, operate to remove loose bodies and any adhesions in the bursa. Usually the bursa itself is also excised.

Hip complaints in children and adolescents

Perthes' disease

Perthes' disease afflicts children between the ages of 3 years and 11 years. Its precise cause is unknown. The bone structure of the head of the femur becomes deformed and flattened due to lack of blood flow to the head of the femur (osteonecrosis). The child complains of tiredness and of pain in the groin and sometimes the knee, and a limp is present. The diagnosis is made by X-ray examination, bone scan and MRI. Depending on the severity of changes in the femoral head, the treatment varies from surgery to none at all. The healing process is prolonged. Although Perthes' disease only affects the hip joint, pain is sometimes absent from that joint and is felt instead in the knee, which is why X-rays should be taken of both knee and hip joints. Children with this condition usually have to avoid jumping and high impact activities.

Femoral head epiphysiolysis

A slippage of the growth plate at the neck of the femur (epiphysiolysis) occasionally affects boys aged 11–16 years. Pain begins in the groin region, but, as is usual in hip disorders, is also felt in the knee. It can be triggered by sporting activity. It is important that young people who complain of this type of symptom should be X-rayed to exclude the possibility of slipped epiphysis. Surgery is usually required.

Synovitis of the hip

Acute pain in the hip in children is usually caused by an inflammation (synovitis) of the tissues around the hip joint. Symptoms are progressive pain from the hip joint and unwillingness to use the hip and sometimes even pain when walking – which can result in a persistent limp. Inflammation of the hip joint is usually seen mainly in children under the age of 10 years and is considered to be a benign, self-healing disease, which should be examined and treated in hospital.

Tip

Pain that the child locates to the knee can be caused by a hip problem.

Hip disorders in children and adolescents described above should be distinguished from serious conditions such as bone infection (osteomyelitis), tuberculosis, rheumatic diseases and tumors.

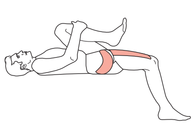
Rehabilitation of hip, pelvis, groin and thighs

It should be noted that the rehabilitation of the hip, pelvis, groin and thighs are included together since the muscles in this area interact. Pain around the pelvis, hip and thigh involves the body's major muscle groups, which can lead to disability that may require a long rehabilitation. The cause of pain must be defined since the pain may be associated throughout the extremity from the foot to the hip joint. Frequently rehabilitation exercises of the hip and pelvis is proprioception training.

Mobility training for the hip joint

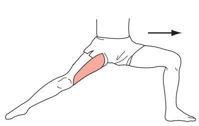
Stretching of the hip flexors (iliopsoas)

Kneel on your right leg, with the left foot remaining on the floor. Rotate right foot outward and simultaneously bend to the side to the left.



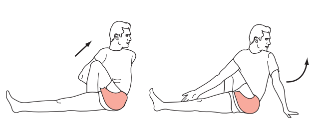
Thomas stretch (iliopsoas)

- Sit on the edge of a table or foot end of an examination table.
- Pull one knee up to the chest and hold it with both hands.
- Lie down and then let one leg hang over the edge. A stretch should be felt in the front of hip. Do not arch your back.
- Hold for 20 seconds, repeat 5–6 times.



Lunge movement to the side (adductors)

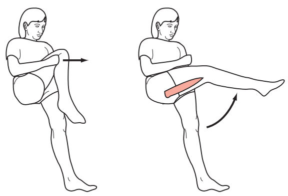
- Stand with legs wide apart and straight body.
- Place the body weight on one leg, bend at the knee on the same side and keep the other leg straight. A stretch should be felt on the inside of the thigh.
- Hold for 20 seconds, repeat 5–6 times.



Rotational hip stretch (gluteal muscles)

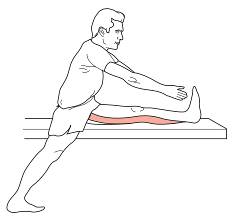
- Sit with your right leg stretched forward and the left crossed over the right leg with foot on the floor.

- Place the inside of the right elbow around the left knee and pull your left knee up toward your right shoulder. The stretch should be felt over the left side of the gluteal muscles.
- Hold for 20 seconds, repeat 5–6 times. Repeat on other side.
- Variation (erector spinae and gluteal muscles): in the same position, you can also press the left knee away from you and turning your body to the left. This stretch is felt in the back.
- Hold for 20 seconds, repeat 5–6 times on each side.



Piriformis stretch (piriformis, gluteal muscles)

- Lie on your back with knees bent and feet on the floor.
- With the opposite hand, grab onto the knee.
- Pull the leg diagonally upwards across the chest toward the opposite shoulder.
- Hold for 20 second, then relax.
- Repeat with other leg.

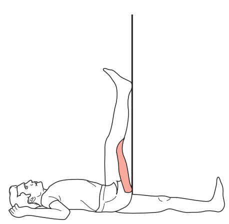


Seated stretching of hamstring (hamstrings muscles)

- Sit on the long side of an examination table or the like, with one leg extended along the table top and the other leg off the edge on the ground.
- Bend forward at the hip, towards your toes, until a stretch is felt on the back of the thigh. Be sure to keep your back straight.
- Hold for 20 seconds, repeat 5–6 times.

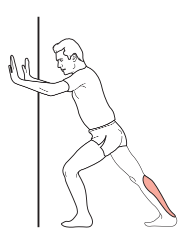
Active mobility training of the hamstrings

- Lie on your back on the floor with one leg stretched along the floor and the other leg held with hands on the thigh pointing towards the ceiling.
- Bend and straighten the leg actively towards the ceiling.
- Repeat 3 sets of 15 repetitions



Diagonal stretch against wall (hamstrings muscles)

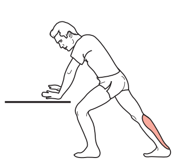
- Lie on your back on the floor, with one leg through a door-opening and the other leg up against the wall with straight legs.
- Gradually move closer to the wall and let the straight leg glide upward until a stretch is felt in the back of the thigh. Be careful not to rotate the hip or bend the knee.
- Hold for 20 seconds, repeat 5–6 times.



Stretching of calf muscles

Outer layer (gastrocnemius)

- Stand a step from a wall with nose pointed towards the wall.
- Place one foot in front of the other.
- Keep the back leg extended, heel on the floor, toes pointing straight ahead.
- Place hands against the wall and lean forward until a stretch is felt in the back of the knee.
- Hold for 20 seconds, repeat 5–6 times.

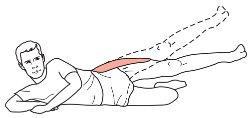


Deeper layer (soleus)

- Do as above but with a slight bend in the knee of the back leg. The stretch should be felt somewhat further down in the calf.
- Hold for 20 seconds, repeat 5–6 times.

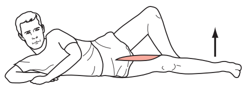
Basic exercises for strength training of muscles around the hip joint

All exercises should be performed slowly and controlled. Resistance can be added by using ankle weights or elastic bands. Do 2–3 sets of 10–15 repetitions.



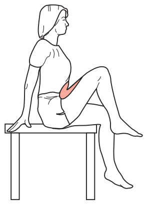
Hip abduction (gluteus minimus/maximus)

- Lie on the good side, and slowly lift the injured leg sideways, straight up.
- Hold for 5 seconds and return slowly.
- Repeat 3 sets of 10.



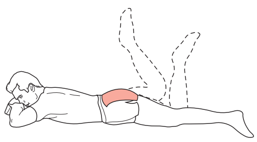
Hip adduction (groin muscles)

- Lie on the injured side, slide the good leg behind the injured.
- Raise the injured leg up about 15 cm (6 in.) off the floor.
- Hold for 5 seconds and return slowly. Repeat.
- Options: lie on your back with a ball that is soft, about the size of a soccer ball, between the legs. Squeeze the ball and hold for 10 seconds.
- Repeat 3 sets of 10 (see Hölmlich hip exercise).



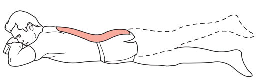
Hip flexion (rectus femoris, iliopsoas)

- Sit with legs hanging over the edge, with a 90° flexion of the knee and hip.
- Lift a straight leg up in the air by bending at the hip.
- Hold for 5 seconds and return slowly. Repeat.



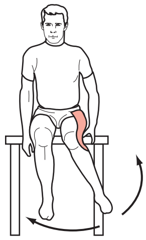
Gluteal extension (gluteus maximus)

- Pelvic lift: lie on your back with legs bent 90°.
- Lift your pelvis off the floor. Hold for 10 seconds. Repeat 3 sets of 10 repetitions.



Hip extension (hamstrings, gluteus maximus)

- Lie on your stomach with your legs straight.
- Lift the injured leg at the hip, keep the leg straight all the time.
- Hold 5 seconds return slowly. Repeat.



Inward /outward rotation of the hip (inward/external rotators)

- Sit on a table with the knees on the edge and bent.
- Rotate the lower leg from the hip by swinging the leg outwards, hold for 5 seconds.
- Return slowly and then rotate inwards, hold for 5 seconds, return slowly. Repeat.
- Standing hip exercise: standing on one leg, place a rubber band around the other leg's ankle. By changing the direction of the support leg, load the leg with resistance in that direction of movement making use of several different directions (N, S, E, W).
- Perform 3 sets of 10 repetitions.
- Maintain a neutral spine; do not compensate to get more ROM.
- Training on a sliding board is beneficial for groin injuries.

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18

Thigh Injuries in Sport

The thigh includes a major bone, the femur, which is surrounded by three major compartments of large major muscle groups separated by fascia (connective tissue membranes). The medial compartment contains the adductors, the posterior compartment, the hamstrings and the anterior compartment, the quadriceps. Injuries to the thigh muscles are relatively common in sports; tears and ruptures in the thigh muscles are common in sports with explosive movements and starts, as in soccer, football and the sprints done in long jumping and throwing events, where a fast approach is necessary. The hamstrings (muscles on the back of the thigh, which partly extend the hip and bend the knee joint) are particularly affected.

Injury to the hamstring is now the most common injury in sports such as soccer, track and field sprints, American and Australian football and rugby. Hamstring injuries often cause a long absence from the sport on the elite professional level (see below).

Pain in the thigh can also be caused by stress fracture, compartment syndrome and referred pain. Indistinct pain in the thigh may be due to stress fracture or sciatica (see p. 344).

Muscle injuries to the posterior side of the femur

Hamstring ruptures

The hamstring muscles (biceps femoris, semimembranosus and semitendinosus) act as flexors of the knee joint and as extensors of the hip. However, the short head of the biceps (caput brevis) acts mainly as a flexor of the knee. The lateral hamstrings (biceps femoris) also act as an external rotator of the tibia and the medial hamstrings (semimembranosus and semitendinosus) act as internal rotators of the tibia. Complete tears (ruptures) usually occur at the muscle–tendon junction, or at their insertion (Fig. 18.1).

It should be noted that the hamstring muscles have a muscle–tendon junction almost the entire length of the muscle, since there is a tendinous connective tissue sheet (aponeurosis) that runs through the entire length of the tendon. The semitendinosus muscle also has transverse band-shaped tendinous structures in the muscle belly, which constitute weak areas in the muscle (see below).

A hamstring injury occurs as a result of overload during an excessive muscle contraction while the knee flexes and hip extends. Sprinters have an incidence of hamstring injuries of 0.87/1,000 hours of activity. Players competing in contact sports such as soccer, American and Australian football and rugby are especially vulnerable to this type of muscle damage and have an incidence of 0.92–0.96/1,000 hours of activity. Badminton and tennis players can also be affected, but serious total ruptures, however, are most common in water skiing (Fig. 18.2).

Injury mechanism

There appears to be two types of activities that cause hamstring injuries, each with a different prognosis:

1. Injuries that occur when running at high speed: this type of injury is mainly localized in the long head of the biceps femoris. Return to sport is possible within an average of 16 weeks.
2. Damage during slow hip flexion with stretched knee, e.g. in dancers. This type of injury is located near the origin of the hamstrings on the pelvis bone (ischial tuberosity). The injury involves the adductor

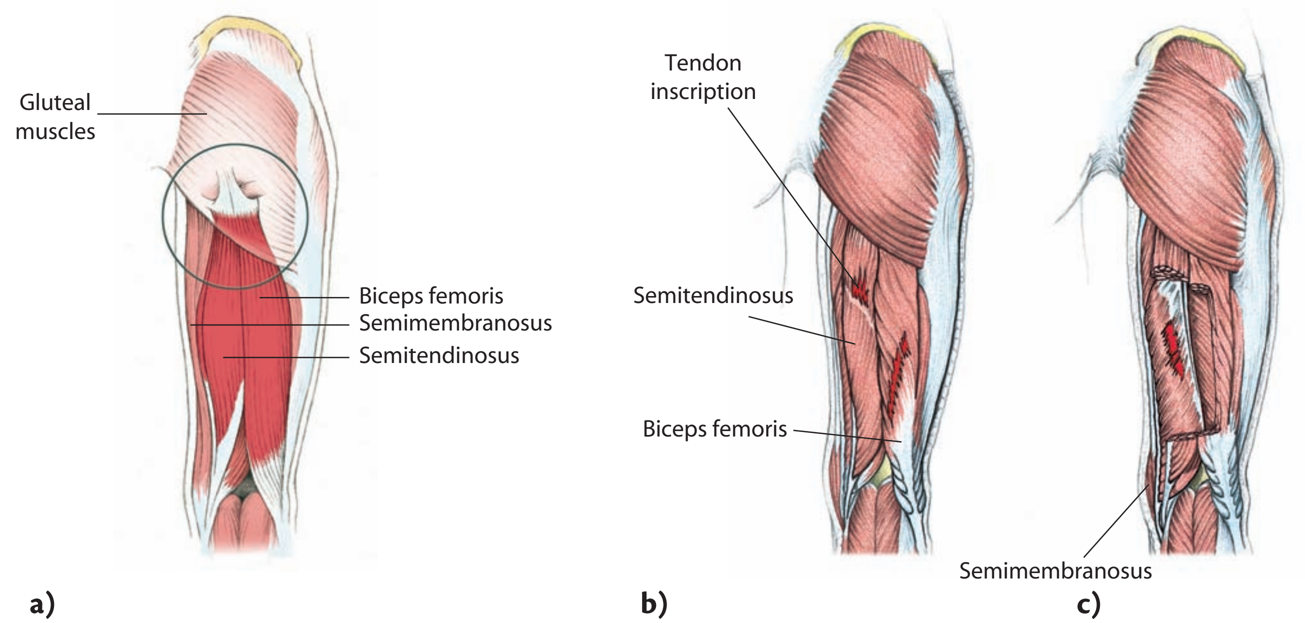


Figure 18.1 Hamstring muscles on the posterior side of the femur. **a)** Anatomical illustration showing the medial two hamstring muscles: semimembranosus and semitendinosus, and the lateral biceps femoris muscle. The most common injury location for a total rupture of the hamstrings are at the origin on the pelvis (ischial tuberosity) (see the circled area); **b)** frequently injured areas of the semitendinosus and biceps femoris are at the muscle–tendon transition. Ruptures can occur in the semitendinosus where the tendon transverse inscriptions are angled obliquely; **c)** common localization of tears of the semimembranosus muscle–tendon transition in the middle and lower part of the thigh.

Figure 18.2 Hamstring injuries are currently a very common problem in many sports. **a)** Water skiers are very vulnerable to total hamstring ruptures (with permission, by Bildbyrån, Sweden); **b, c)** partial hamstring tears are common in other sports.

magnus (33%) in addition to the semimembranosus and quadratus femoris (87%). Return to sport is possible within an average of 50 weeks.

Localization

Hamstring injuries usually occur isolated to the biceps femoris and thereafter in combination with the semimembranosus in 66% of cases. Multiple injuries involving the biceps femoris and semitendinosus represent 33%. When all three hamstring muscles are involved at the same time the injury occurs at or near the origin of the ischial tuberosity.

Ruptures can occur anywhere within the long muscle–tendon junction because the tendon overlaps the muscle along the entire muscle course (except for the semitendinosus transition, where the transverse

Tip

This means that a rupture can occur almost anywhere along the course of the hamstring muscles.

band-shaped tendinous structures are the weak areas, where ruptures occur).

Symptoms and diagnosis

- There is typically a history of the athlete noticing a 'bang' in combination with a sudden onset of intense pain in the posterior thigh muscles associated with explosive activity. It feels like 'being stabbed by a knife'.
- The pain may be severe when doing movements that engage the muscle in question. It is important to examine if there is a radiating pain to ensure that the pain is not from, for example, the back or nerves. If this is the case the radiating pain must be analyzed closely to determine their effect on different sciatic nerve roots (see sciatic syndrome, p. 344).
- Magnetic resonance imaging (MRI) may be helpful. If there are still difficulties in distinguishing these syndromes from a hamstring injury, the patient should be further examined.
- A detailed clinical examination should be performed within 1–2 days; this can determine where the damage is localized and which muscles are involved.
- Posture and gait should be inspected.
- Local tenderness upon palpation of the muscle belly is found when the athlete is standing in a stooping position or with the athlete prone. Palpation should be performed both during muscle relaxation and muscle contraction (Fig. 18.3A).
- The hematoma may reach the skin after a few days, causing sometimes a rather extensive discoloration often distally below the injury (Fig. 18.3B).
- Sometimes a palpable defect can be present in the muscles, especially the more extensive ruptures, although this is not typical for a minor injury.
- Testing the active and passive range of motion (ROM) can provide valuable information. In general, mobility is significantly reduced compared with the healthy leg. In the acute phase ROM may be pain related when the athlete bends the knee and extends the hip against resistance; in the later phase the ROM can be affected by scarring tissue.

Figure 18.3 Injuries to the upper part of the hamstring muscles. Local tenderness on palpation of the muscle belly. The finger shows the hamstring muscles origin on his leg (ischial tuberosity). The athlete should be examined in the prone position.

- Manual muscle testing is performed. The strength can be tested during knee flexion, knee extension, hip extension and hip flexion against resistance. It is useful to compare with the other side (Fig. 18.4).

Imaging – MRI and ultrasound scans

In the acute phase MRI and ultrasound examination are considered to be equally valuable. MRI is more sensitive in identifying minimal damage where less than 5% of the muscle is involved (Fig. 18.5). The main advantages and disadvantages in terms of imaging are presented in Table 18.1.

In summary, ultrasound provides better resolution (spatial resolution) compared with MRI and it allows functional and dynamic evaluation of the muscles and tendons. It has the capability to combine a physiological evaluation of blood flow, is well tolerated and non-invasive. Ultrasonic imaging equipment is today very small and light and is available in the size of a cigarette pack. However, the use of contrast in soft tissues works as well in ultrasound as with MRI.

Imaging should be performed within 1–2 days after the injury occurred because the size of the swelling is at its maximum after 24 hours and starts to decrease after 48 hours. The grading of a hamstring injury is considered to be best 48–72 hours after the injury has occurred, which is the reasoning for the recommendation that an MRI or an ultrasound should be performed within this time.

Figure 18.4 Manual muscle testing is performed in the prone position. **a, b)** Flexion of the knee against resistance is a test of the hamstring function; **c)** extension of hip against resistance with straight knee; **d)** hamstring muscles in the relaxed state; **e, f)** hamstring muscles are tested against resistance and swelling may be detected in the injured area of the tendinous transverse inscription in the middle of the semitendinosus.

Table 18.1 Comparison between magnetic resonance imaging (MRI) and ultrasound, i.e. advantages and disadvantages of the imaging of hamstring injuries.

	MRI	Ultrasound
Low cost	-	+
Sensitivity for clinician's experience and quality	-	++
Simplicity of use	++	+
Assessment of prognosis	+	+/–
Avulsion fractures diagnosis	+	+/–
Reproducibility	++	+/–
Dynamic evaluation	-	++
Availability	+/-	++
Assessing the extent of damage	++	+/–
Examination time length	+/–	++
Follow-up examination	++	+

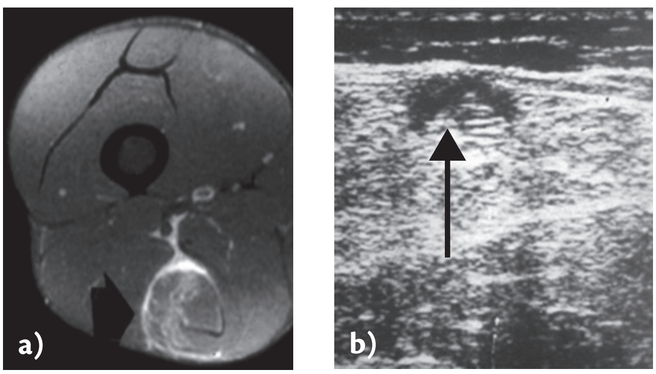


Figure 18.5 Imaging (MRI) **a)** showing intramuscular injury with intermuscular bleeding (courtesy of Magnus Tengvar, Sophia Hospital, Stockholm) and **b)** ultrasound of injured hamstring muscle. Arrow indicates location of tear.

Tip

Ultrasound has many advantages:

- Ultrasound is cost effective and easy to transport even to the point of having it on site.
- Above all, dynamic examinations can be performed.
- Overall, this means that ultrasound is likely to be increasingly used in the field of Sports Medicine.

It should be noted that a fairly large number of suspected hamstring injuries are not seen on MRI. In these cases it probably comprises non-detectable tissue damage or minimal muscle fiber rupture and one must then exclude pathological changes in the spine or other neurological pain causing the radiating pain.

These types of injuries are characterized by a gradual onset of pain and usually require a shorter rehabilitation period, often 6–8 days, compared with an MRI-verified injury that has an average of 20–23 days before return to sport.

Tip

Posture, gait, palpation of the muscle belly, ROM, manual muscle testing and tests for radiating pain within 2 days after the occurrence of the injury have been identified as the most relevant diagnostic factors.

In elite athletes it is recommended to perform a follow-up study with MRI or ultrasound if the hamstring injury has not healed within 4–6 weeks. This is important for monitoring the healing and rehabilitation progress and to support a proper assessment before returning to sport (Fig. 18.6).

Treatment

- The acute care phase should include 2–4 days of immobilization as this improves muscle regeneration.
- Rest, apply ice, compression and elevation (possibly crutches) for 3–5 days.
- After 2–5 days, start a training program, which includes stretching. Early mobility training ensures a good orientation of the collagen fibers and good filling of the gap between ends of the rupture. As the pain decreases and ROM increases, the program progresses.
- The continued treatment is usually conservative; it should be initiated early and be well planned in phases (see p. 383).
- In the case of total ruptures, surgery should be considered at an early stage.

Muscle injury grading

Muscle ruptures are sometimes divided into three different degrees according to the severity of the injury:

- Grade I and II muscle ruptures are partial muscle injuries.
- Grade I injury is a minimal injury with muscle damage <5% of the muscle's volume being involved. Grade I heals within a time period of about 1–2 weeks.
- Grade II injury consists of damage in 5–50% of the muscle's volume. Both Grade I and II are treated conservatively with prompt rehabilitation initiated after a few days. Grade II heals within a time period of about 3–12 weeks. However, an extensive hematoma can make a difference and may need surgery.

- Grade III injury is usually a complete rupture or an avulsion fracture. This should be treated surgically if the injury affects the function and/or causes great discomfort or gives rise to an extensive hematoma. Emergency surgery should be performed on active individuals that have an acute total rupture of the hamstrings. Healing time can range from 3–12 months.

A four grade classification system has also been published based on the ROM after 48 hours.

Prognosis and return to sport

- Prognosis for hamstring injury is based on a proper grading as mentioned above.
- Injury location has also been proven to be important for the prognosis:[1]
  - ✓ injuries localized near the origin of the hamstrings on the pelvis (ischial tuberosity) also occur as mentioned above, by slow hip flexion with the extended knee, e.g. in dancers; this injury leads to a slow return to the activity (31–50 weeks);
  - ✓ injuries located on the long head of the biceps femoris occur when running at high speed; return to sport is possible at an average of 16 weeks.

Tip

The injury mechanism and injury severity are important prognostic factors. It should be noted that the clinical assessment is more certain in predicting the time for return to sport, compared with MRI.

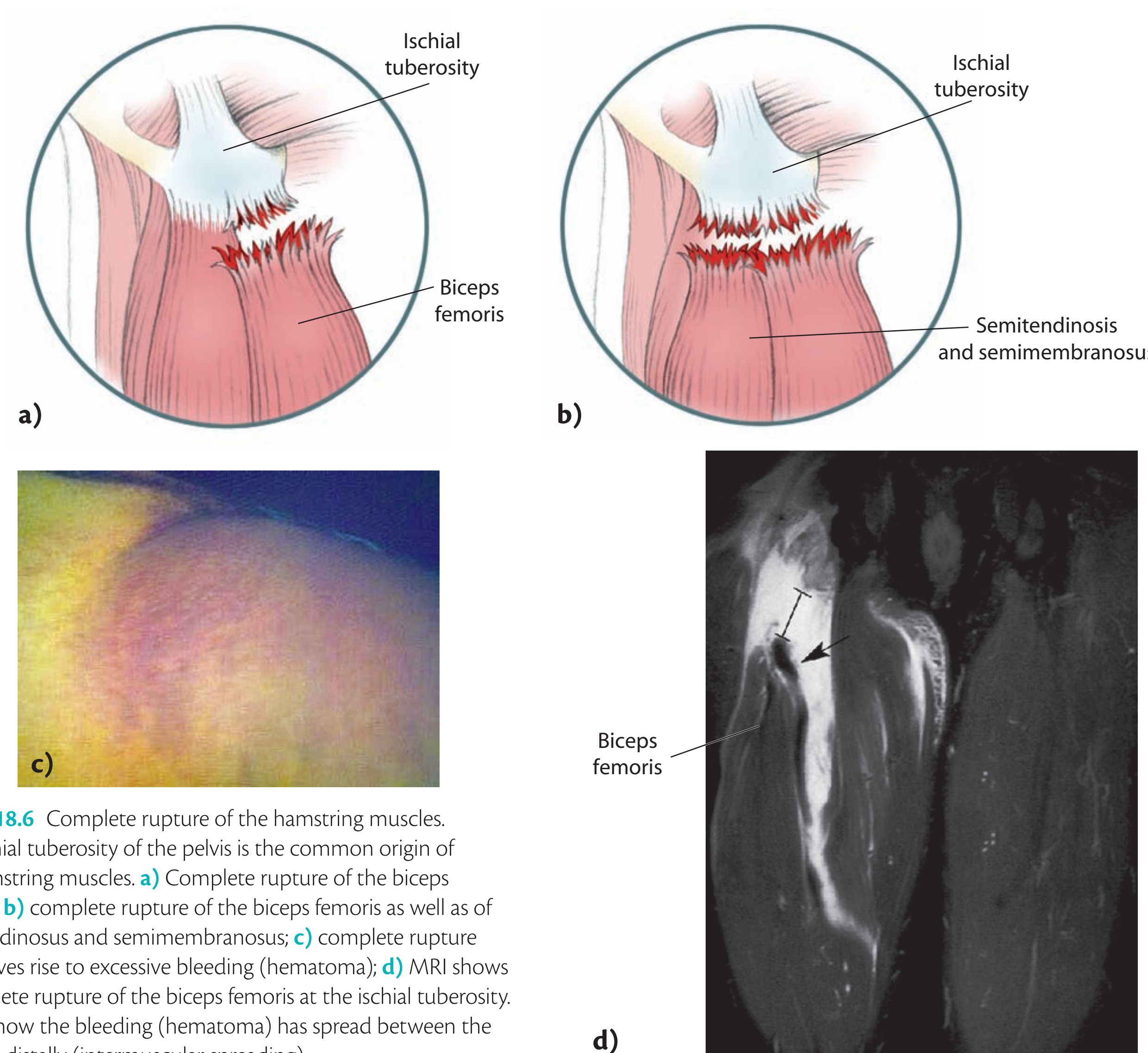


Figure 18.6 Complete rupture of the hamstring muscles. The ischial tuberosity of the pelvis is the common origin of the hamstring muscles. **a)** Complete rupture of the biceps femoris; **b)** complete rupture of the biceps femoris as well as of semitendinosus and semimembranosus; **c)** complete rupture often gives rise to excessive bleeding (hematoma); **d)** MRI shows a complete rupture of the biceps femoris at the ischial tuberosity. Notice how the bleeding (hematoma) has spread between the muscles distally (intermuscular spreading).

Recurrent injury

- It is common for hamstring injuries to recur after a period of rehabilitation or return to sport (recurrence rate 12–43%); Sports Medicine staff should improve their performance in this regard.
- Risk factors include the athlete's age and previous injury.
- An injured player has a 2–3 times higher risk of getting a new hamstring injury.
- If the injury is not completely healed and rehabilitated and return to sport occurs too early, there often occurs a re-injury to the same place.

Tip

It is necessary to have proper respect for a hamstring injury and not accept a return to sport before the injury is proven healed and the athlete well trained and in balance.

Injury to biceps femoris muscle

The two-headed muscle of the hamstring muscles (biceps femoris) is the most commonly injured muscle of the hamstrings. It is located on the posterior side of the thigh bone (femur) on the lateral side and bends the knee joint but also extends the hip. The biceps femoris muscle is thus strong in knee flexion, and it may suffer partial or total rupture as well as overuse injuries. When the injury is in the knee area, it is mostly at the muscle–tendon junction or tendon attachment to the fibula, where there may be an avulsion where bone fragments can be displaced. The injury often occurs in combination with a rupture of the lateral collateral ligament (LCL). The injury commonly affects athletes in contact sports, wrestlers and track and field, etc.

Symptoms and diagnosis

- Local tenderness and swelling occur at the insertion of the biceps into the posterior aspect of the fibula head and/or the muscle–tendon junction on the posterior distal aspect of the thigh (Fig. 18.7).
- Pain occurs when the knee joint is bent against resistance.
- Muscle function is absent in cases of complete rupture.
- In cases of injury due to overuse a typical pain cycle is present.
- An X-ray examination can sometimes show that fragments of bone have been torn loose from the fibula head. An MRI scan will confirm the diagnosis.

Treatment

The athlete should:

- Apply ice and compression bandage in the acute phase.
- Rest, apply local heat, and use a heat retainer until there is no pain during exertion.
- Perform strength training and stretching after the acute phase.

The physician may:

- Prescribe anti-inflammatory medication.
- Apply a cast in rupture cases.
- Perform surgery when there is a total rupture or displaced bone fragment.

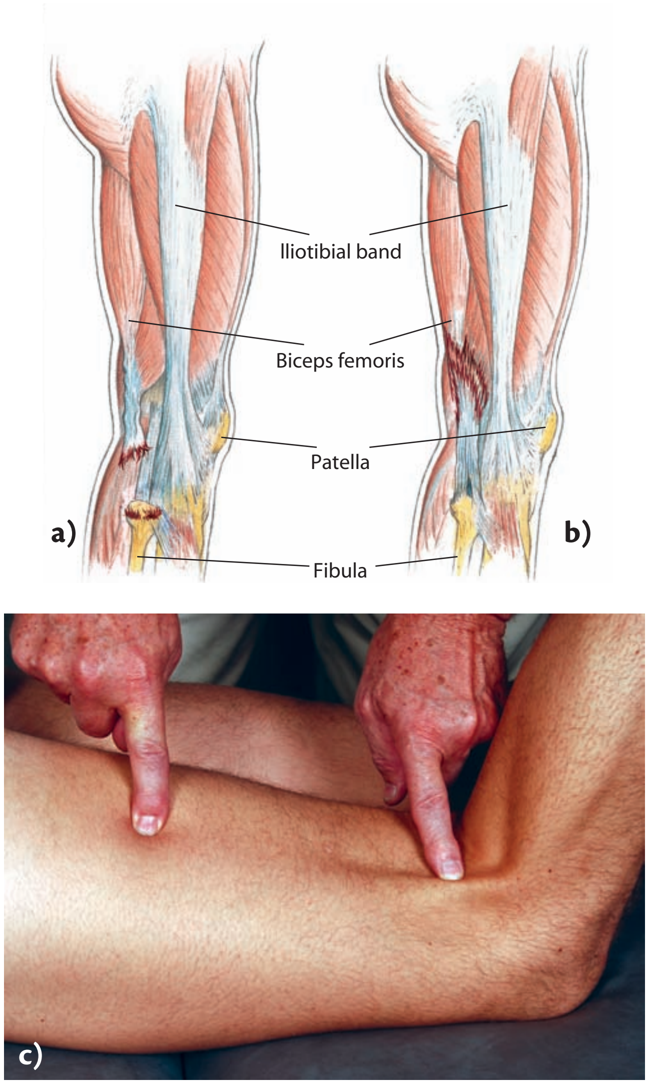


Figure 18.7 Distal biceps femoris muscle/tendon injuries. **a)** Rupture of the biceps femoris tendon at the level of the insertion at the fibula; **b)** rupture of the biceps femoris muscle at the muscle-tendon junction; **c)** location of most distal common areas where the biceps femoris can be injured.

Injury to the front (anterior), outside (lateral) and inside (medial) of the femur

Contusions and compression injuries from trauma

Direct trauma to a muscle (contusion) causes a rupture, often with extensive tissue damage and bleeding in the deep muscles when the contracted muscle is pressed against the underlying bone. Compression ruptures also occur in the superficial muscles, with symptoms similar to those caused by a strain (see p. 389).

Different types of muscle bleeding

During physical activity there is a massive redistribution of the amount of blood the heart pumps out per minute (cardiac output). Cardiac output to the muscles is 15% at rest and increases to 72% during hard physical work.

Tip

In other words, a large amount of blood passes (perfuses) through the muscles when actively exercising.

The extent of bleeding when a muscle gets injured is directly proportional to the muscle perfusion and inversely proportional to the degree of muscle tension. The injury effect, however, depends on where the bleeding is located and on its extent, and therefore we will not continue to make a distinction between the causes of muscle bleeding.

Hemorrhage

Intramuscular hemorrhage is bleeding within the muscle and can be caused by a muscle strain or a blow to the muscle (Fig 18.8). Bleeding occurs inside the muscle fascia that surrounds the muscle. It therefore increases the pressure inside the muscle, counteracting the hemorrhage because the blood vessels are being compressed. Intramuscular bleeding can lead to acute compartment syndrome (see p. 475), due to increased pressure within a compartment; however, this condition is rare. This type of bleeding can cause long-term problems. If the muscle fascia breaks the hemorrhage will spread to be intermuscular, the pressure drops and the injury may be perceived as less serious. Persistent or increased swelling and increased discoloration of the skin distal to the injury indicates fascial injury.

Intermuscular hemorrhage occurs between muscle bellies when the muscle fascia and nearby blood vessels are damaged. To begin with, an increased pressure occurs and the hemorrhage spreads between the muscles. Thus, the pressure drops rapidly. A typical sign of an intermuscular hemorrhage is a hematoma, 1–2 days after the injury below the injured area due to gravity. Contraction force and other muscle function returns shortly after the injury. An intermuscular bleed has the possibility of a rapid recovery without significant reduction of muscle power if an active rehabilitation is undertaken. An intermuscular bleeding can also occur after an intramuscular bleeding with injury to the fascia, see above.

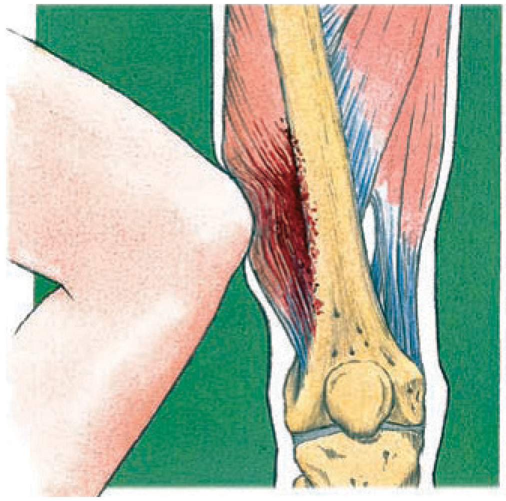


Figure 18.8 With direct trauma, such as a knee to the thigh, a muscle rupture can occur often combined with bleeding (hematoma) in the deep muscles that are compressed against the underlying bone.

Treatment of contusion injuries

The athlete/coach can, regardless of the cause of the bleeding, stop or reduce it by:

- Rest for 12–36 hours. This improves the regeneration of muscle tissue in the injury.
- Reduce weight-bearing – crutches should be used until a definite diagnosis has been made.
- Due to the hemorrhage, the athlete should always rest and offload for 1–3 days to limit further bleeding and scarring and to enable the muscle cells to regenerate. It is clearly shown that a brief period of rest after an injury followed by rehabilitation results in the best healing and strength recovery of the injured muscle.
- Apply a pressure bandage to the injured area to stop bleeding.
- Cool the injured area to relieve the pain.
- Elevation.
- Whenever there is any suspicion of a major muscle rupture or significant bleeding a physician should be consulted as soon as possible.

Tip

Bleeding in a muscle due to an injury should not be treated with massage and alike in the acute phase.

If substantial muscle bleeding is present the physician may admit the athlete to a hospital for observation. Bleeding and swelling may increase, impairing the blood supply and raising the pressure within the muscle. Without treatment, complications may ensue. If the bleeding is slight and there is some uncertainty about the nature and extent of the injury, the physician may prescribe rest for 1–3 days. It is difficult in the acute stage to be precise about the type and extent of injury involved. During the first 3 days it should be assumed that the muscle injury may be potentially serious.

It is important that an accurate diagnosis is made, since premature exercise of a muscle affected by extensive intramuscular bleeding or total rupture can cause challenging complications of further bleeding and increased scarring. This in turn increases the risk for a prolonged healing process and possibly permanent disability. The ongoing treatment depends on the diagnosis.

Treatment after 72 hours

After the initial, acute treatment minor partial ruptures, intermuscular bleeding and small intramuscular hematomas should be actively treated with:

- Continued pressure with elastic bandage.
- Local heat treatment; contrast treatment with heat and cold can have a good effect.
- Active muscle exercises should be carried out according to specific principles (see p. 200).

Tip

If the symptoms from the injured muscle remain unchanged or worsen, this increases the suspicion of an intramuscular hemorrhage and tissue damage.

The physician may then perform:

- Renewed local examination.
- Measurements of the intramuscular (intracompartmental) pressure.
- Puncture the suspected hematoma or fluid with a low gauge needle in the injured area, and suction out blood or fluid if possible, for analysis.
- Ultrasound or MRI examination: ultrasound provides adequate information on the extent of damage and the state of the healing process and is simple to perform; in the acute phase MRI gives full and detailed information.
- Surgery where the hematoma is removed and any damaged muscle tissue is addressed.

Once the diagnosis is established there are several treatment options:

- In most cases, elastic compression bandage and rest with offloading for 1–3 days is recommended, after which active muscle training starts as soon as pain and ROM allows, according to the principles set out (see p. 200).
- Prescribe when deemed necessary anti-inflammatory medication.
- Surgery in rare cases with extensive bleeding and tissue damage, especially if it is intramuscular.

Rehabilitation

Rehabilitation after surgery is planned in consultation between the athlete and physician, with regard to the injury's location and severity. If rehabilitation starts at an early stage healing is faster, the circulation in the muscle becomes restored and muscle strength improves. Shortly after the operation, static muscle training can begin, and later start building up muscle strength and flexibility by switching to dynamic movement training, initially with no weight.

Healing time

A muscle injury is considered to be healed when no tenderness is present and no pain occurs with maximum loading of the muscle. When the athlete has regained full muscle function, full flexibility in the surrounding joints and can produce otherwise normal movement patterns, training without restrictions can resume.

An intramuscular hemorrhage is frequently associated with tissue damage. In such cases, the healing time can be 1–6 weeks or more. The injured athlete can then usually return to their sport activities after another 1–2 weeks but it can take longer, depending on the extent of muscle tissue damage.

Tip

Do remember that objective control of tissue healing by ultrasound or MRI should be done in all major muscle injuries.

Rupture of the four-headed muscle of the anterior thigh (quadriceps)

The four-headed muscle of the thigh (quadriceps) consists of a group of four muscle bellies on the anterior aspect of the femur: the rectus femoris (Fig. 18.9), vastus medialis, vastus lateralis and vastus intermedius. These muscles contain predominantly type II muscle fibers and are best suited to rapid, forceful activity. Most quadriceps ruptures are of the compression–contusion type, but strains do occur.

Ruptures of the quadriceps muscle can occur as a result of impact against contracted muscles, typically in soccer when a player's knee hits another's thigh, or from a sudden, vigorous explosive contraction of the muscle such as in a fast start or sprint. In cases of rupture caused by external impact (contusion ruptures, p. 392), the muscles lying close to the bone are most commonly affected. Superficial muscle ruptures are usually caused by overload and are usually located in the muscle–tendon junction.

Symptoms and diagnosis

- The athlete often notices a stab of intense pain as the injury occurs. Similar pain recurs on exertion.
- The muscle may go into spasm.
- There is intense tenderness over the injured area.
- Increasing swelling and skin discoloration occur.
- Pain can be elicited by contracting the muscle against resistance (Fig. 18.10).

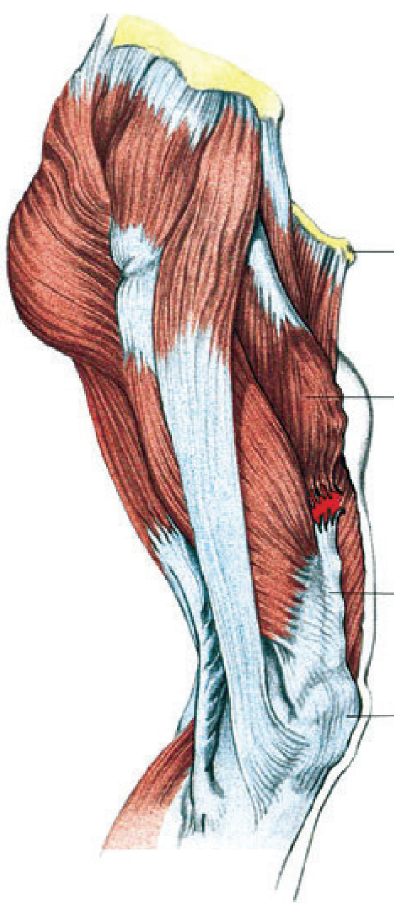


Figure 18.9 Rupture of the rectus femoris of the quadriceps.

Figure 18.10 Pain can be triggered when the muscle is extended against resistance.

- In cases of a complete or major partial rupture a defect can be felt in the muscle.
- Ruptures in the thigh muscles are treated according to the guidelines stated on p. 200. In football/soccer and American football injuries caused by kicking can cause the muscle to be completely ruptured and requires surgery.

Healing and complications

- The healing time varies from 2–12 weeks depending on the extent of the bleeding and whether the rupture is partial or complete.
- Scar tissue in the muscles adds to the risk of a further rupture.
- Significant hematoma inappropriately treated can result in heterotopic bone formation (see below).

'Charley Horse' (traumatic myositis ossificans)

In sports, this injury occurs from a direct trauma to the muscle. An incidence of 9–17% has been reported. In blunt trauma to the thigh, e.g. a knee against the lateral thigh in football, hemorrhage can occur in the muscle tissue, most often in combination with tissue damage (Fig. 18.11). If the injury after a major bleeding is left untreated, it can cause scar tissue to calcify and ossification occurs. This type of injury is especially common in contact sports such as soccer, rugby, handball, ice hockey and bandy. The muscle function and mobility of the knee is reduced, and the risk of a recurrent injury occurring in the same area increases.

Myositis ossificans is in fact a tumor-like growth of bone in an area that has been exposed to trauma with tissue damage and hematoma. This injury is not uncommon among growing individuals after sports injury. It can be found in many other patient populations, such as after a fracture from a fall and after a total hip replacement surgery. It can occasionally be mistaken as more serious pathology, such as bone cancer.

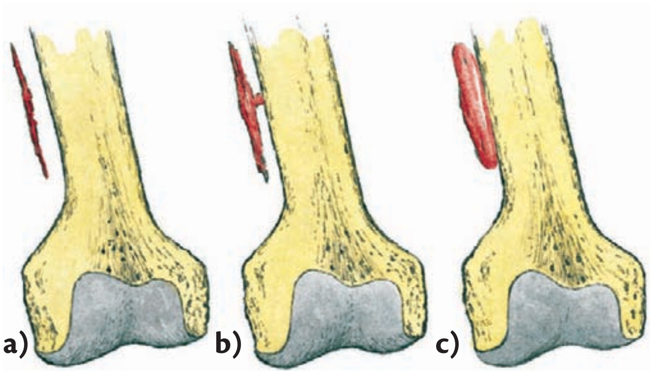


Figure 18.11 'Charley horse' (myositis ossificans traumatica). A direct trauma to the muscle with resultant hemorrhaging, which over time turns into an ossification. **a)** Bone formation (ossification) in soft tissues without connection to the underlying femur; **b)** ossification with connections to the femur; **c)** ossification directly on femur.

Symptoms and diagnosis

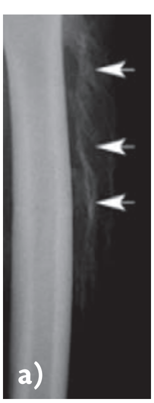
- The athlete can often recall a particular trauma initiating the symptoms.
- Localized pain and tenderness.
- Inability to flex the knee joint is a typical sign. Pain in knee flexion remains for 1–2 weeks or longer.
- Active quadriceps contractions causes pain.
- X-rays taken 2–4 weeks after the injury show the presence of bone formation that normally should not be (heterotopic) around the injury site. After 3–4 weeks, small calcifications and the beginnings of bone formation can be observed. Between the third and sixth week the bone mass consolidates in size. It can be eventually connected to the femur by a broad base or a stalk (Fig. 18.11).
- CT scan shows the exact size and location.

Treatment

- At the time of injury the priority is to restrict bleeding and limit the hematoma. Compression is important. Knee joint mobility must be restored and supervised training from a physiotherapist is recommended.
- Once the hemorrhage is under control, careful isometric contractions combined with gentle, active flexion exercises can sometimes be started. The athlete should not feel discomfort during exercise. Stretching exercises are not permitted at this stage. When the knee joint can be flexed to a 90° angle, it is time to progress the training program with exercise against resistance.

The athlete can usually be treated conservatively as above. The prognosis is good, and it is possible to return to normal training 5–10 weeks after a severe compressions rupture.

If the athlete does not regain normal ROM in the knee despite conservative treatment, surgery may be necessary. According to available literature the ossification self-absorbs, but often not until after 6 months. Many athletes do not want to or cannot wait this long. We believe that this time frame can be shortened considerably and the surgery can be performed when there are sharp edges, i.e. within 4–8 weeks with good results. The bone formation (ossification) will be removed in its entirety (Fig. 18.12).



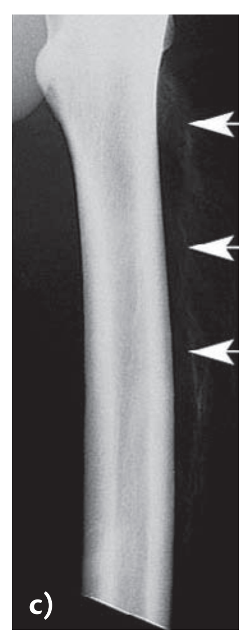


Figure 18.12 'Charley horse' (myositis ossificans traumatica). **a)** X-ray image taken 4–8 weeks after trauma showing bone formation near the femur; **b)** ossified tissue after radical operative removal of bone formation 8 weeks after the trauma; **c)** X-ray taken after 12 months shows normal cortical bone. The ossified tissue is gone and there is no sign of new ossification.

Compartment syndrome

The thigh muscles are surrounded by connective tissue membranes (fascia). However, they are not as clearly divided into muscle compartments as those of the lower leg muscles. Nevertheless, some athletes, especially long-distance runners, cross-country skiers, and ice hockey players, who use their thigh muscles intensively, experience thigh pain, weakness, and fatigue associated with sports activity.

The pain can arise within minutes, and may be bilateral. There is no associated trauma. The pain can be anterior, lateral or posterior, or involve the whole thigh. There are usually no neurological symptoms and intramuscular pressure measurements are often normal.

The diagnosis is made using the process of elimination. When physical therapy, including stretching, has been tried for a long time without improvement, fasciotomy surgery (opening of the fascia) anteriorly and/or posteriorly may be discussed. Fasciotomy can provide good relief, but there is no support for such a treatment in the literature. Occasionally, the rectus femoris, vastus medialis and vastus lateralis are involved, and should be fasciotomized separately. This may sometimes give good relief.

Less common causes of thigh pain

Stress fracture of the femur

This is rare. For locations and principles of management, see p. 150.

Vascular malformations

These may be suspected if the athlete has pain during activity. These athletes should consult a physician as they may need to be referred to a vascular surgeon.

Radiating pain, referred pain

See p. 345.

Tumors

Soft tissue tumors of the thigh are often sarcomas, which can be divided into two main types: osteosarcoma, which develop from bone, and soft tissue sarcomas, which develop in the soft tissues such as fat, muscles, nerves, connective tissue, blood vessels and skin. Soft tissue tumors are more commonly benign than malignant.

A benign tumor of fatty tissue called lipoma is the most common benign soft tissue tumor. Liposarcoma is a malignant adipose tissue tumor. Tumors of the muscles and nerves are uncommon.

Tip

If a tumor or a swelling is large, e.g. greater than 5 cm, and located deep in the tissue, it may very well be a cancer.

To confirm the diagnosis an X-ray and MRI should be performed, which not only can identify the size and depth of the tumor, but also its relationship to the surrounding tissues. A biopsy, i.e. a sample of the tissue, indicates the degree of malignancy, which determines the prognosis. Positron emission tomography (PET) has recently been developed to detect and monitor how the tumor responds to treatment.

Treatment may include radiation therapy, often combined with surgery to reduce the risk that the tumor returns. Chemotherapy is used to treat some tumors.

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Further reading

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2. Orchard JW, *et al.* The early management of muscle strains in the elite athlete: best practice in a world with a limited evidence basis. *Br J Sports Med* 2008;42(3):158–9.
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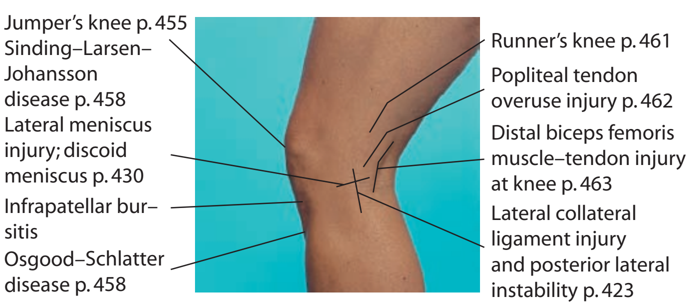
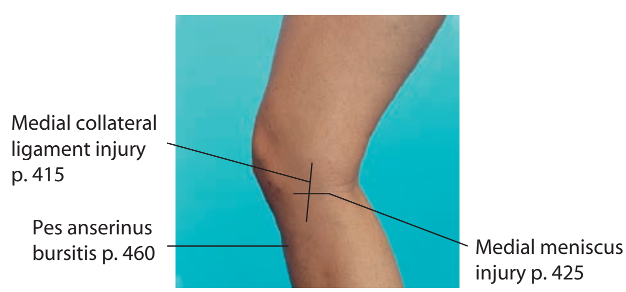
19 Knee Injuries in Sport

The knee joint is an anatomically and biomechanically very complex joint that plays a major role in all physical activity and sports. The knee joint is the joint that suffers the most injuries in sport, even if reliable incident numbers are lacking. At an ordinary Sports Medicine clinic, of all patients, patients with injured knees represent between 30 and 50%. The most commonly injured structures in the knee that athletes seek a physicians's advice for are: anterior cruciate ligament (ACL), the medial (inner) meniscus and the medial (inner) collateral ligament (MCL), which together account for over two-thirds of all traumatic knee injuries in sport. Other structures which may be injured include lateral (outer) meniscus, lateral (outer) collateral ligament (LCL) and posterior cruciate ligament (PCL). Articular cartilage is often damaged simultaneously with ligament and meniscus injuries, but can also be injured in isolation (see p. 158) (Figs 19.1–19.4).



19.1



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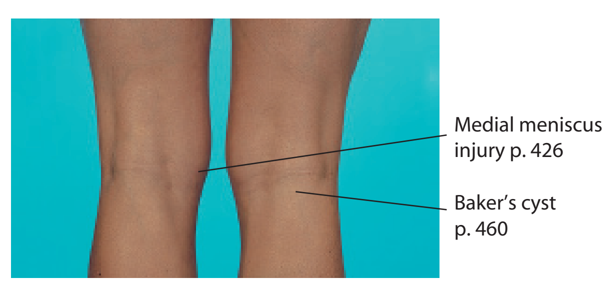


19.4

Figure 19.1–19.4 Overview of the location of the most common injuries in the knee joint.

Rupture of the ACL is serious and causes the loss of many training and competition sessions. An ACL injury remains the single biggest problem in Sports Medicine traumatology, i.e. orthopedic Sports Medicine. The annual incidence of ACL injuries is high: 81–85 per 100,000 people aged 10–64 years old. Despite the development of good prevention measures, the overall risk of ACL injury in fact has not decreased since the 1990s.

On top of this is a number of overload injuries, of which the most common are patellofemoral pain syndrome (PFPS) and chronic changes (degeneration) of the patellar tendon (patellar tendinopathy.)

Most of these injuries are caused by extreme stress due to twisting and turning motions in sports such as skiing and football/soccer, which in northern Europe together account for half of all knee injuries. Other contact sports such as team handball, basketball, American football, etc. also have a high number of knee injuries, especially ACL injuries (Fig. 19.5). Female athletes at a young age have about 2–3 times more ACL injuries than men in sports such as football/soccer, basketball and handball. The greatest incidence of ACL injuries is in recreational downhill skiers, while professional downhill skiers have among the lowest, and no gender difference exists. MCL and meniscus injuries occur in sports such as judo, gymnastics and the like.

Figure 19.5 a–c) Trauma to the knee is common in football/soccer and downhill skiing. (With permission, by Bildbyrån, Sweden.)

Functional anatomy and biomechanics

The knee joint connects the thigh bone (femur) and shin bone (tibia). The knee cap (patella) is located in the patellar tendon and glides during knee movements in a groove (sulcus of the trochlea) on the femur. The patella provides a biomechanical advantage for the four-headed thigh muscle (quadriceps) to extend the knee joint. The contact surfaces of the three bones are lined by articular cartilage, and the joint is surrounded by a fibrous joint capsule with a synovial membrane towards the joint cavity. The stability of the joint is maintained by four strong ligaments: the MCL, the LCL, the ACL and the PCL. The MCL and LCL prevent side-to-side motion, while the ACL and PCL restrict abnormal front and back movements. Together they prevent the knee from hyperextension and hyperflexion, as well as rotation. The fibrous joint capsule also contributes to stability. Excessive torsion forces on these ligaments can cause them to rupture. The MCL and ACL are often injured together. The surgical methods for repair of these injuries are constantly improving, allowing the athletes often to resume their sport after treatment. Injuries to the PCL and LCL are more difficult to treat, especially if they include the fibrous joint capsule and other structures to the back of the knee.

Medical history and examination

Grading

Ligament injuries to the knee can be graded according to the severity of the injury, into three grades:

- Grade I: there is tearing within the microstructure but no obvious elongation of the ligament.
- Grade II: the ligament is stretched and there is a partial tear.
- Grade III: a complete tear causing the ligament to separate.

A thorough examination of a knee injury is essential for a correct diagnosis.

Medical history

The medical history should include an analysis of the injury mechanism. A perception of the magnitude of force and the direction of impact at the moment of injury are important factors in the severity and type of injury.

Inspection of the injured area

There may be swelling around as well as within the joint. Discoloration over the ligament or along its path indicates bleeding and a ligament injury. In cases of effusion the swelling usually extends above the patella. The examiner can establish whether such an effusion is present by pressing the area above and below the patella with both hands while at the same time pressing the patella toward the femur with the thumb of one hand (Fig. 19.6).

When there is an effusion the patella meets a spongy resistance that ceases when the articular surface of the patella is compressed against the femur. When the pressure is released the patella can be seen to rise again because of the underlying fluid.

Palpation

The examining physician should palpate the joint lines of the knee, checking for tenderness that may indicate a meniscus injury. The palpation should continue over the course of the collateral ligaments noting the location of tenderness, since this may be the injury site. Swelling caused by an effusion can be felt.

Figure 19.6 Examination of effusion in the knee joint. Place the hands in the area above and below the patella and then press the hands towards each other, so that the fluid is collected under the patella. Then with a finger press the patella against the femur; when pressure is released the patella will lift from the femur if fluid is present in the knee.

Testing the range of motion

The examining physician should look for restriction of extension and flexion of the knee; however, the patient rather than the examiner should move the knee in order to control the pain. Pain on movement or a decreased range of motion (ROM) can be a sign of meniscus injury as well as ligament injury.

Stability examination

A stability examination is essential for the physician to decide if a possible ligament injury is of such severity that the knee is unstable. It is important that the muscles are relaxed when testing. If the athlete's pain is too severe, in order to examine it may be necessary to wait a day or two or perform the examination under general anesthesia. The following tests are warranted for:

- The ACL: Lachman test, anterior drawer test, pivot shift test (see p. 408 Fig. 19.17).
- The MCL: valgus stress test (a stress placed on the outside of the knee forcing the lower leg outward in relation to the femur) (see p. 420 Fig. 19.35).
- The PCL: posterior drawer test and quadriceps active test (see p. 417 Fig. 19.28).
- The LCL: varus stress test (a stress placed on the inside of the knee forcing the lower leg inward in relation to the femur) and reverse pivot shift test (see p. 423 Fig. 19.40).
- The PCL and LCL for posterior lateral instability: reverse pivot shift test.

Aspiration

Withdrawal of fluid by way of a needle aspiration of the knee joint can be performed in cases of extensive swelling in order to verify if there is blood present in the fluid (Fig. 19.7).

Tip

If blood is present a serious injury within the knee must be suspected.

Radiology

Plain X-rays are essential in any serious knee injury, to exclude fractures, avulsions or to show defects of the bone lying beneath the articular cartilage. An X-ray shows the bones of the knee joint and joint space height. Soft tissue, such as ligament, cannot be seen on an X-ray. X-rays taken while the athlete is supporting weight can show changes in the thickness of the articular cartilage. Thinning of the cartilage, which indicates early osteoarthritis, will cause the femur and tibia to appear closer together.

Magnetic resonance imaging

Magnetic resonance imaging (MRI) (Fig. 19.8C) is useful for evaluating the skeleton and soft tissues (ligaments, tendons, muscles, capsule and meniscus). The images can show swelling in the bone that accompanies fractures and it shows PCL ruptures very well. For the ACL, the sensitivity for detecting tears is good, although it is sometimes difficult to decide whether the injury is complete or partial. In most situations MRI is unnecessary because the diagnosis can be made by clinical examination. In unusual or difficult cases an MRI with high sensitivity will show an ACL or meniscal tear. MRI using contrast agents (dGEMRIC technique, i.e. gadolinium MRI of cartilage) has been developed

Figure 19.7 Aspiration of an effusion or bleeding and/or an injection can be done with or without a local anesthetic. (Courtesy of Björn Engström, ArtroClinic, Stockholm.)

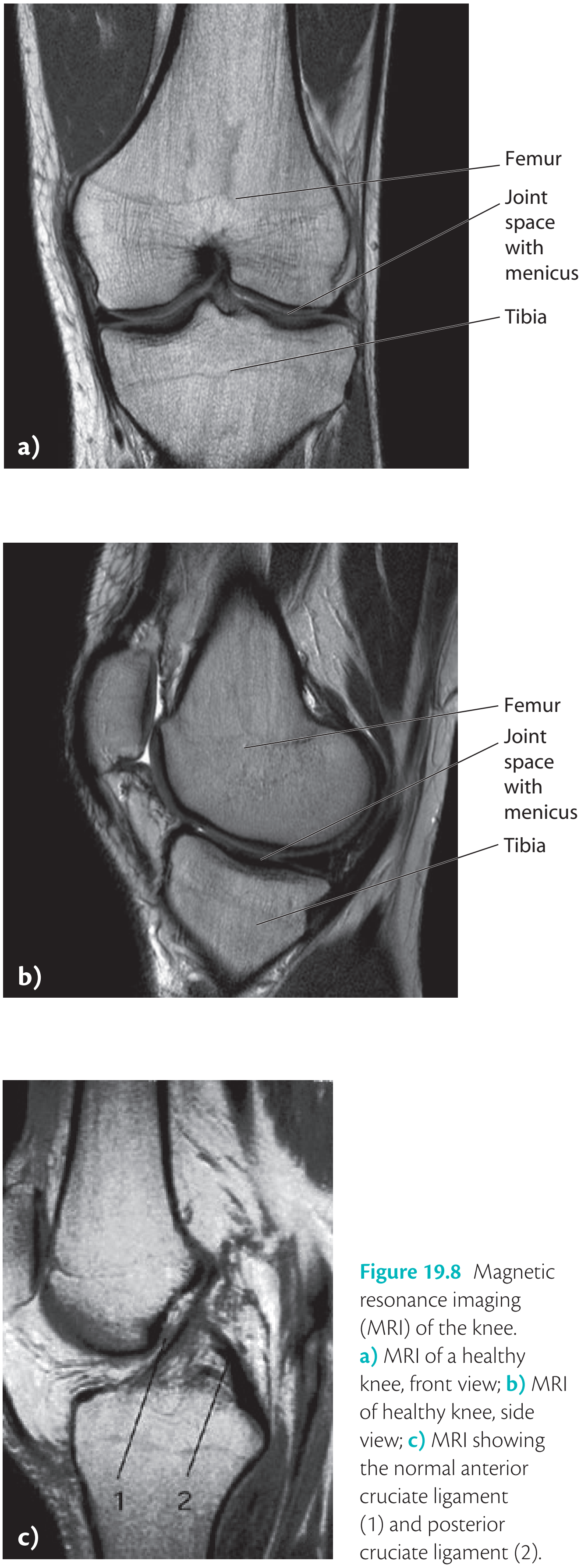


Figure 19.8 Magnetic resonance imaging (MRI) of the knee. **a)** MRI of a healthy knee, front view; **b)** MRI of healthy knee, side view; **c)** MRI showing the normal anterior cruciate ligament (1) and posterior cruciate ligament (2).

relatively recently. This technology has increased the sensitivity for detecting articular cartilage injuries, early osteoarthritis, bone marrow edema, and damage to the trabeculae in the bone under the cartilage, known as a 'bone bruise'.

A bone scan (scintigraphy) demonstrates areas of increased (or decreased) bone metabolism. The method is sensitive for stress fracture and osteonecrosis (a dead part of a bone). It is now seldom used.

Arthroscopy

In some countries, arthroscopy is routinely used as a diagnostic instrument. This procedure is probably unnecessary since a diagnosis is usually apparent by a physical examination or non-invasive examination methods such as MRI. However, if the injury is to be treated arthroscopically at the same time it is a great advantage. When the clinical examination and other tests are not conclusive, an arthroscopy offers the best opportunity for examination of internal structures of the knee joint (Fig. 19.9).

Arthroscopy was developed by innovative orthopedic surgeons in Japan. Prof. Masaki Watanabe (1912–1994), who described the arthroscopy as we know it in 1958, is today called the 'Father of the Arthroscope' (Fig. 19.9B). On May 4, 1962, Masaki Watanabe MD performed the first arthroscopic menisectomy using the arthroscopic instruments he developed.[1]

Arthroscopy is a method increasingly used for the assessment of damage of structures outside the joint, such as bursae, tendons and tendon sheaths. When used to inspect backs and internal organs it is then called endoscopy. Arthroscopy can be safely performed under local anesthesia, but in many places epidural or general anesthesia is used (Fig. 19.10).

Where clinical examination and other tests are inconclusive, arthroscopy gives the best examination of the structures within the knee joint. It will not evaluate injury to structures outside the joint (skin, nerves, muscles, tendons). Arthroscopy is performed under local, spinal or general anesthesia.

Anesthesia

An injection of local anesthetic may be helpful in the location of pain disorders and is primarily used to detect pinched nerves (entrapment) and neuromas (an abnormal growth at the end of an injured nerve). An injection of local anesthetic solution at the neuroma will temporarily eliminate the pain.

Ligament injuries

Anterior cruciate ligament injuries

The ACL is the most common of the ligament injuries to the knee joint. The loss of the ACL function does not only result in abnormal kinematics (motion, movement patterns) but often in severe degenerative changes in the knee joint over time, such as osteoarthritis (see p. 441). A rupture of the ACL is the most common serious injury occurring in sports traumatology.

Tip

The ACL injury is sport's biggest problem and is still an injury with many difficult and unresolved issues, such as best surgery, graft choice and tension, criteria for return to sport etc., despite extensive research. This injury requires a lot of experience, reflection, commitment and choice of optimal treatment technology to get a successful outcome and allow a return to previous activity level.

Anatomy

The human ACL is a complex structure at every level. The ligament is designed to act as a stabilizer while allowing normal joint motion throughout the functional ROM. The ACL is a band of strategically oriented connective tissue, that connects the femur and tibia (Fig. 19.11). It has an average weight of 20 g (0.7 oz) and an average length of 35 mm (1.4 in.). It is narrow in the middle, fanning out inferiorly and to a lesser extent superiorly. The ACL attaches to the posterior aspect of the medial surface of the lateral femoral condyle. There is a rim of bone of 2.5 mm between the posterior ACL fibers and the posterior articular cartilage margin. Distally the ACL is attached to a fossa in front and lateral of the tibial spine (intercondyloid eminence of the tibia). The tibial attachment is somewhat broader than the femoral attachment.

The ACL consists of an anteromedial band that is taut with the knee in flexion and relaxed when the knee is in extension, and a posterolateral bundle that is tight in extension and relaxed in flexion. An interconnecting intermediate band may be identifiable, which is tight through the whole ROM from extension to flexion.

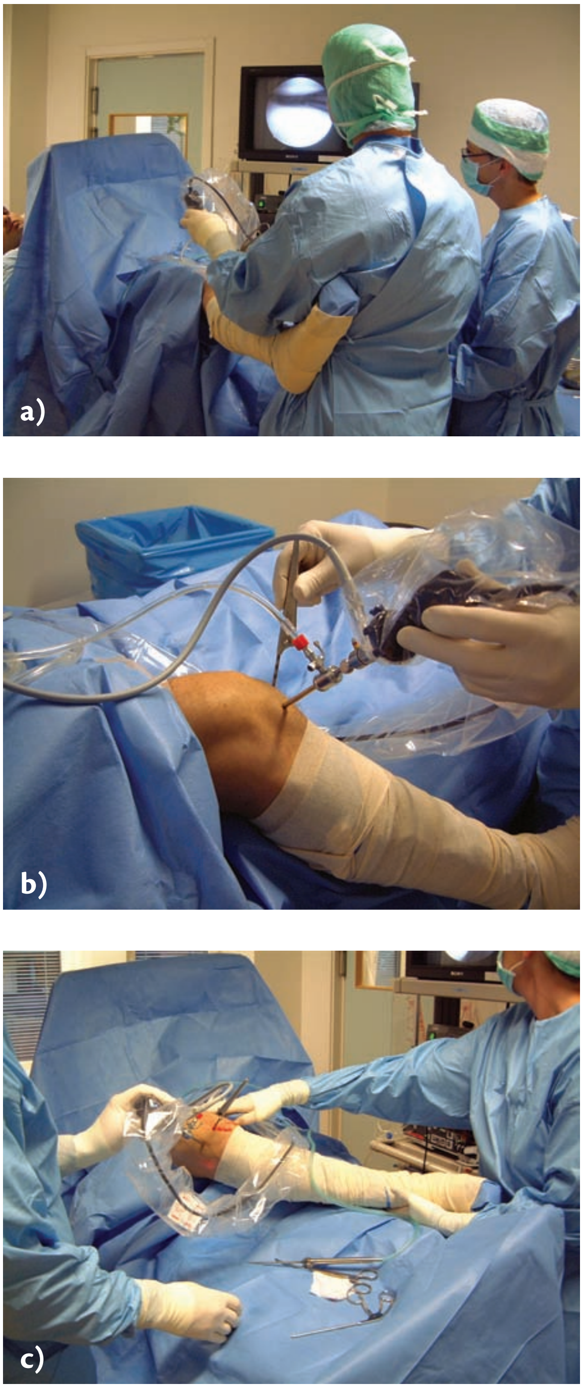


Figure 19.9 Set-up for an arthroscopy. This is carried out advantageously under local anesthetic. **a)** Arthroscopy of the knee joint with the image on the TV screen; **b)** arthroscopy of the knee joint using a hook in order to feel different tissues; **c)** overview of arthroscopy surgery with instruments on the table (courtesy of ArtroClinic, Stockholm, Sweden); **d)** Prof. Masaki Watanabe, Tokyo Teisin Hospital, Japan who described the arthroscope we use today in 1958; **e)** on May 4, 1962, Masaki Watanabe MD performed the first arthroscopic meniscectomy using the arthroscopic instruments he developed (courtesy of Prof. Hideshige Moriya, Chiba University, Chiba-city, Japan).

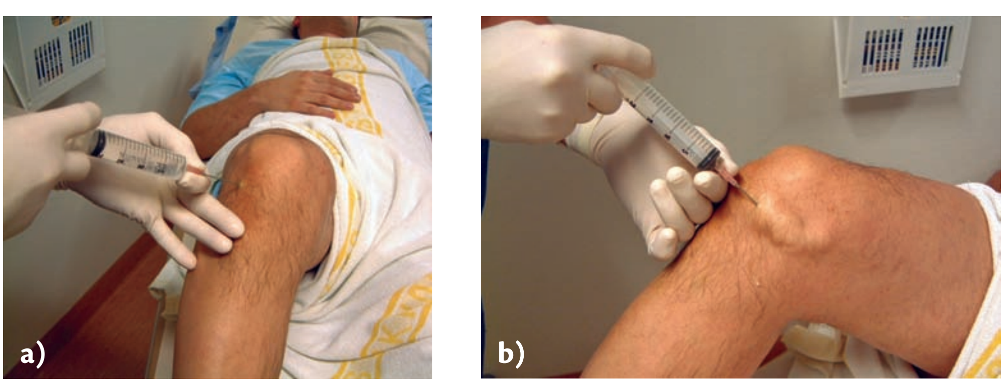


Figure 19.10 a, b) Local anesthesia in the knee for arthroscopy surgery and pain relief after surgery in selected cases. (Courtesy of ArtroClinic, Stockholm, Sweden.)

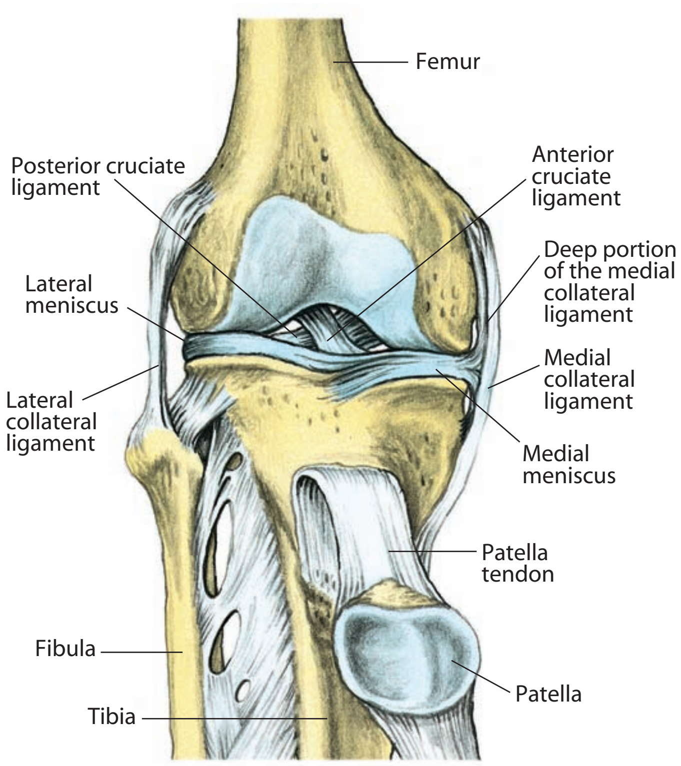


Figure 19.11 Anatomical image of the right knee, front view.

The ACL is an intra-articular ligament surrounded by synovial tissue. It is well vascularized, and contains nerve endings that may have a proprioceptive function.

Biomechanics and function

The ACL is the second strongest ligament in the knee with a maximum load of around 2200 N (500 lb). In extreme extension, the anteromedial band is slack and the posterolateral band is tight; with increasing flexion, there is tightening of the anteromedial band and increased laxity in the posterolateral band (Fig. 19.12).

The ACL prevents the anterior movement of the tibia in relation to the femur. The ligament takes up 75% of the anterior force in full extension, 87% at 30° of flexion, and 85% at 90° of flexion. Other stabilizing structures are the iliotibial band, the medial and lateral capsule, plus the medial and lateral collateral ligaments. In ACL-deficient knees, the medial extra-articular structures resist anterior (forward) translation and outward rotation throughout the ROM, while the lateral collateral ligament and the posterolateral structures resist anterior translation in a straight knee only. The medial meniscus also resists anterior translation through the ROM. The ACL is the main stabilizer for anterior translation of the tibia in relation to the femur. Together with the PCL, the ACL resists and limits hyperextension, hyperflexion and internal rotation (Fig.19.13).

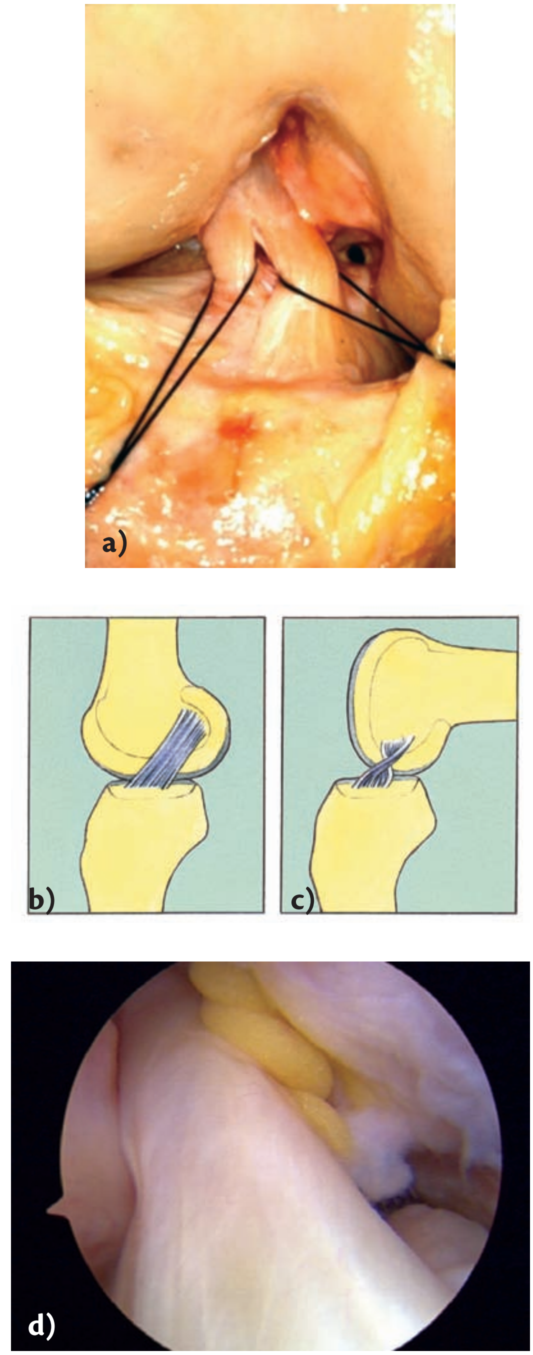


Figure 19.12 Anterior cruciate ligament (ACL) is composed of three main functional portions; the anteromedial, the intermediate and the posterolateral, the first and the latter are given the greatest functional value. Both of these portions interact via the intermediate portion through its collagenous bridge. **a)** the anteromedial and posterolateral parts separated by dissection through the intermediate tissue (courtesy of Prof. Savio Woo, University of Pittsburg, Pennsylvania, USA); **b, c)** the anteromedial band is tight on knee flexion and relaxed at knee extension, conversely the posterolateral band is tight when the knee is extended and relaxed when flexed; **d)** the anterior cruciate ligament seen through an arthroscope with the knee in 90° of flexion showing that the anteromedial band is tense (courtesy of ArtroClinic, Stockholm, Sweden).

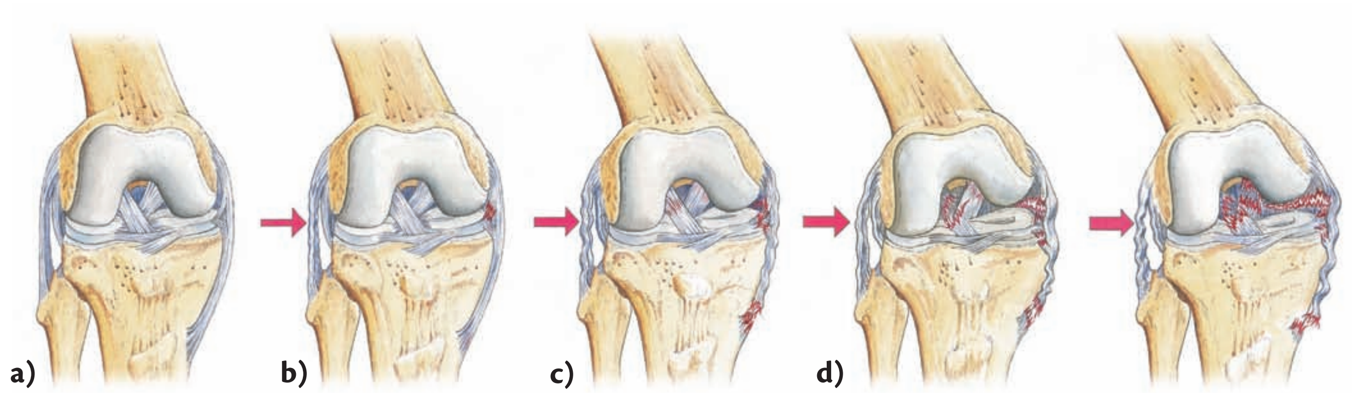


Figure 19.13 Progression of damage after trauma to the outside of the knee joint. **a)** Normal uninjured knee; **b)** with a force from the outside, the deep portion of the medial collateral ligament (MCL) ruptures; if the trauma is larger the entire MCL ruptures; **c)** additional force can lead to even anterior cruciate ligament (ACL) rupture; **d)** if the force is very large even the posterior cruciate ligament (PCL) ruptures.

Mechanism of injury

Isolated injuries of the ACL can occur with a twisting impact, either in internal rotation, hyperextension or in external rotation and valgus. In alpine skiing there are two typical injury mechanisms: ACL injury caused by the ski boot and the 'phantom-foot' injury (see p. 111 Fig. 6.27).

Trauma to the outside of the knee, forcing the knee into valgus and lower leg in external rotation can cause a combined injury of the ACL, MCL and joint capsule (Fig. 19.14). The same injury may result from trauma to the inside of the foot. A combined injury involving the ACL, LCL and the rear lateral joint capsule can occur when the trauma occurs to the inside of the knee joint (or against the outside of the foot) forcing the knee into varus and lower leg in internal rotation. Combination injuries also affect the PCL and can occur after any form of large force trauma against the knee, either outside or inside, and for injuries occurring from hyperextension and hyperflexion. In general any excessive force that causes a dislocation or subluxation of the knee may result in an ACL injury.

Bone avulsion injuries of the ACL can occur, especially in hyperextension and hyperflexion injuries in growing individuals. Avulsion of the tibial insertion is not uncommon in young athletes.

Injury mechanism of ACL injuries in adolescent girls

The number of ACL reconstructions differs between the sexes during the adolescent years. Women as a whole have 2.6 times more ACL injuries than men.

It is important to understand the underlying cause, or risk factors concerning an ACL injury. The external environmental, hormonal, anatomical and biomechanical factors are considered risk factors for ACL injuries. External risk factors may include the type of sport, footwear, playing field, environmental factors and the playing position of the athlete (i.e. in football/soccer). There is a higher incidence of ACL injuries in football/soccer as a defender than attacker/forward. In handball players in the back zone have the highest risk, while line players and goalkeepers have the least risk. Surface friction is a risk factor. An athlete's complete external and internal risk factor profile for an ACL injury is still unclear because the majority of the available scientific studies have been on isolated variables. Limited knowledge is available on the effects of sports-specific factors, such as rules, referees, coaches, weather/climate, the coefficient of friction between the shoe and surface, the effects of aging, degree of skill, psychological factors and previous knee injuries.

What role do the sex hormones have? There is a significant increase in ACL injuries in female athletes in their teens during the ovulation phase. These findings suggest that sex hormones may play a part in the incidence of female ACL injuries. Gender differences such as structural and mechanical properties of the human ACL have been identified. It has been shown that women have smaller ACLs, less stiffness, lower strain tolerance, lower energy absorption and lower strength (load to failure). These findings may be consistent if anthropometric differences are taken into consideration. There is no difference shown on the grade of ACL injury, based on the intake of birth control (contraception) medications.

Anatomically there is evidence that notch width, i.e. the width of the opening in the femur where the ACL attaches, in an injured knee is smaller than the notch width of normal controls. This indicates that there is a correlation between notch width and ACL injury. Increased generalized laxity, greater hyperextension (genu recurvatum) and reduced iliotibial band flexibility

Figure 19.14 Jumping and 'cutting' sports have an increased risk for anterior cruciate ligament injuries in young people in their teens. **a, b)** Sports that include jumping increase the risk of knee injuries (B, photo, Henrik Peterson); **c, d)** young footballer/soccer players have an increased risk for knee injury (c, photo, Henrik Peterson; courtesy of the Swedish Football Association).

have been found to discriminate between women with and without a history of ACL injury. Effect of lower limb anatomy on the neuromuscular and biomechanical function and risk of ACL injury is unclear. It should be noted that anatomic factors are difficult to modify.

Decreased core stability can affect the dynamic knee stability. Factors related to core stability predict an increased risk of ACL injuries with high sensitivity and moderate specificity in female athletes but not in male athletes. It may be noted that dancers and figure skaters have fewer ACL injuries because they have excellent trunk control. Their training emphasizes torso strength, balance and agility.

It has been shown that the knee joint movement and loading during a landing among women basketball players during a match situation are predictors of the risk of an ACL injury as well as among other female athletes. Women who prepared for landing after a jump, with less hip and knee flexion, increased quadriceps activity and decreased hamstring activity resulting in an increased load, had a higher risk for injury on the ACL during landing. In summary, damage occurs during the landing after a jump, dynamic direction change, cutting or deceleration. A combination of the forward shift of the lower leg, lower leg valgus and pivoting of the lower leg to the femur is the most common mechanism of injury.

Tip

Likely components for an increased incidence of ACL injuries in women include:

- Potential neuromuscular imbalances that can be related to ACL injury mechanism components.
- Women demonstrate a more 'quadriceps dominant' neuromuscular pattern than men.
- Hamstring recruitment has proven to be significantly higher in men compared with women.
- The ratio between hamstring and quadriceps muscles' point of maximum strength (peak torque), which is a good measure of strength, tends to be higher in men than women.

Injury prevention

An effective well planned preventive program may be of benefit, but must include the following components:

- Proper neuromuscular training can decrease the maximum forces in the landing phase of a jump.
- A reduction in the size of the adduction (movement towards the midline of the body)/abduction (movement away from the midline of the body) momentum around the knee can predictably reduce landing forces.
- Exercise significantly improves hamstring strength and power, and reduces imbalances in the strength ratio between hamstrings and quadriceps muscles as well as bilaterally.
- Adduction and abduction momentum can be reduced through training from approximately 40 nm (29.5 ft lb) to 20 nm (14.8 ft lb).
- In addition, compensation for high maximum landing forces through good hamstring activity would be helpful.

Characteristics of a good program are that it:

- Attempts to change the dynamic loading of the knee joint through neuromuscular and proprioceptive training.
- Emphasizes proper landing technique; the athlete should land softly on the forefoot and roll back to the hind foot while knee and hip flexion are involved in the landing.
- Trains landing on both feet instead of one foot, when possible.
- Avoids change of direction, cutting activities, pronounced dynamic knock kneed stance (valgus) of the knee upon landing and squatting while focusing instead on the 'knee over the toe position' (Fig. 19.15).
- Increases hamstring, gluteus medius (one of the three buttock muscles), and hip abductor strength and properly trained decelerations technique.
- Needs a good cooperation from sports governing bodies, sports scientists, sports physicians, coaches, parents and athletes for successful implementation (Fig. 19.16).

Clinical examination

- There are a number of clinical symptoms that indicate an ACL injury.
- Thorough medical history is essential. If the athlete describes an injury caused by a rotation, flexion, direct trauma, rapid deceleration or landing, an ACL injury should always be suspected.
- Sudden onset of pain, sometimes an audible clicking, popping or snapping.
- The knee joint gives out. Immediately after an injury the athlete can often leave field or floor by themselves, but this should not allow the examiner to believe that no injury has occurred.

Figure 19.15 Landing after a jump. For injury prevention, it is essential to focus on the 'knee over the toe position' when landing, that determines the degree of adduction (inward angulation) of the hip joint resulting in increased valgus load (inward angulation) in the knee joint. **a)** The correct position of the knee joint during leg landing. The landing is characterized by a slight outward angle of the hip joint and knee joint neutral position with the load over the foot; **b)** faulty position of the knee joint during leg landing; faulty landing is characterized by adduction of the hip joint with subsequent valgus angulation of the knee joint and the load directed to the inside of the foot where the knee is forced to even greater valgus angulation with accompanying external rotation of the foot and the lower leg (courtesy of F-MARC); **c)** demonstrating the start position in the training of adequate landing; **d)** landing with both legs on bent knees and adequate width between the feet for safer landing; **e)** landing on one leg is an important training exercise. (Photos, Heijne/Frohm.)

Figure 19.16 A skilled football/soccer physician is able to get an idea of how serious an injury is during the on-field examination. (Courtesy of Harald Roos, University of Lund, Physician for Helsingborg IF, Sweden.)

- Over time, repetitive episodes of the knee 'giving way' and the athlete is close to losing balance or falls because of knee instability. This indicates a serious ACL injury that usually requires surgery.
- Swelling may develop within a few hours and cause pain. The swelling is due to a bleeding within the knee joint (hemarthrosis). Whenever there is a hemarthrosis present after a trauma, an ACL injury should be suspected, since in 70% of cases an ACL injury has caused the bleeding.
- Joint aspiration is sometimes used whereby the fluid is drawn out; if blood is in the aspirated fluid an ACL injury is very probable. The procedure also gives pain relief.
- The active and passive ROM is restricted. The athlete usually has reduced knee mobility, especially after a few days post injury.

Clinical tests for ACL injury include:

- Lachman test (Fig. 19.17A): considered to be a very reliable test for an ACL injury. It is basically an anterior 'drawer sign' with the knee bent at a 20–30° angle and the lower leg (tibia) in neutral rotation. The examiner uses one hand to stabilize the distal femur, while the other hand firmly grasps the proximal tibia. The test is performed as the examiner pulls the tibia forward relative to the femur with a gentle anterior translation force. The examiner evaluates if there is a firm/solid or soft endpoint.
  - ✓ A positive Lachman test indicates with high certainty a torn ACL as the sensitivity for the Lachman test is 96% for complete ruptures and 68% for partial ruptures.[2,3]
- Anterior drawer sign test (Fig. 19.17B): has limited reliability but can be valuable in the complete evaluation of the knee's status. The athlete is supine with the hips flexed to 45°. The thumbs are placed on the superior anterior aspect of tibia. The test is performed with the knee bent to 70–90° and with the tibia in neutral or inward rotation. The examiner pulls anteriorly on the proximal tibia for an ACL test. Normal test result shows no more than 6–8 mm of forward laxity. Increased anterior tibial displacement on the femur compared to the uninvolved side along with endpoint laxity indicates an ACL tear.
  - ✓ This test, however, is not as reliable as the Lachman test because hamstring muscles and the posterior horn of the medial meniscus can obstruct the movement.
  - ✓ An anterior drawer sign test with the tibia in external rotation tightens the posteromedial portion of the joint capsule. If forward movement is present (equal to forward movement with the leg in neutral position), it indicates an injury to the ACL and perhaps injury to the posteromedial capsule and the MCL.

'Pivot shift test' (rotational anterior drawer sign test) (Fig. 19.17C): a good test in the hands of an experienced examiner. The sensitivity of this test is significantly less compared to the Lachman test. This test may be difficult to perform, particularly at the acute phase of the injury. A disadvantage of this test is that it is not always positive even if the cruciate ligament is completely damaged. Another disadvantage is that the test can be painful or discomforting for the athlete. If the athlete can't relax the reliability of the test decreases.

- The pivot shift test is, however, good for identifying the presence of rotational instability, which needs to be corrected with reconstructive surgery. A positive pivot shift test can be a surgical indication if the injured person is young and active, as it suggests that the damage to the ACL is serious.
- Lateral stability of the knee inward and outward (respective valgus varus stability) is assessed with the knee joint in 20–30° flexion and with a straight leg to rule out damage to the medial and lateral ligaments respectively (see p. 417 Fig. 19.28).
- The joint between the patella and the femur (patellofemoral joint) should also be examined.
- X-rays are required to exclude skeletal injury.
- MRI is widely used. However, this is rarely warranted when the diagnosis can usually be made based on history and physical examination. On the other hand, MRI may be useful for diagnosing combination

injuries, such as bone, articular cartilage, the distribution of bleeding and tissue damage (Fig. 19.18).

- Arthroscopy (Fig. 19.19) gives the definitive diagnosis, especially if the examination is combined with the hook probe test of the ACL. A diagnostic arthroscopy, however, is usually superfluous when the diagnosis can be verified in conjunction with the surgical treatment.

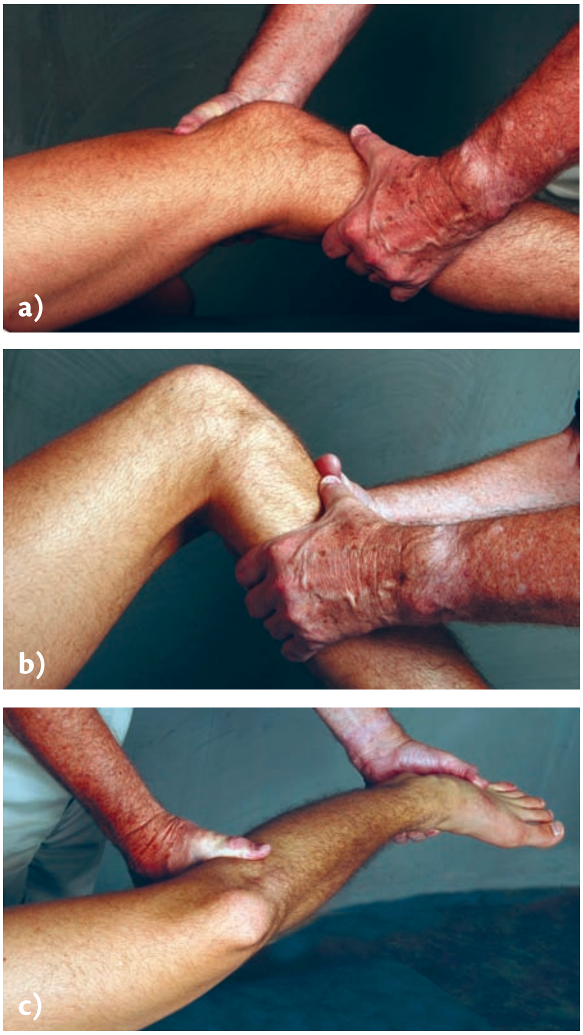


Figure 19.17 Stability tests of the anterior cruciate ligament (ACL). **a)** Lachman test: this is an anterior drawer test with the knee in 20–30° of flexion. The examiner uses one hand to stabilize the distal femur, while the other hand firmly grasps the proximal tibia. The test is performed as the examiner pulls the tibia forward relative to the femur with a gentle anterior translation force;
b) anterior drawer test: this test is performed with the knees in 70–90° of flexion and with the athlete supine and the hips flexed to 45°. The thumbs are placed on the superior anterior aspect of tibia and with the tibia in neutral or inward rotation. The examiner pulls anteriorly on the proximal tibia for an ACL test. This test can also be used with the tibia in external rotation. If forward movement is present it indicates not only an injury to the ACL, but also perhaps an injury to the posteromedial capsule and the medial collateral ligament; **c)** pivot shift test is performed with a valgus angulation of the knee and internal rotation force of the lower leg is applied to the extended knee and with a slight distal traction on the leg. The knee is then flexed and in the initial stages (approximately 20–30°) of knee flexion, the tibia will sublux anterolaterally on distal femur as the examiner applies a valgus and internal rotation force on the knee. With further flexion of the knee (past approximately 60°), the tibial anterolateral subluxation reduces (shifts) back into place as the iliotibial band goes from extending to flexing the knee.

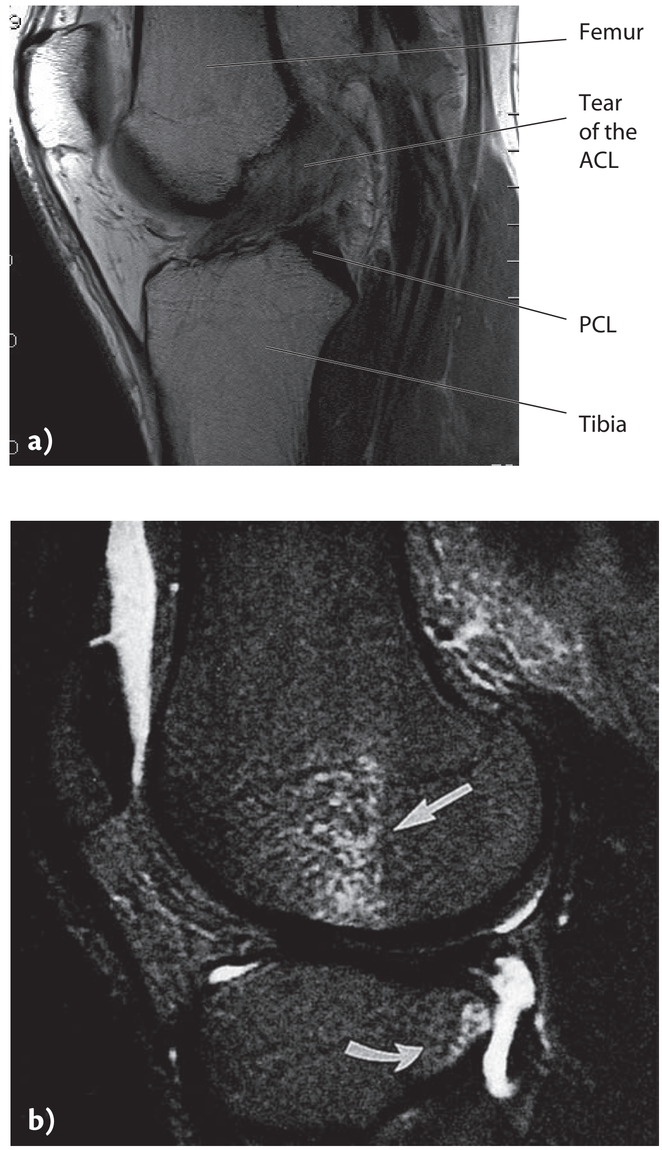


Figure 19.18 Magnetic resonance imaging (MRI) of the knee. **a)** MRI shows an anterior cruciate ligament (ACL) injury (arrow). This examination is usually needed when a diagnosis cannot be made based on history and physical examination; **b)** trauma that causes damage to the ACL can cause the tissue to swell. A fluid collection may occur (arrows) in the femur and the posterior edge of the tibia. Fluid accumulation can also be caused by bleeding due to small fractures (in the trabecular bone), so-called 'bone bruise'.

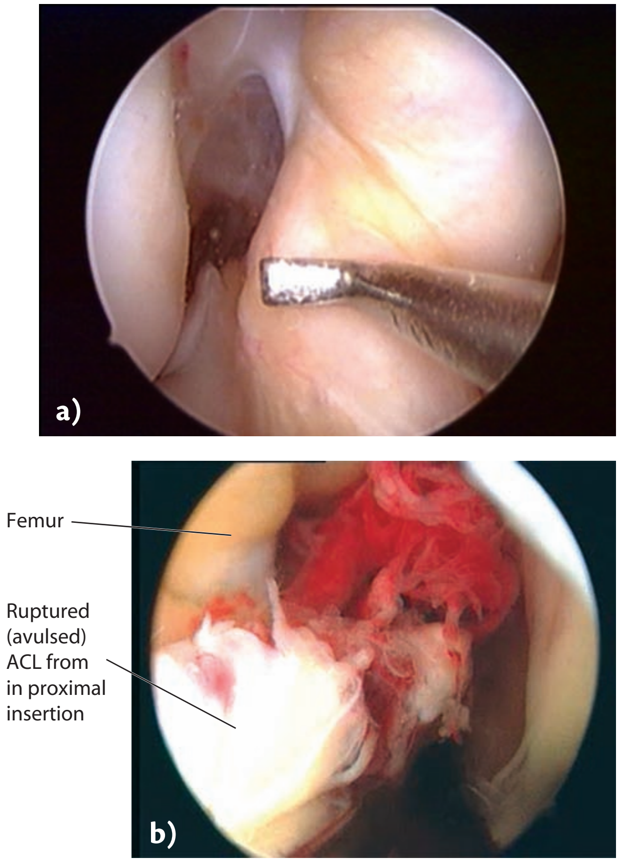


Figure 19.19 Arthroscopy of a knee joint. **a)** Examination and testing of the anterior cruciate ligament (ACL) by using a probe; **b)** arthroscopic image of a ruptured ACL. (Courtesy of ArtroClinic, Stockholm.)

Treatment

No single treatment protocol is applicable to all patients: treatment must be appropriate to the acuteness of the injury, the presence or absence of other lesions involving the knee, the age and level of activity of the patient, the degree of instability, the type of injury to the ACL and the ability of the patient to comply with a therapeutic program. The factors that decide the treatment are:

- The patient's age: there is no definitive limitation in age since increasingly people are active in later life. Patients 50–60 years old may be treated operatively if they are very active and/or the knee is very unstable.
- The activity level is probably the major factor in deciding whether to operate. Surgery is likely to be most beneficial in a very active patient, since these patients are often more willing to participate in the necessary intensive rehabilitation program. Less active people who are not performing cutting or pivoting activities or can accept modifying their activity level can often manage well and do not need surgery.
- Combination injuries are also an important factor in surgical decision making. Many believe that injuries to other major ligaments increase the likelihood that non-operative treatment of the ACL will lead to functional instability, but this is still controversial. Tears of the ACL often have associated injuries to one or both menisci. When a repairable meniscus lesion is confirmed in association with a complete tear of the ACL, reconstruction of the ACL at the same time as the meniscal repair is generally recommended. A meniscal tear often recurs if the ligament has not been repaired. However, in a patient with a chronic ACL tear, no history of 'giving way' episodes, and an irrepairable meniscus, the torn part of the meniscus can be removed from the knee with a reasonable chance that the symptoms will be eliminated but an increased risk of future arthrosis will be present.
- Degree of instability: whether patients who have generalized ligamentous laxity have more instability symptoms after ACL injury than those with normal laxity is controversial.
- Recurrent 'giving way' and positive pivot shift: athletes who have a torn ACL with abnormal anterior translation of the tibia on the femur compared with the other leg, but who have a negative or only a slightly positive pivot shift sign, have been shown to have fewer problems after non-operative management than patients who have a more dramatic pivot shift result. Patients with a history of 'giving way' and a positive pivot shift usually need surgery.
- Patient compliance: a patient who undergoes ACL surgery must be able and willing to participate in a prolonged postoperative rehabilitation program. A patient who is compliant with the rehabilitation in the initial phase after the trauma is likely to be compliant with rehabilitation after surgery.

Tip

With all these considerations in mind, patients should be evaluated individually and candidates for surgery should be carefully selected.

Conservative treatment

Elderly patients often manage well without surgical treatment, and likewise those who are not very active and who do not participate in athletic endeavors that include sharp turning and pivots. Some patients choose to await the outcome of conservative non-surgical treatment. When increased symptoms with the knee joint occur such as 'giving way', pain or swelling develops, surgery may be necessary at a later stage. Patients should be informed about this option. 'Wait and see' has long been considered to involve risks such as more incidents of the knee 'giving way' with increased damage to the knee joint, cartilage and menisci.

In a notable article it was found that young active individuals with acute ACL injury who were treated with early surgery and rehabilitation did not have better results than those who had a conservative rehabilitation strategy with the possibility of a surgery at a later date. The latter strategy reduced the number of ACL reconstructions substantially. In a 5 year follow-up the researchers found the same results, i.e. that there were no differences between knees surgically reconstructed early or late and those treated with rehabilitation alone.[4]

Conservative treatment includes the following measures:

- The acute care is to control the degree of swelling and pain, use knee brace, ice treatment, administer anti-inflammatory medication and gradually increase the ROM with appropriate exercises. The rehabilitation of the muscles should be set at the speed the injured tissue can handle – preferably as quickly as possible. The use of fixation knee braces and casting used for a few days but should be removed as soon as possible.
- Functional training should begin as soon as possible and, if possible, should include activities like cycling, swimming and simple running. These activities can begin as soon as full ROM and no swelling is present in the joint. Risky activities that include sharp turns should be avoided altogether for 6–12 weeks after an ACL injury.
- If the athlete is returning to activity that includes elements such as sharp turns, a knee brace (orthotics) can be used. The brace should provide support through the ROM and prevent hyperextension. It can also prevent the gliding forward (translation) of the tibia relative to the femur during low forces. However, it is not yet fully conclusive how effective a functional knee brace is, and these orthotics should be primarily reserved for patients that sometimes experience the knee 'giving way' (see Fig. 19.26). There may be reasons to make minor operative interventions for minor meniscal tears, obstruction in the joint from the broken end of the ACL rupture, locking, catching, recurrent swelling or persisting pain and discomfort in the knee joint. In such cases, a preoperative MRI may be helpful in assessing the damaged structures.

Tip

Patients treated conservatively should:

- Be informed that early surgery does not always give better results compared with those who had a conservative rehabilitative strategy with the possibility of reconstructive surgery at a later date.
- Be informed of the risks of not undergoing surgery.
- Be given the opportunity for surgery if the knee has episodes of 'giving way', repetitive inhibiting pain or swelling.

Surgical treatment

Generally speaking highly active individuals are in the greatest need of surgery. Indications for surgery include knee joints that are clearly unstable, recurrent joint swelling and pain, major meniscal damage that is repairable as well as substantial damage of the articular cartilage. The patient must understand the importance of compliance to the entire treatment and rehabilitation program.

After acute injury, it is considered advisable to postpone operation until the knee has recovered and the swelling and pain have subsided. The surgery is planned for preferably 2–8 weeks after the injury. Although the additional delay has little significance, it may marginally reduce the chances of a successful end result.

The operation should be performed by skilled surgeons experienced in ACL surgery, as this limits

Tip

Faced with impending surgery the patient should have complete information.

Patients should be told:

- There is not yet any surgical procedure that in detail can replicate the complete normal anatomical characteristics of the ACL.
- The surgery cannot fully re-create the normal biomechanical function in the knee joint.
- The results are relatively good and give approximately 80–90% improvement for the individual.
- Not everyone can return to the activity level that they had before the surgery.

the risks. Rehabilitation is demanding and requires the patient is compliant and follows all instructions.

Operation technique

- The surgical approach should follow anatomical principles and allow the patient to start moving the joint as soon as possible.
- The surgeon should be sure to place the graft isometrically, i.e. in the anatomically correct position, with the right tension and good fixation.

The choice of graft is important. Most surgeons use the patient's own tissue for reconstruction (autograft). An autograft taken from either the patellar tendon or one of the hamstring muscle tendons are both good grafts (Figs 19.20, 19.21). Sometimes, at reoperation, foreign tissue (tissue from a deceased donor, 'allograft') can be used; however for athletes this method should not be the first choice. Synthetic ligaments should be avoided as they are too rigid and according to experience not given to good results.

The operation can be performed by means of arthroscopy or through a small opening of the joint. A standard arthroscopic technique for ACL surgery (endoscopic technique) means that the screw for fixation of the graft in the femur can be put in place through the joint (Figs 19.22, 19.23). The surgical technique can be varied by additional small incisions placed on the outside of the knee joint for fixation of the graft in the femur. This technique may be easier and more reliable. It is essential that the surgeon uses the reconstruction technique he/she is familiar with.

During long-term follow-up it has been found that ACL reconstructions with a single band (single bundle) do not completely prevent osteoarthritis development at a later stage. A factor regarding this development is a certain residual rotational instability. Reconstruction with two bands (double-bundle) is a technique where two bands are used to restore ligament biomechanical functions and thus improve rotational stability (Fig. 19.24). Some surgeons believe that this double bundle technique better restores the normal anatomy of the ACL and it improves the knee kinematics, gives better performance and also reduces the incidence of arthritic development. Long-term results of this technique are lacking at this time. The future may show that a more correct anatomical reconstruction may be triple-bundle reconstruction.

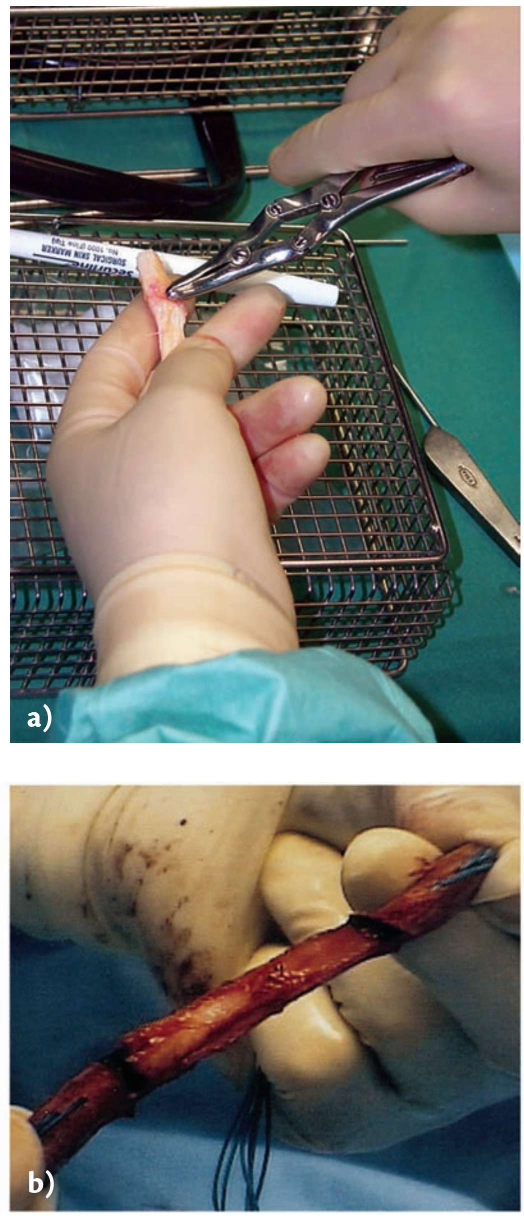


Figure 19.20 Anterior cruciate ligament reconstruction surgery with patellar tendon graft: a portion of the patellar tendon with bone at both ends can be used as a new ligament (graft). **a)** The graft is processed on a side table; **b)** sutures have been inserted into the graft so that the graft can be pulled through the premade tunnels.

Tip

A reconstruction of the ACL is not a simple operation and requires a skilled and experienced surgeon and a cooperative (compliant) patient for a good result.

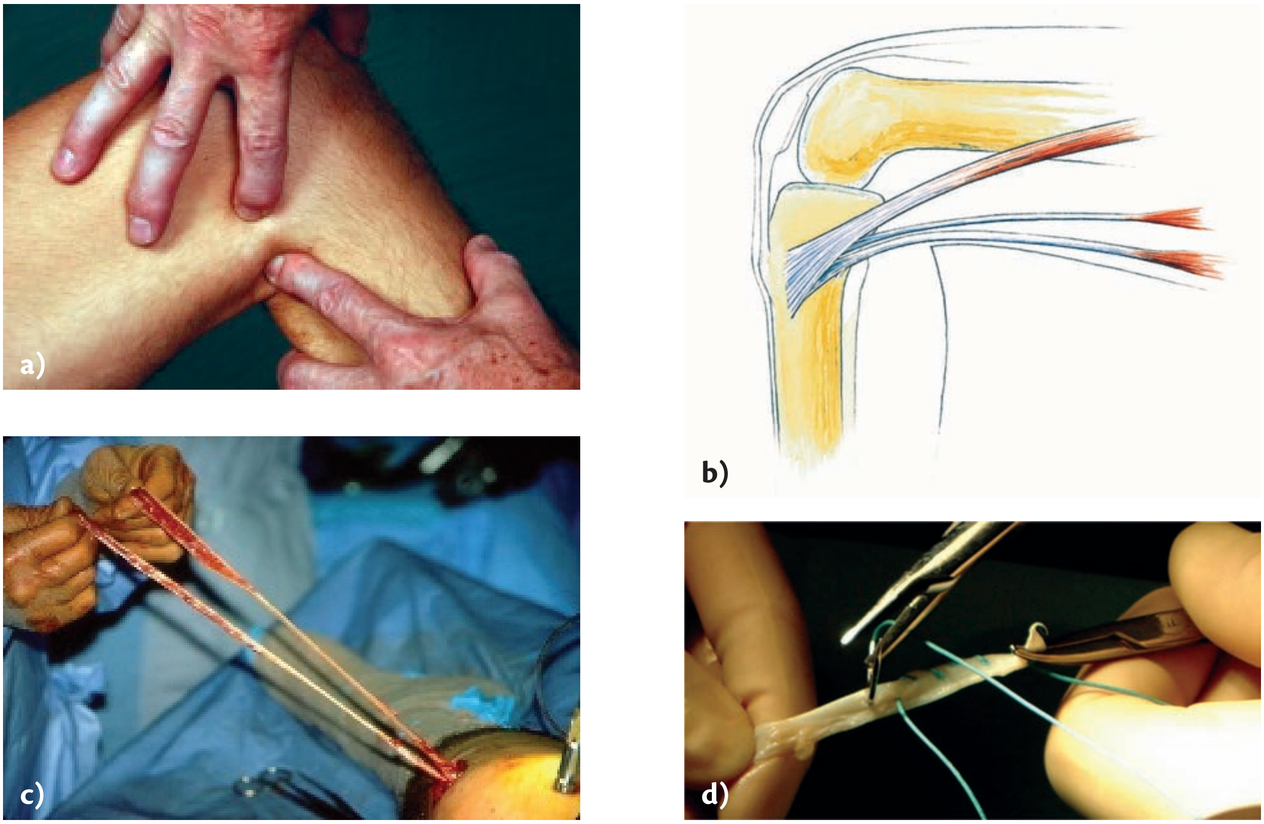


Figure 19.21 Hamstring tendons such as the semitendinosus and gracilis tendons can be used as cruciate ligament graft. **a)** The localization of the hamstring tendons in the knee; **b)** these tendons attach jointly with the sartorius tendon on the knee's medial side of the tibia to form the 'goose foot' (pes anserinus), sartorius tendon (top), gracilis tendon in the middle and the semitendinosus tendon on the bottom; **c)** the tendons are released from their muscles to be prepared to use for the reconstruction. The tendons can be used as a free graft or with the attachment intact, preserved in the 'goose foot'; **d)** the tendons are sutured together and prepared with pull out sutures in the ends.

Good pain control may be achieved by injection of analgesic before, during and after surgery, in combination with cold treatment (Fig. 19.25). This has made it possible for most operations to be performed on an outpatient basis. Some patients may need to stay overnight.

Rehabilitation

Pain and swelling should be the first thing to treat, by compression and cold therapy.

Early mobility training can also help to reduce the swelling.

- The muscles that are most important to regain their strength are the quadriceps and hamstring muscles. Hamstring muscles work as agonists, i.e. support the ACL, and the exercising of them should be initiated early. Muscle mass cannot however, increase as long as pain and swelling exist.
- A knee orthosis (KO) is of limited value in the rehabilitation process after an ACL reconstruction, provided that the operation went well. In some cases, however, a functional KO is perceived to be of value, when the athlete is to return to full sporting activity. The stabilizing effect is limited, however, especially when it comes to activities at high speeds. Although KOs do not provide full protection for a reconstructed ligament it is felt they have a positive effect on most of the athletes who use them. In conjunction with regular everyday activity they often have a significant positive effect (Fig. 19.26).

Tip

Many feel subjectively that an orthosis/brace provides some support and a feeling of security which is also important.

Return to activity

The athlete can often gradually return to an increased activity level. Cycling has been proven to be a safe rehabilitation method for the ACL. It's fine to start

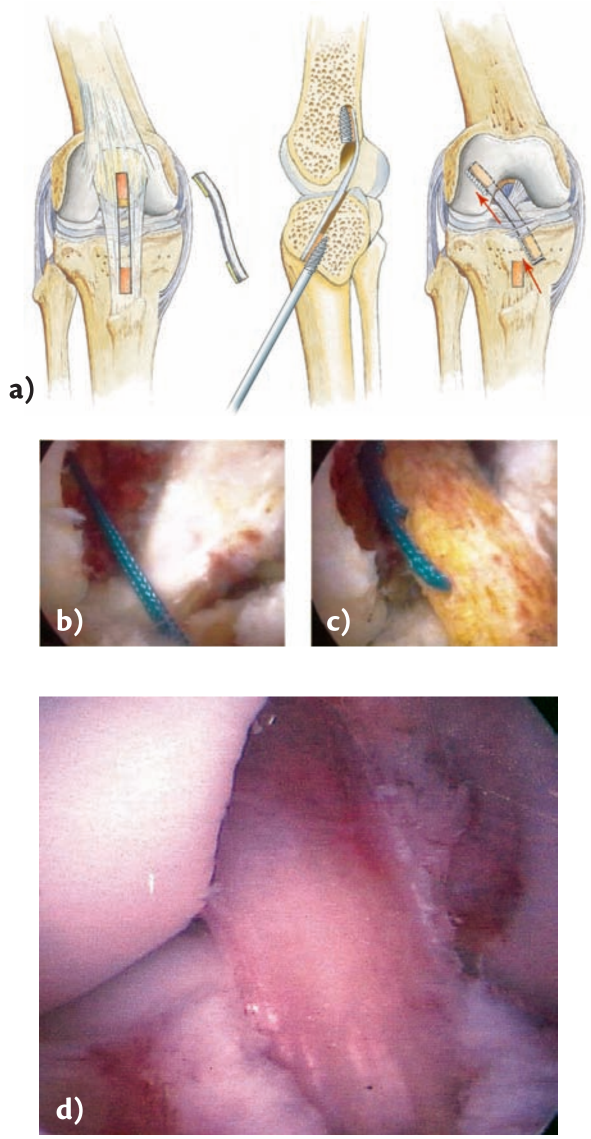


Figure 19.22 Anterior cruciate ligament reconstruction with a portion of the patellar tendon. **a)** The middle portion of the patellar tendon is taken with bone plugs at both ends, which are taken from the patella and tibia (left); the graft is passed through bone tunnels made in the femur and the tibia; the graft is secured with screws in bone tunnels in the femur and the tibia seen from the side (middle) and from anterior (right); **b)** the suture to the graft is passed through a bone tunnel in the femur as seen during arthroscopy; **c)** pull out sutures used to pass the graft through into the tunnels as seen during arthroscopy; **d)** arthroscopy shows graft tightened and fixated.

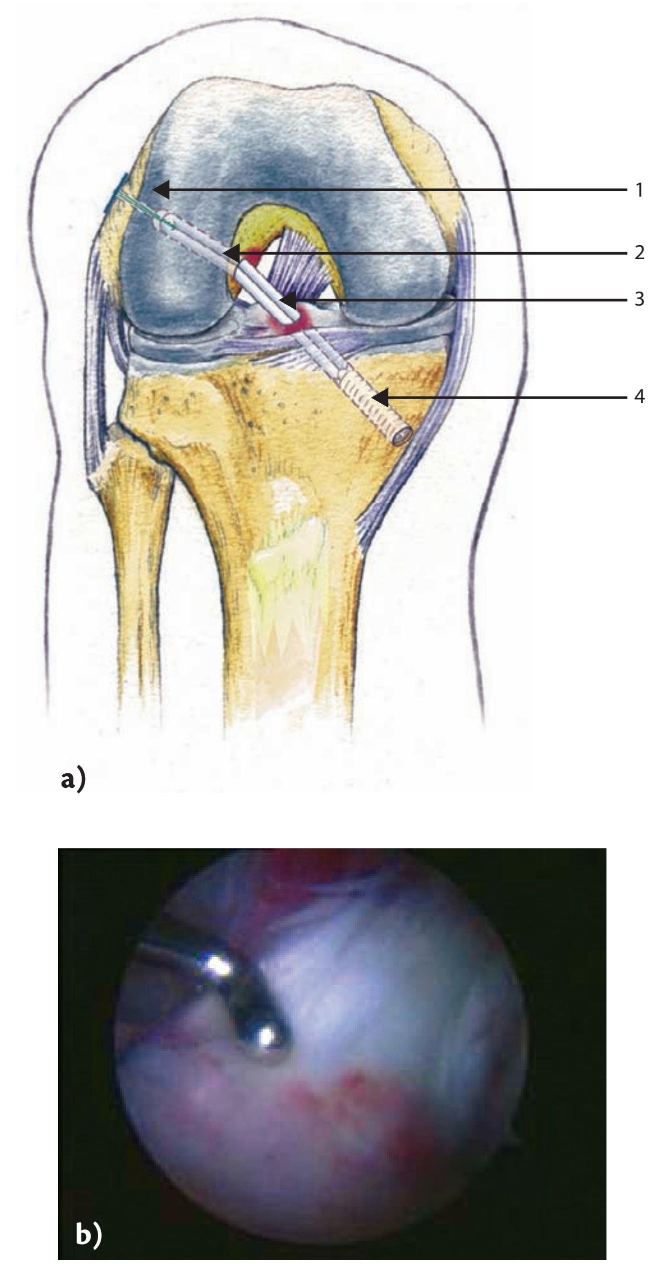
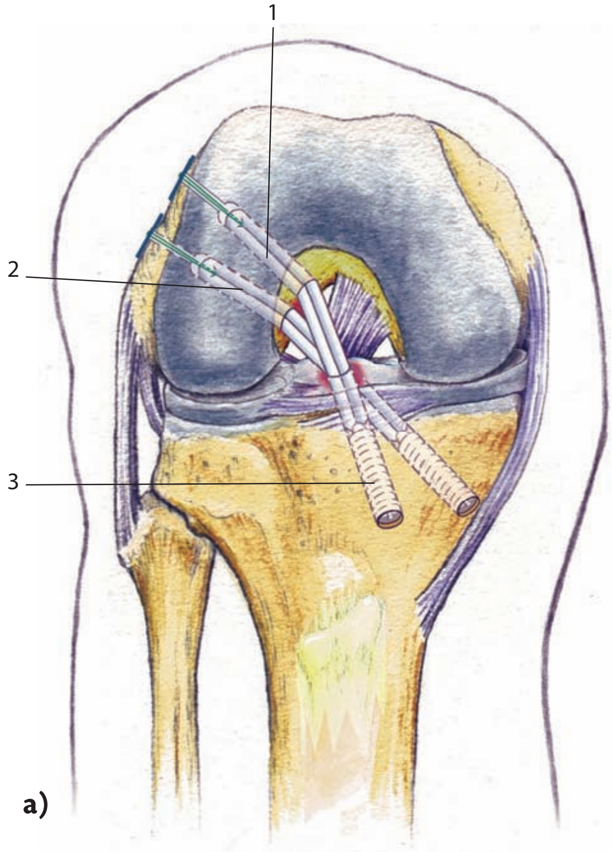


Figure 19.23 Anterior cruciate ligament reconstruction with a hamstrings graft (semintendinosus and gracilis tendons). **a)** The graft is passed through a tunnel in the tibia, through the joint and out through a tunnel in the lateral femoral condyle. The graft can be secured with a variety of options. 1: course of the graft through the tunnel in the tibia with a screw fixation in the tunnel; 2: course of the graft through the joint; 3: tunnel in the femur with tendon graft; 4: fixation of the graft on the outside of the femur; **b)** graft seen through the arthroscope.

cycling as soon as the ROM has reached 100°, typically within 3–4 weeks after reconstruction of the ACL. After 2 months, the athlete can usually begin running; however, activities that include sharp turns and pivoting should be avoided until the athlete has regained at least 85% of the strength of the thigh muscles compared with the healthy side. Such activities are potentially possible 4–6 months after surgery.

There are few scientific studies that have examined the return to sport at the same level as before the injury:

- Football/soccer: football/soccer players in the Champions League, i.e. the highest elite level can usually start training 6 months after an ACL reconstruction and actively play football/soccer



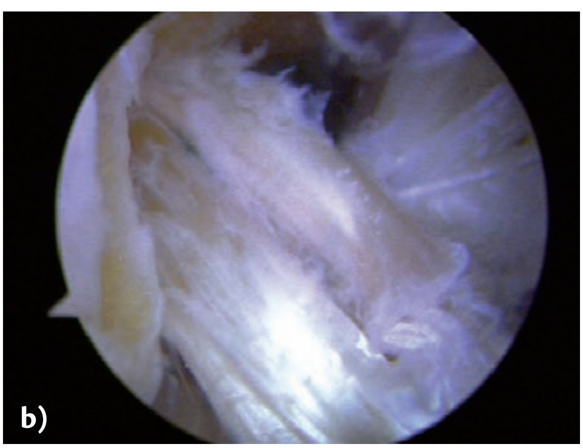


Figure 19.24 Double-bundle reconstruction technique, which involves a reconstruction of two grafts, which means that two of the cruciate ligament portions are reconstructed; **a)** Schematic drawing showing the method. 1. Anteromedial bundle 2. Posterolateral bundle 3. Screw fixations; **b)** double bundle reconstruction seen through the arthroscope (courtesy of ArtroClinic, Stockholm).

competitively after 9–10 months. 94% of the players have a full return to competition within 12 months. It should be noted that these elite players have gone through a rigorous rehabilitation process of several hours a day and have had the optimal support of skilled physical therapists in their rehabilitation.

Figure 19.25 Pain can be regulated well by using cold treatment such as a cryo-cuff. (Courtesy of 2014 DJO, LLC. Used with permission from DJO, LLC. All rights reserved.)

- American Football: in a recent study, 63% of players in the National Football League (NFL) returned to full competition level at an average of about 11 months after ACL reconstruction surgery. This is slightly lower than in previous studies. It was shown that more seasoned players are more likely to return to full competition level compared with others.
- Athletes in general: among active people 80% of cases return to some form of sports participation. An estimated 50–60% return to the activity level they had before surgery, as well as 40–60% of chronic cases.

Tip

There is no generalized template for the rehabilitation goal to successfully return to sporting activity. The rehabilitation must be tailored to the individual to succeed.

Return to sports at the elite level may itself be a risk factor for developing osteoarthritis.

Results of ACL injury treatment

- The results after an ACL reconstruction are often quite good, but perhaps not as good as the injured athlete would like them to be. It should be noted that the results can vary greatly.
- The results are largely dependent on the operating orthopedic surgeon's experience, the physiotherapist and the patient's participation in active rehabilitation.
- Chronic and acute injuries are treated using the same principles for the operation. In chronic cases the operation may be slightly modified where more bone is removed (notchplasty) to create space for the ligament. In chronic conditions there is often

Figure 19.26 Functional knee bracing may be of value to an individual after a knee injury in everyday activities and in certain sporting activities. **a)** Lightweight brace, which provides durable support for an injured anterior cruciate ligament (courtesy of 2014 DJO, LLC. Used with permission from DJO, LLC. All rights reserved); **b)** SofTec® Genu, Bauerfeind knee brace.

damage to the articular cartilage and menisci, therefore the prognosis is not as good as in acute injuries, but the results are still satisfactory.

Risk of osteoarthritis

It is still unclear whether an operation over time can prevent serious degenerative changes in the joint and that dual-band reconstructions in future could reduce osteoarthritic development.

Tip

Recent experience shows that an ACL reconstruction may not prevent further degenerative changes, i.e. despite surgical stabilization osteoarthritis may develop in the young athlete.

Long-term results after an ACL injury show that independent of the treatment, there is a prevalence of 50% with X-ray verified changes in the joint suggesting development of osteoarthritis 15 years after the injury. Since ACL injuries often occur early in life, especially in women, many are clearly symptomatic already at 35 years of age. Return to sport activity at the elite level seems to be a risk factor for later development of osteoarthritis of the knee.

Tip

- Successful treatment of an ACL injury is still a complex task and requires specialized skills.
- The risk of later development of osteoarthritis of the knee joint is evident.
- Return to sport activity at the elite level seems to be a clear risk factor for later development of osteoarthritis of the knee.
- Treatment should be tailored to the individual and their desired activity level.

Medial collateral ligament injuries

The MCL is one of the knee ligaments that is most often damaged. Damage to the medial (internal) structures of the knee joint has an incidence of 0.24 per 1000 active hours. They are twice as common among men as among women (0.36 vs. 0.18). It is very probable that many minor injuries to MCL are not documented as they are never reported to the physician. The treatment of these injuries has changed from surgical repair in the 1970s to today's widespread conservative treatment with early rehabilitation.

Anatomy

Medial knee stability is maintained by the medial static and dynamic stabilizers extending from the anterior to the posterior midline of the knee. The static structures are the superficial MCL, the posterior oblique ligament (POL) and the middle third of the capsular ligament (Fig. 19.11). Dynamic stability is provided by the 'goose foot' (pes anserinus) tendons, and especially the semimembranosus tendon.

The superficial MCL is the largest structure on the knee's medial side. It runs distally from its origin on the medial femoral epicondyle and attaches on two points on the tibia. The upper (proximal) origin on the thigh bone (femur) is oval and is 3–5 mm behind the medial epicondyle. The two lower (distal) attachments of the superficial MCL are located on the tibia. The posterior more proximal attachment is about 1 cm below the joint space and is partially shared with the deep MCL and the anterior more distal attachment has a broad base directly into the bone 5–7 cm below the joint space on the anterior medial portion of the tibia, just below the pes anserinus attachment. These two attachments result in two functionally distinctly different parts of the superficial MCL. The anterior fibers are taut and supportive throughout the entire flexion and the rear fibers are relaxed during flexion but tense during extension. The MCL is tense during external rotation of the tibia.

The middle third of the joint capsule, which constitutes the deep portion of MCL, is a short structure, approximately 2–3 cm long. It is attached to the medial meniscus and lies below the superficial MCL, which it has a partial common attachment with on the tibia approximately 10 mm distal to the joint space.

The deep and superficial parts are often fused proximally. This ligament is relatively lax to allow knee movements but short enough to stabilize the meniscus. The deep portion of the ligament is divided into the meniscofemoral and meniscotibial ligament part. A rupture can occur either adjacent to the attachment on the meniscus, tibia or above the meniscus, regardless of where the rupture occurs in the superficial part of the MCL.

The POL is a thickened portion of the joint capsule, which originates on the epicondyle just behind the superficial part of the MCL and attaches on the tibia condyle just below the joint space and on the medial meniscus posterior horn. This structure is important for medial stability. The POL is relaxed during flexion.

Biomechanical analysis shows that the MCL's main function is to resist the forces that give valgus (a stress placed on the outside of the knee forcing the lower leg outward in relation to the femur, 'knock-kneed'), and external rotation of the tibia relative to the femur. The superficial part of the MCL has been found to account for 57% of the medial stability at 5° knee flexion and up to 78% at 25° of flexion. The deep part of the MCL accounts for 8% at 5° and 4% at 25° flexion, while the POL accounted for 18% and 4%, respectively.

Symptoms and diagnosis

- The injury mechanism among skiers is both an indirect valgus trauma of the knee and external rotation of lower leg (Fig. 19.27). Football/soccer players among others can have considerable damage to the MCL done by a direct trauma to the outside on the lower part of the thigh or upper part of the lower leg.
- Pain may occur acutely. Lack of strong pain does not rule out a serious injury. Sometimes the pain is more pronounced in smaller injuries than large.
- Injury to the MCL can impair walking ability. Athletes with severe grade III injuries cannot walk without support in 50% of cases.
- Joint swelling is unusual; swelling suggests a larger injury in the knee itself.
- Tenderness is common over the injured area, especially over the medial femoral epicondyle.
- It is important to test the stability with a valgus stress test (Fig. 19.28).

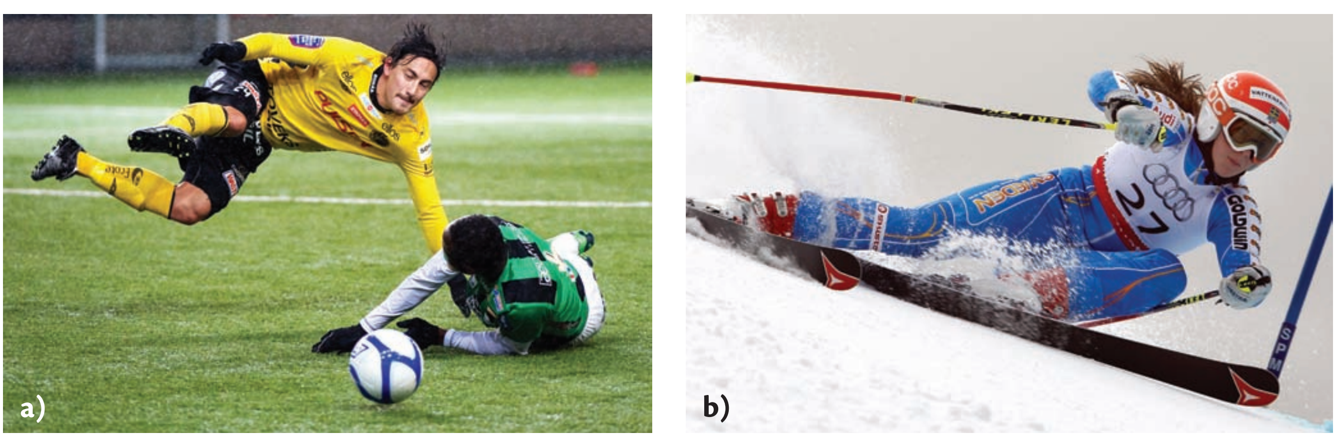


Figure 19.27 Ligaments in a knee joint are subjected to great stress especially at the elite level in both contact and individual sports, such as **a)** football/soccer and **b)** downhill skiing. (With permission, Bildbyrån, Sweden.)

Figure 19.28 Valgus stress test for stability of the medial collateral ligament. **a)** With the knee in full extension the examiner with one hand on the outside of the knee joint and the other hand on the inside of the ankle tests the stability by applying pressure to the knee medially and laterally to the inside of the foot; one can determine if instability is present or not by comparing with the other leg; **b)** the same maneuver is performed with the knee bent to 30° flexion; **c)** alternative options with the foot held in the examiner's armpit.

The following grades of injury apply:

- Grade 0 - normal, i.e. no joint opening
- Grade I – 1–4 mm joint opening.
- Grade II – 5–10 mm joint opening.
- Grade III – 10–15 mm joint opening.

In grade I and II tears a well-defined endpoint or resistance is felt during the valgus test, but a grade III rupture finds no endpoint or distinct resistance. Note: not even when complete MCL rupture is present will there be a valgus instability at full extension if the PCL and the posterior joint capsule are intact. The medial instability should first be tested at 30° knee flexion but also with straight leg.

Lachmans test for stability of the ACL should be performed with a high grade of MCL instability. 95% of cases of a grade III injury to the MCL have an associated ACL injury. Anteroposterior, lateral, and patellofemoral X-rays are required for all patients with knee injuries. Fractures should be excluded. In doubtful cases, MRI may be used to identify the exact location of the MCL injury as well as associated meniscus and cruciate damage (Fig. 19.29).

Treatment

- Correct diagnosis is the basis for a successful treatment. Acute, isolated grade I and II injuries to the MCL should always be treated conservatively with early rehabilitation.
- For grade I and II injuries strength and early mobility training can begin as soon as tolerated by pain (see pp. 463, 468 Table 19.2).
- A stabilizing knee brace may be helpful.
- If the athlete at the end of the first treatment week has made considerable progress, i.e. the knee joint has full extension, no effusion and tenderness present, it is likely that the athlete can return to normal physical activity (including contact sports) within 3–8 weeks.
- The treatment of grade III injuries is dependent on what other injuries there are. It is generally considered that a significant anterior, medial subluxation of the tibia (in other words, a high grade of medial instability) cannot occur without ACL rupture. The consensus is that in a combination injury of the MCL and ACL, a reconstruction of the ACL should be done arthroscopically and a repair of the MCL in open surgery. Rehabilitation for these combination injuries is the same as for isolated ACL injuries. Early mobility training is of great importance, since an operation of the MCL causes the knee joint to stiffen.

Tip

Treatment of an isolated injury of MCL is basically conservative. If there is an ACL injury at the same time, surgery may be considered. Then early mobility training is important.

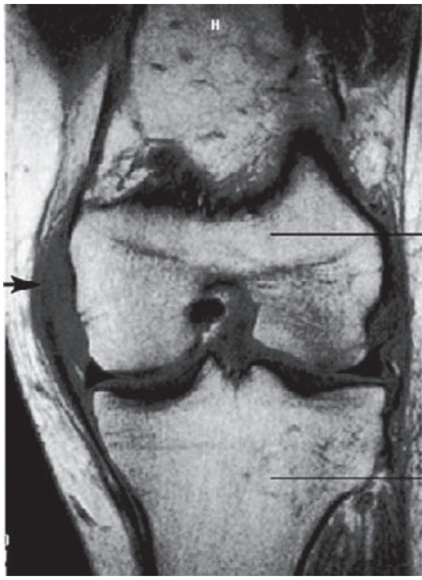


Figure 19.29 Magnetic resonance imaging showing a total rupture of the medial collateral ligament in the knee joint (arrow). 1: Tibia; 2: femur.

Figure 19.30 Stabilizing brace/orthosis (shown here with range of motion stability) often have good effect on grade I and II injuries. (Courtesy of Nea International BV.)

Complications and return to sport activity

There are rarely any complications from injuries to the MCL. In some cases there may be residual pain to some extent over the proximal origin. Earlier athletes were bothered by stiffness, but this has now been nearly eliminated due to early mobility training. Still, the instability of the knee joint can be prolonged if the damaged structures of the MCL do not heal properly. In those cases a reconstruction surgery should be done. This should be done anatomically and by an experienced knee surgeon. The importance of intensive rehabilitative work cannot be emphasized enough. Early mobility training, including weight bearing and strength exercises should begin as soon as possible.

Return to sports is permitted as soon as the athlete is comfortable with his knee and there is no functional deficit:

- Grade I sprain may be within 1–2 weeks.
- Grade II sprains need a little longer; athletic endeavors can be allowed when there is no pain or valgus instability and only slight tenderness – about 2–4 weeks.
- Grade III injuries are more problematic: athletes need acceptable stability with the valgus stress test and 80% strength on strength testing. Functional activities can then usually be well tolerated. Sometimes there may be a need for a knee brace (Fig. 19.30).

Combined ACL–MCL injuries

Combination injuries of the ACL and MCL are quite common, especially in skiing. The general consensus for this injury is to first treat the MCL injury with a functional rehabilitation program: this generally involves using a functional brace for complete MCL tears for about 4–6 weeks. After this the ACL tear can be addressed, usually by surgical reconstruction in active individuals. This allows optimal treatment of both injuries since it is best to wait a few weeks after an ACL tear to avoid excess stiffness of the knee, which can occur after early surgery.

Opinions are, however, divided concerning the treatment of a complete rupture of the MCL, when even a joint capsule rupture exists and the two ends of the MCL are significantly separated. In such cases, the conditions for satisfactory healing are not present and surgical repair is indicated.

When there is a complete rupture of MCL the risk of residual instability is increased, which can be difficult to overcome. MRI is used in the assessment (Fig. 19.31).

Surgical repair of the MCL should be performed within 1–2 weeks after the injury, and if necessary, the ACL reconstructed simultaneously.

PCL injuries

PCL tears of the knee are not very common; they constitute less than 5% of all major knee ligament tears.

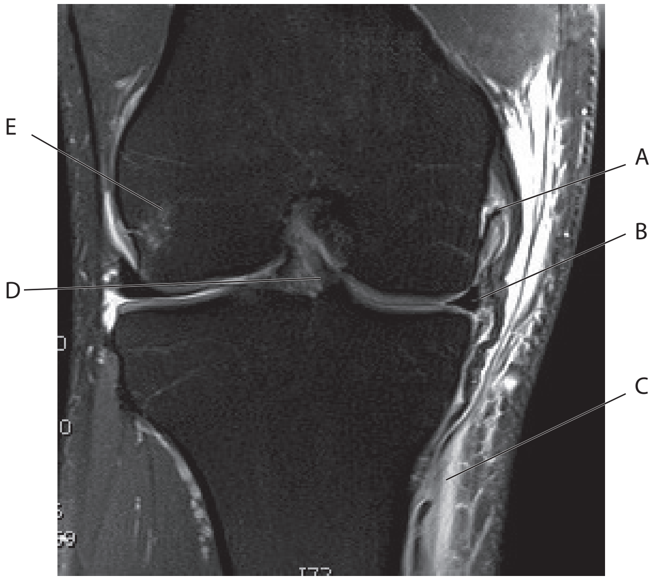


Figure 19.31 Magnetic resonance imaging can be used for assessment of combined injuries. A: avulsion fracture of the medial epicondyle; B: tear of the medial meniscus from the deep portion; C: rupture of the distal attachment of the superficial portion of the medial collateral ligament; D: anterior and posterior cruciate ligament injuries; E: bleeding in the subchondral bone - "bone bruise".

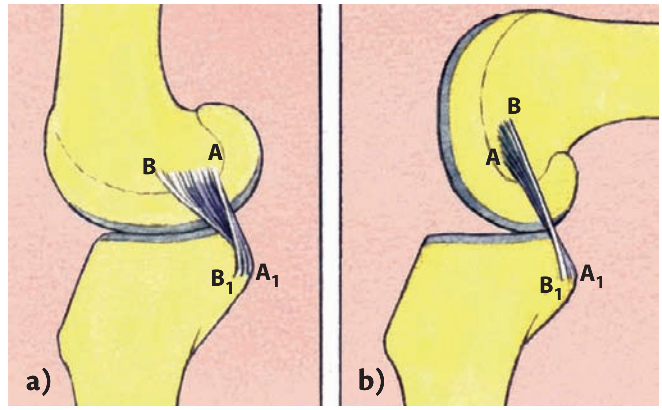


Figure 19.32 Posterior cruciate ligament (PCL). **a)** A-A1 is called posteromedial bundle and is tight in extension; **b)** B-B1 is called anterolateral bundle and is tight in flexion.

Anatomy

The PCL has an average width of 15 mm and length of 40 mm. It is fan-shaped, being narrowest in the mid-portion and fanning out superiorly and, to a lesser extent, inferiorly. The PCL originates on the posterior surface of the tibia and passes superiorly and anteromedially to insert on the lateral wall of the medial femoral condyle. The PCL consists of a larger anterior band, which is taut in flexion and relaxed in extension, and a smaller posterior band, which is taut in extension and relaxed in flexion (Fig. 19.32). In 70–100% of knees there is either an anterior or a posterior meniscofemoral ligament (passing from the meniscus to the femur). The posterior meniscofemoral ligament to the lateral meniscus is called the ligament of Wrisberg and is more frequently present than the ligament of Humphrey, which is the anterior meniscofemoral ligament. It should be pointed out that the PCL is an intra-articular ligament (inside the joint), but has an extra-articular (outside the joint) distal insertion on the tibia.

Biomechanics and function

The PCL is stronger than the ACL. The PCL is relatively taut in extreme extension, but it has less tension when the knee is flexed, and has least tension at about 30° of flexion. As flexion increases, the PCL begins to tighten again, being maximally taut in full flexion. The PCL provides 95% of the strength to prevent the posterior movement of the tibia in relation to the femur. Secondary stabilizers are among others the posterior lateral capsule, popliteus muscle and tendon, the postero-oblique portion of MCL, the LCL and deep medial portion of the MCL. The functions of the PCL are to resist forces causing a posterior shifting of the tibia to the femur, to resist hyperextension, to limit internal rotation, to limit hyperflexion and to prevent varus and valgus positioning.

Mechanism of injury

The most common cause of a PCL injury is a posteriorly directed force on the upper front of a flexed knee, such as a dashboard injury in a motor vehicle accident. In football/soccer, a player may receive a trauma to the anterior proximal surface of the tibia while attempting to slide tackle an opponent, and thereby force the tibia back to cause a PCL tear (Fig. 19.33). The PCL may also be torn through a fall on a flexed knee while the foot is in plantar flexion. An isolated PCL tear may also occur when the athlete's knee is forced into hyperflexion while the foot is in dorsiflexion. Another mechanism of an acute PCL injury is a sudden, unexpected hyperextension of the knee (Fig. 19.34).

Injuries to the PCL are often avulsions and tears of the tibial attachment, and occur typically in dashboard and hyperextension injuries. An avulsion from the tibial attachment is more frequent in growing individuals than in adults.

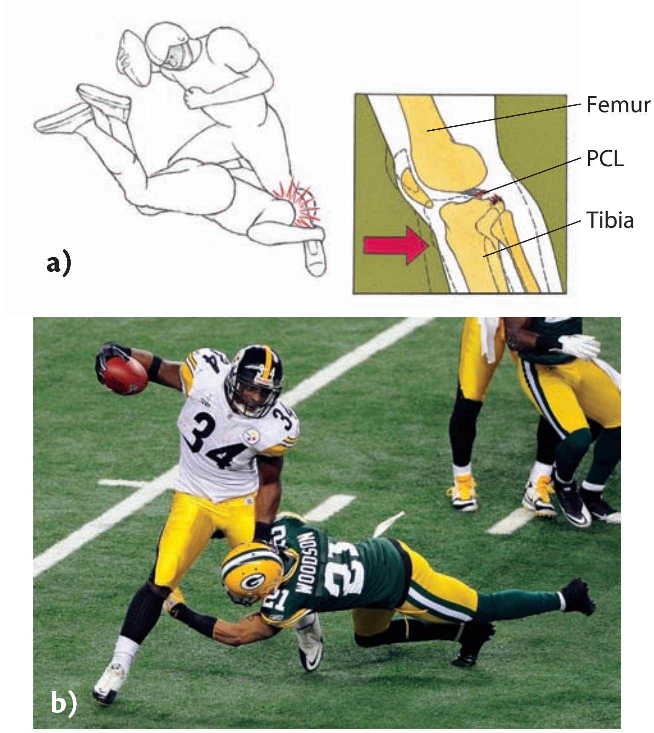


Figure 19.33 Injury mechanism, for a posterior cruciate ligament (PCL) injury. **a)** PCL injuries can be caused by trauma from the front to the lower leg; **b)** American football is a risk sport for this injury (with permission, by Bildbyrån, Sweden).

Figure 19.34 Injury mechanisms that can cause an isolated posterior cruciate ligament injury. The athlete's knee can be forcefully hyperflexed while the foot is in dorsal or plantar flexion.

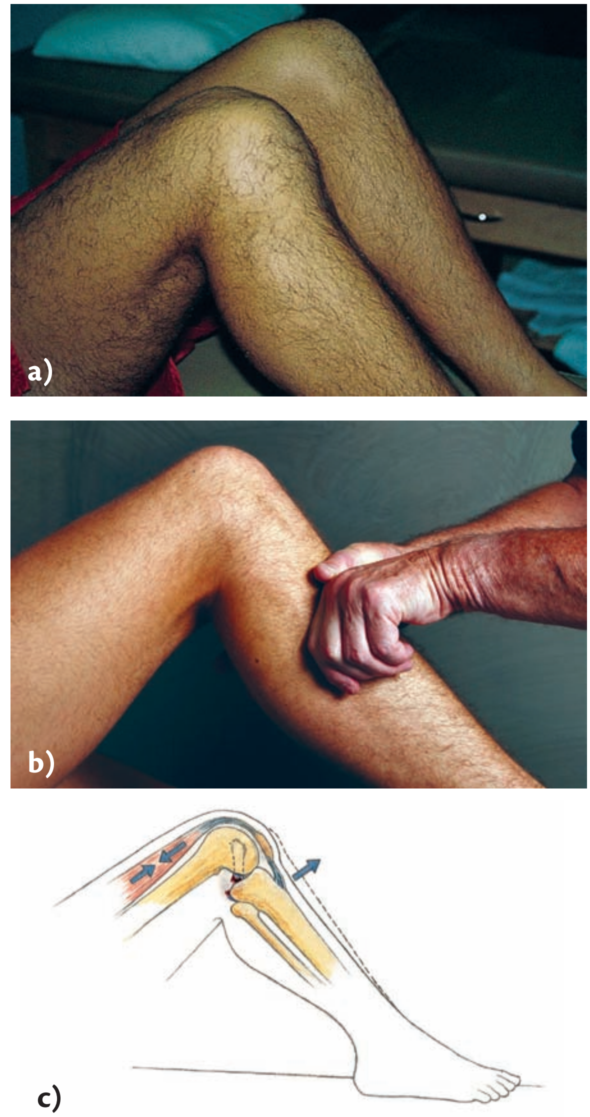


Figure 19.35 Tests for the stability of the posterior cruciate ligament (PCL). **a)** Spontaneous posterior displacement (drawer) of the tibia in relation to the femur, the posterior sag test; **b)** posterior drawer test. The knee joint is held in 90° of flexion with neutral rotation of the lower leg. The hands are placed on the front of the lower leg anterior proximal upper portion. Push posteriorly in relation to the femur. Comparison should be made with the other side; **c)** active quadriceps test for PCL rupture. The patient lays on their back with their knees bent at right angles. During an active contraction of the quadriceps muscle the tibia is reduced to a normal position from a posterior drawer if a rupture of the PCL is present.

Symptoms and diagnosis

- A mild bleeding within the joint (hemarthrosis) is usually found in an acute isolated PCL injury. Typically there is an increase in pain with knee flexion beyond 90°. Generally, the swelling and the pain are less than in ACL injuries.
- Patients with symptomatic chronic PCL deficiency, have often associated patellofemoral pain and recurrent instability to support the diagnosis.

There are several tests that indicate a PCL injury:

- The posterior sag sign is a posterior displacement of the tibia when the knee is flexed 70–90° (Fig. 19.35A).
- The posterior drawer test is a classic test revealing posterior displacement of the tibial plateau in relation to femur with the knee flexed to 90° (Fig. 19.35B).

The tibia should be in neutral rotation during the test. If there is 3–10 mm of increased movement this usually indicates a partial PCL tear. If there is more than 10 mm increased displacement in the posterior drawer, a complete PCL rupture is likely and the indication for surgery increases. A posterior drawer test is sensitive in chronic PCL deficiency, but in acute cases, false-negative findings are not uncommon.

- ✓ The posterior drawer test has been shown to be positive in 31–76% of cases in which serious injury to the PCL was verified. The secondary stabilizing structures of the posterior lateral corner have an important secondary restraint, and can give a false-negative result.

- In the quadriceps active test, the patient is supine and the knees are flexed to 90° (Fig. 19.35C). If there is an insufficiency in the PCL in this position, the tibia visibly slides forward when the patient actively contracts their quadriceps.
- Pathological hyperextension of the knee is not uncommon, but can be a nonspecific finding in chronic PCL injuries. This test is usually easy to perform without pain in chronic PCL-deficient knees, but in acute injuries pain may hinder the examination.
- Plain X-rays will exclude major fractures and bony avulsions.
- MRI is a useful research and diagnostic tool. MRI may miss a tear if the ligament appears only elongated without a disruption in the ligament continuity. An MRI scan is indicated for the diagnosis of PCL injuries if the clinical findings are uncertain and in planning a revision surgery for postoperative complaints (Fig. 19.36).

The diagnosis can be verified by:

- Examination under anesthesia; this may be general, epidural, spinal or local. When the patient is relaxed, the diagnosis is often obvious.
- Arthroscopy. This will give directly information about the injury, especially when a hook probing is included (Fig. 19.37). This is important, since in some cases there is no disruption in the ligament continuity, more that the ligament is elongated.

Injury progression

The natural progression of PCL injuries is not yet clearly understood. It has been reported that in conservatively treated isolated injuries, 80% resulted in a good result and return to sport. Other studies have found that 90% complained of pain during activities, and 50% had difficulties walking 6 years after injury. Long-term reports with 15 year follow-up indicate osteoarthritis (see p. 165) in 80%; this outcome may be activity related. It also showed a patellofemoral osteoarthritis in 62% of cases after 15 years. Poor outcome is correlated with

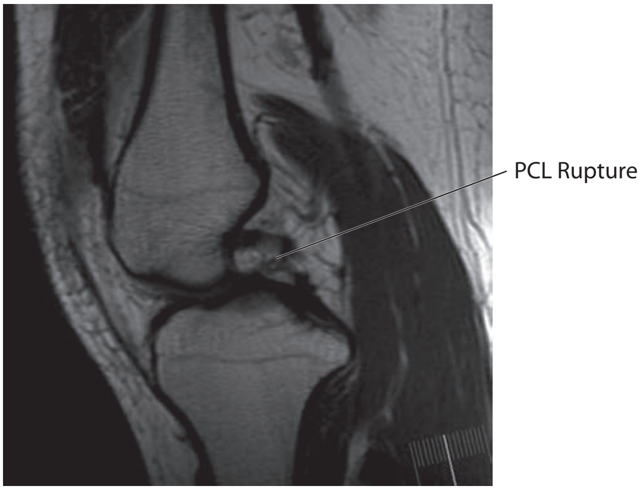


Figure 19.36 Magnetic resonance imaging of a ruptured posterior cruciate ligament.

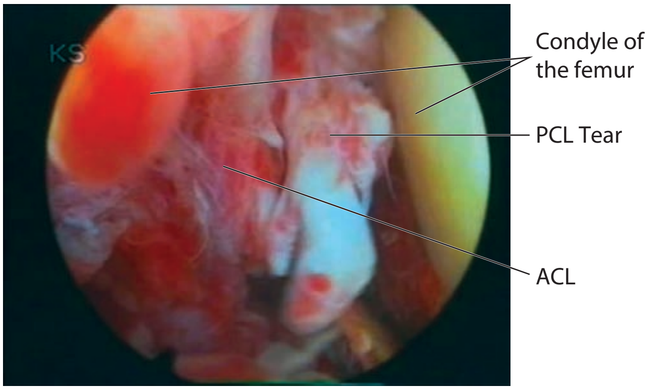


Figure 19.37 Arthroscopy image of a middle substance rupture of the posterior cruciate ligament. (Courtesy of ArtroClinic, Stockholm.)

chondromalacia, meniscus injury, quadriceps hypotrophy and degenerative changes in the knee. The proposed natural progression in PCL-deficient knees is as follows:

- Functional adaptations: 3–18 months.
- Functional tolerance with some osteoarthritis development: 15–20 years.
- Osteoarthritic deterioration of the knee after 25 years.

PCL injuries with bony avulsion

In dislocated PCL bone avulsions, open or arthroscopic reduction and internal fixation is the method of choice. Excellent results can be achieved after re-attachment using sutures through drill holes or by fixation with screws (Fig. 19.38). Early controlled mobilization in a knee brace is usually possible.

Isolated intrasubstance tears

Conservative treatment with intensive rehabilitation is often used for isolated PCL injuries, especially if the posterior translation is less than 10 mm. Conservative treatment includes a brace (Fig. 19.39) or splint support for 2 weeks, and then early functional rehabilitation.

Quadriceps strengthening is important and can compensate for functional PCL insufficiency. Studies of athletes indicate that conservatively treated PCL injured knees have residual posterior laxity compared with the uninjured knee, but the great majority of athletes seem to be functionally stable and are often asymptomatic. Return to full activity following an isolated PCL injury is possible within 2–8 weeks of injury. The short-term outcome is usually good if a strong quadriceps function can be maintained. If the posterior displacement is not controlled with quadriceps activity, the long-term outcome may be osteoarthritis especially in the patellofemoral joint.

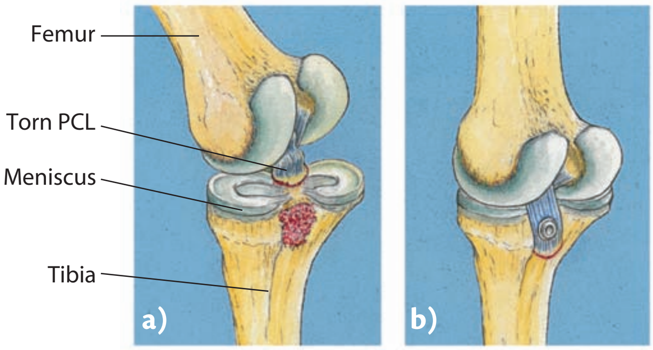


Figure 19.38 Posterior cruciate ligament (PCL) avulsion injury. **a)** PCL injury with a bone fragment tear from the posterior upper part of the tibia; **b)** fixation of bone fragments with a screw.

Figure 19.39 This orthosis (brace) is designed specifically for the rehabilitation of the knee after a posterior cruciate ligament reconstruction or during conservative treatment. (Courtesy of Albrecht GmbH.)

Surgical treatment of acute PCL injuries is controversial. If the posterior displacement of the drawer test is more than 10 mm, surgery should be considered since it is then likely that secondary stabilizers also have been injured. The surgical indication increases if the PCL tear is combined with other ligamentous injuries. The surgical technique is the same as for chronic PCL instability.

Tip

Isolated PCL injuries are treated most often conservatively with intensive rehabilitation.

Chronic PCL instability

If the athlete has functional symptoms of 'giving way' or discomfort despite rehabilitation, or more than 10 mm posterior laxity on the posterior drawer test, surgery should be considered. Many surgical techniques have been described. The majority have failed to prevent posterior instability completely. Some patients have a residual posterior drawer or sag compared with the normal contralateral knee.

- The most commonly used grafts for PCL reconstruction are:
  - ✓ The patellar or quadriceps tendon from the injured knee.
  - ✓ An allograft (graft from a cadaver); the Achilles tendon is now the mostly used transplant (common overseas, predominately in the USA).
  - ✓ Augmentation of the existing PCL with the hamstring tendons.
- Surgical techniques, which mostly include arthroscopy, is technically demanding and detailed, needing an experienced surgeon.

Early mobility is usually allowed after PCL surgery, but is limited to 0–60° during the first few weeks. Partial weight bearing is usually recommended for 8–10 days and thereafter as tolerated. Isometric quadriceps exercises are started within the first few days, followed by straight-leg raising as soon as possible. Hamstring muscles should be activated later. Functional activities should start as soon as possible. However, there is controversy over the best postoperative rehabilitation protocol. Depending on the type of sport, 75–85% of patients can return to activity 4–8 months after surgery.

LCL injury and posterior lateral instability

The LCL is the primary restraint to varus stress of the knee (when the lower leg is pressed outward in relation to the femur, 'bowleg'). It is most commonly injured in combination with one of the cruciate ligaments. The mechanism of injury is usually hyperextension in combination with a varus stress of the knee. The posterior lateral complex consists of the biceps femoris tendon, the lateral head of the gastrocnemius muscle tendon, the arcuate popliteal ligament, the LCL and the popliteus muscle–tendon unit. The physician's examination and the treatment will vary, depending on the structures involved.

Diagnosis and treatment

LCL insufficiency

Diagnosis of LCL insufficiency is made by eliciting varus instability during an applied varus stress on the tibia with the knee flexed at 30° (Fig. 19.40). Laxity of 5 mm indicates functional LCL insufficiency. Varus opening of 5–10 mm indicates a combined LCL and popliteus injury, and more than 10 mm indicates an LCL, popliteus and ACL or PCL injury. In these cases there is also instability in a fully extended knee.

Serious LCL insufficiency may be treated by surgical augmentation of the existing ligament with, for example, the biceps tendon, a hamstring tendon or an allograft.

Popliteal tendon injury

If there is symptomatic posterior lateral instability with a varus opening of more than 5–10 mm, or if there is a 10–15° increase in external rotation of the lower leg when measured at 30° of knee flexion, a popliteal tendon injury should be suspected (see Fig. 19.42).

Posterolateral instability and PCL injury

The posterolateral drawer test assesses instability in external rotation. The reverse pivot shift can also detect posterolateral instability (Fig. 19.41). The lateral tibial plateau is subluxed posteriorly by placing the joint in flexion and by holding the foot in external rotation. When the knee is extended with pressure on the lateral aspect of the tibia, a shift relocates the joint, at about 30° of flexion. A reverse pivot shift, however, can occur in 35% of normal knees. When diagnosing these injuries, it is important to observe the gait for increased external rotation of the foot, painful heel strike or the presence of a varus thrust (i.e. the injured knee is moved outward

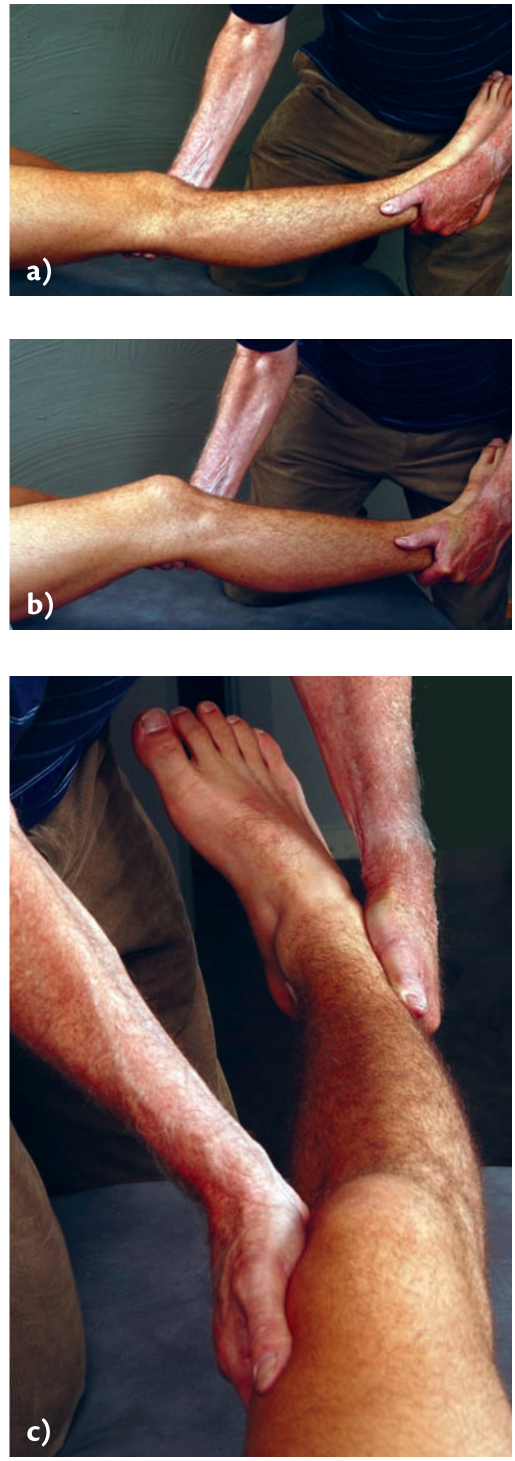


Figure 19.40 Varus (bow-legged) stress test. **a)** Varus stress test is performed with the knee extended. One hand of the examiner is held on the inside above the knee and the other hand on the outside ankle. The knee is pressed outward and the foot inward. The level of instability is determined in comparison with the healthy side; **b, c)** the same maneuver performed with the knee in 30° of flexion. The degree of instability is compared with the healthy side.

Figure 19.41 Reverse pivot shift test for rear lateral instability. The knee joint is held with one hand from the outside, and the other hand at the foot. The knee joint is pressed inward, the foot is turned outwards under simultaneous bending. A slipping of the tibia backward can be experienced. The degree of instability is compared with the uninjured side.

in a sudden jerking motion when the leg is weight bearing).

Athletes who have acute posterolateral rotatory instability need urgent surgical repair. If the surgery can be done within a couple of days the prognosis for a good result is higher. The peroneal nerve needs to be evaluated during the procedure. Postoperatively the patient is fitted with a brace allowing motion between 0–60° and restricted to partial weight bearing for 1–2 weeks. Thereafter, ROM and weight bearing can increase as tolerated.

Tip

Damage to the posterior lateral structures are difficult to treat successfully. If surgery is required it should be performed within a couple of days, because the probability of a good result is significantly higher.

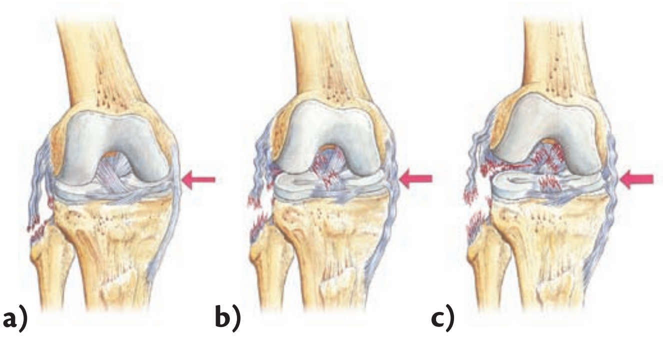


Figure 19.42 Injury caused by trauma to the inside of the knee joint. **a)** Moderate trauma will result in injuries to the lateral side of the knee including, e.g. the lateral collateral ligament and also the popliteal tendon; **b)** larger trauma also causes a rupture to the anterior cruciate ligament; **c)** very large trauma ruptures even the posterior cruciate ligament.

Combined ACL–LCL injuries

Damage to the LCL and posterolateral structures (Fig. 19.42) is probably the most debilitating of ligament injuries (especially in the case of combined injuries). If such an injury is diagnosed too late, they are extremely difficult to treat. Unsatisfactory or unsuccessful treatment outcomes are common. Best results are obtained with surgery within the first 1–2 weeks after the injury. When there is a combination injury of the ACL and the LCL they should be treated simultaneously; usually a reconstruction of the ACL only is done.

Knee dislocation

For a dislocation (luxation) to occur in the joint between the femur and tibia a sizable external force is required. In most cases the injury takes place in connection with a traffic or hunting accident, but sometimes can occur in sports. In approximately 30% of cases there is an associated circulation complication and often nerve damage as well. Since the blood flow to the lower leg can be disturbed it is important to reduce the dislocation immediately.

After the joint has been set in the correct position, an immediate assessment of leg arteries must be made via an arteriogram if possible. An alternative to this is careful observation through the blood flow measurements using Doppler technology. Dislocation of the knee requires admission for observation in hospital. If arterial damage and poor blood supply is present to the lower leg immediate surgery is necessary with blood vessel suturing or bypass surgery.

Tip

This is one of the truly acute risk conditions in orthopedics. It is immediately essential to ensure that circulation to the leg is satisfactory.

A dislocation of the knee joint causes multiple ligament ruptures, and the ligaments that rupture are dependent on trauma direction of the luxation. Often there is a rupture of both the ACL and PCL as well as LCL and MCL, plus capsule structures. Surgical repair and reconstruction of the damaged ligaments is becoming more common following dislocation, although satisfactory results have been reported after conservative treatment with cast for 6–8 weeks.

If surgery is preferred the best results are achieved if it is performed within the first 1–2 weeks, when at least the collateral ligaments and joint capsule should be sewn together. The ACL and PCL can be reconstructed later. If the patient's condition delays the procedure, the full reconstruction can be done later, but the results are not as good. Knee dislocation is a devastating injury and most athletes will have difficulty returning to their previous level of activity. Return to sport may be possible within 9–12 months.

Meniscus injuries

Injuries to the knee joint cause more problems for athletes than injuries to any other joint. The most common knee injuries are lesions of the medial and lateral menisci. The sports with the highest prevalence of meniscal injuries are football/soccer, American football, basketball, and baseball and skiing, i.e. sports with rotational and 'cutting' motion (Fig. 19.43). The incidence of meniscal injury that results in meniscectomy (remove part of or the full meniscus) is 61 per 100,000 individuals. Treatment of meniscal lesions with arthroscopy has become the most common orthopedic surgical procedure, and in many orthopedic centers constitutes 10–15% of all surgery.

Tip

The meniscus plays an important and significant role in the knee's function and biomechanics. Reduced function and degenerative changes in the knee joint have been reported after the removal of the meniscus (meniscectomy).

a)

b)

Figure 19.43 a, b) The risk of injury to a meniscus is present in multiple sports such as football/ soccer, judo and handball. (With permission, by Bildbyrån, Sweden.)

After medial meniscectomy progressive cartilage damage has been observed on the medial condyle weight-bearing areas. Long-term follow-up of athletes who have had a meniscectomy have shown degenerative changes in 20–80% and unsatisfactory results in 32–50%.

Since the 1980s knowledge of the biomechanical function of the knee has increased. The consensus of recent research is that the meniscus plays an important role in the function of the knee joint, emphasizing its loadbearing function and its stabilizing character during flexion–extension and rotation.

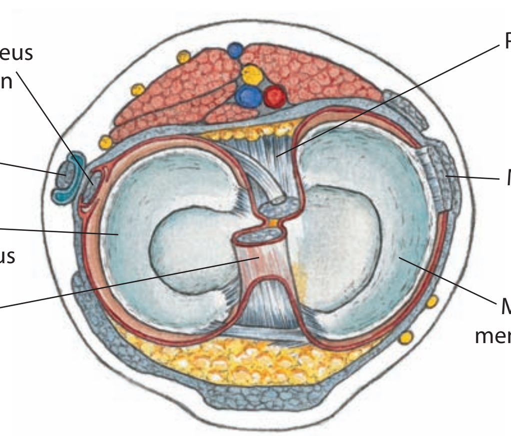
In the past, the meniscus was thought to be an expendable structure, prompting the surgeons to remove it entirely if it was damaged. Complete meniscectomy, i.e. removal of the entire meniscus was considered to be a relatively harmless intervention, after which the athlete could soon return to their normal activity, and results in short-term studies were good. There were many experts who believed that the removed meniscus was replaced by a functional fibrocartilaginous structure, but this has not been verified to become a functional connective tissue structure.

Anatomy

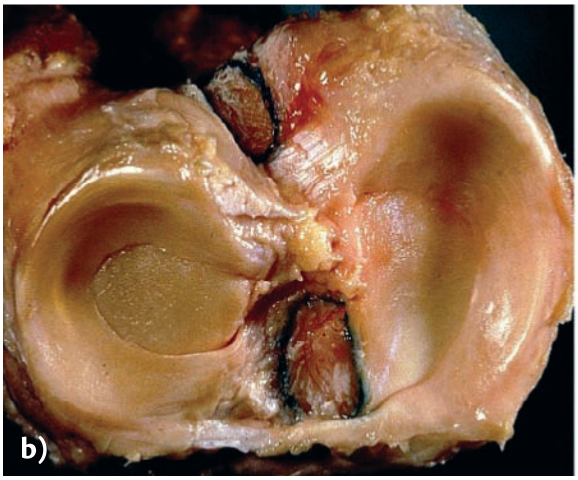
Menisci are crescent shaped. The inner (medial) and outer (lateral) menisci are two C-shaped wedges of fibrocartilage located between the condyles of the femur and tibia. The medial meniscus has a more elongated C-shape than the more circular and wider lateral meniscus, because the posterior and anterior horns of the lateral meniscus are attached to the non-articular area of the tibia plateau, whereas those of the medial meniscus are clear of the plateau anteriorly and posteriorly (Fig. 19.44). The meniscus has a thick convex periphery and a thin concave central marginal edge. The anterior and posterior halves of the medial meniscus differ in width: the anterior portion is much narrower than the posterior. There are, however, individual variations, and occasionally there may be little difference in width between the two halves. A narrow meniscus is less likely to be injured than a broad one.

The medial meniscus is approximately 3.5 cm in length. The anterior horn of the medial meniscus is attached to the anterior surface of the tibia well off the tibial plateau. The anterior fibers of the ACL attachment merge with the transverse ligament, which connects the anterior horns of the medial and lateral menisci. The posterior horn of the medial meniscus is firmly attached to the posterior aspect of the tibia just anterior to the insertion of the PCL. The medial meniscus is continuously attached along its periphery to the joint capsule. At its midpoint, the meniscus is firmly attached to the femur and tibia by the deep portion of the MCL. The medial meniscus has no direct attachment to any muscle, but indirect capsule connections to the semimembranosus tendon may cause the posterior horn to be pulled back at muscle contraction.

The lateral meniscus is almost circular and covers a larger portion of the tibial articular surface than the medial meniscus. The lateral meniscus is consistent in width throughout its course. The anterior horn of the lateral meniscus blends into the attachment of the ACL, whereas the posterior horn attaches just behind the intercondylar eminence, often blending into the posterior aspect of the ACL (Fig. 19.45). There is no attachment of the lateral meniscus to the LCL. Its peripheral attachment is interrupted posteriorly where the popliteal tendon passes. The capsular portion attaches the lateral meniscus less firmly to the tibia than the medial meniscus. The lateral meniscus has more movement than the medial meniscus, and has a ROM that may be as great as 10 mm in an anteroposterior direction. This mobility is explained by the close proximity of the attachments of the anterior and posterior horns and the lack of attachment to the capsular ligament posterolaterally. The firm attachment of the arcuate ligament to the lateral meniscus and the attachment of the popliteus muscle to both the arcuate ligament and meniscus, ensure the dynamic retraction of the posterior segment of the meniscus during internal rotation of the tibia on the femur as the knee begins to flex from its fully extended position.



a)



b)

Figure 19.44 Knee joint viewed from above. **a)** schematic drawing showing the medial (inside) meniscus to the left and the lateral (outside) to the right; both are crescent-shaped structures; **b)** anatomical view of the knee from above on a cadaver knee joint; the insertion areas for the anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) are marked with black. MCL: medial collateral ligament.

Structure, circulation and neuroanatomy

Collagen fibers within the menisci are primarily oriented in a circumferential fashion, thus resisting the loads applied to them by the femur. In this manner they are suitably aligned to resist elongation, much as hoops prevent expansion of a barrel. Radially oriented continuous fibers reinforce the meniscus from the periphery to the inside edge.

The vascular supply of the menisci originates predominately from the inferior and superior lateral and medial genicular arteries. In an adult menisci, the degree of peripheral vascular penetration is 10–30% of the width of the medial meniscus and 10–25% of the width of the lateral meniscus. The remaining part is avascular (lacks blood supply).

Classification of meniscal vascular supply (Fig. 19.46)

- The peripheral third part has the best blood supply, heals best and is called red–red zone.
- The middle part has acceptable blood supply, allowing healing, and is termed red–white zone.
- The central (innermost) third has virtually no blood supply and has the least healing ability and is termed white–white zone.

With age, there is a decline in meniscus vascularity which may be associated with weight bearing. Cells within the central and peripheral regions of the menisci are dependent on diffusion of synovial fluid for their nutrition.

In human menisci, the meniscal horns have significantly more nerve innervation than the meniscal bodies. The central third are totally devoid of innervation. The nerve endings in the menisci have sensory function; they may, therefore, provide some proprioceptive function relating to joint position.

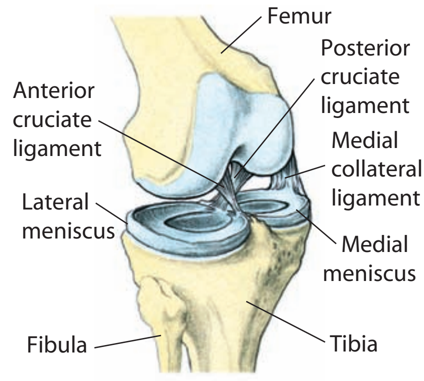


Figure 19.45 Anatomical overview of the knee, front view.

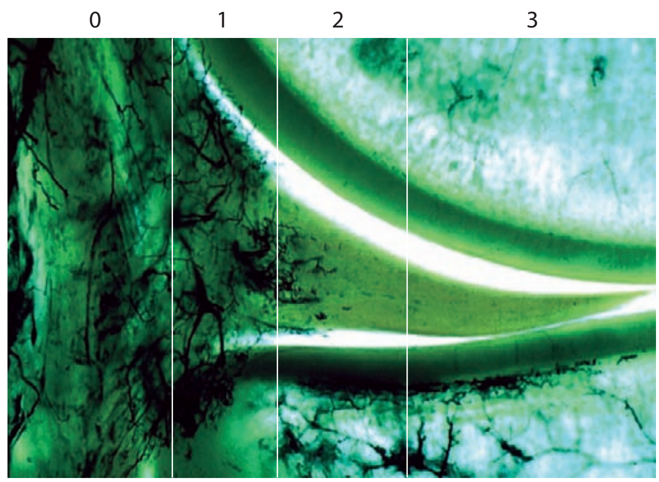


Figure 19.46 A sectional diagram of a meniscus. 0. Blood vessels in the joint capsule, 1. Red-red zone, 2. Red-white zone, 3. White-white zone. (Courtesy of Prof. Steven P. Arnoczky, Michigan State University, Michigan, USA.)

Meniscal functions

Menisci and subchondral bone assist cartilage in absorbing shock. The meniscus absorbs energy by undergoing elongation when a load is borne by the knee joint. As the joint compresses, the wedge-shaped meniscus extrudes peripherally and its circumferentially oriented collagen fibers elongate. Thus, the meniscus absorbs energy and reduces the shock that the underlying cartilage and subchondral bone would otherwise endure. The menisci absorb the greatest amount of energy at relatively low loading rates, but even at more rapid rates the shock absorption characteristics probably still contribute significantly. The shock absorption capacity of the normal knee is reduced 20% by meniscectomy.

The meniscus plays an important role in that it protects both the weight-bearing structures and distributes the load. It transmits 30–70% of the force applied over the joint. The meniscus can resist large compressive forces. As the femur presses down on the tibia, the weight-bearing meniscus elongates because of it is wedge shape, it's circumferentially oriented collagen fibers and the firm attachment of the anterior and posterior horns. Then the posterior horns carry a greater proportion of the force than the anterior horns, while the distribution of the load depends on the amount of knee flexion. At least 50% of the compressive force at the knee joint is transferred through the menisci in extension, with 85% being transferred in 90° of flexion.

The ability of the joint to distribute weight is significantly reduced by the removal of all or part of the meniscus. A meniscectomy significantly alters the manner in which weight bearing occurs at the knee joint. A complete medial meniscectomy reduces the contact area during weight-bearing by 50–70%. The loss of contact area is larger with higher load. If only a portion of the meniscus (partial meniscectomy) is removed there remains more of a weight distributional function than if the whole meniscus is removed, as long as the outer edge of the meniscus is intact. Joint space narrowing, osteophyte formation and flattening of the femoral condyles are frequently observed following meniscectomy, probably resulting from the loss of this function.

Menisci have a role to play in static load reduction on the joint surfaces. Compressive stress (load per unit area) across the knee joint was experimentally found to increase approximately 3 times in dogs and 2.5 times in human cadavers after removal of both menisci.

Another important function of the menisci is to increase joint congruity by filling in the space between the tibia and the femur where they are not in contact. The menisci have an important stabilizing function within the knee joint as they serve to maintain proper positioning of the femur relative to the tibia. The menisci increase stability by deepening the articular surfaces of the tibial plateau and filling the dead space that would otherwise exist at the periphery of the condyle. This also prevents the intrusion of the capsule and synovial membrane between the adjacent articular surfaces. The close relationship of the meniscal attachment to the cruciate ligaments and to the capsular structures also supports the stabilizing role of the menisci.

The menisci play an apparent important role in preventing increased anterior instability when ACL function has been disrupted. Tears of the medial meniscus frequently develop after an isolated rupture of the ACL. The firm fixation of the medial meniscus to the tibial plateau allows it to restrain anterior translation effectively, whereas the less rigidly fixed lateral meniscus does not have the same ability. It can, therefore, be expected that the frequency of delayed tears of the medial meniscus following ACL injury will exceed those of the lateral meniscus.

Meniscus role in dynamic stability of the knee joint is shown by the close relation between the menisci and tendons of the quadriceps popliteus and semimembranosus muscles. Contraction of the quadriceps will thus actively pull both menisci forward as the knee extends.

The menisci also limit extremes in flexion and extension. Before full extension of the knee is attained, there is an 18° external rotation of the tibia with respect to the femur. There is a spiral or a helicoid motion (in a bow outwards) of the tibiofemoral joint, which occurs from 30° or 15° of flexion to full extension of the knee. This action is due to the existence of a larger area weight-bearing surface on the medial condyle than on the lateral. During this spiral motion, the menisci are forced far forward by the impinging femoral condyles. The anterior horns of the menisci then act as a block to further extension. The greater the hyperextension, the tighter the anterior segments of the menisci are held. In full flexion, the posterior horns are pushed posteriorly and assist in blocking any further flexion as long as the ligaments and capsular structures are intact.

Menisci can help to keep the joint well lubricated by distributing nutritional synovial fluid over joint surfaces. Their role here is to reduce the gap where the synovial fluid could otherwise accumulate and reduce friction by synovial fluid acting as a lubricant between the joint surfaces.

Finally, during weight bearing the menisci serve to compress the nourishing synovial fluid into the articular cartilage.

Biomechanics of meniscus injury

Meniscus injuries occur in most sports and are common in contact sports. There are different types of meniscal injuries involved:

- Traumatic meniscal injury: a meniscus injury which can occur in all ages but is predominant among younger athletes. This injury is generally caused by high powered twisting or other trauma to the knee joint.
- Degenerative meniscal injury prevails among middle-aged and older people, generally as part of the degenerative changes in the knee joint with age.

Meniscal injuries often occur in combination with ligament injuries, especially the medial meniscus. The reason for this is partly due to the medial meniscus being attached to the MCL deep portion and that trauma to the knee is often directed toward the outside of the knee, forcing the knee in valgus and outward rotation of the tibia. An injury to the medial meniscus is about 5 times more common than injury to the lateral meniscus. Isolated injury to the menisci is often caused by torsional force to the knee joint.

If an external rotation of the foot and lower leg occurs in relation to the femur, the medial meniscus is most vulnerable, while an internal rotation of the foot and lower leg will cause the lateral meniscus to be more easily injured (Fig. 19.47).

Meniscus injuries can also occur as a result of hyperextension or hyperflexion of the knee. In elderly individuals a meniscus injury can occur during a normal

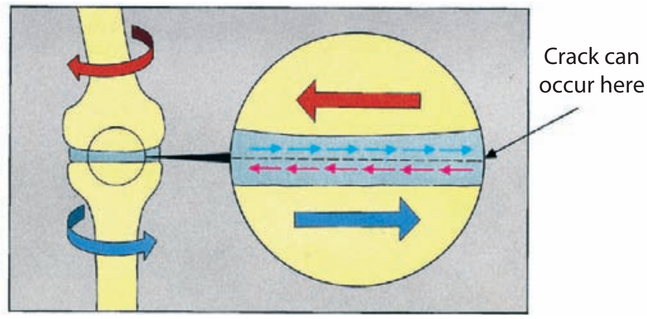


Figure 19.47 Injury mechanism for a horizontal tear of the meniscus. Increased rotation increases the risk of damage to meniscus.

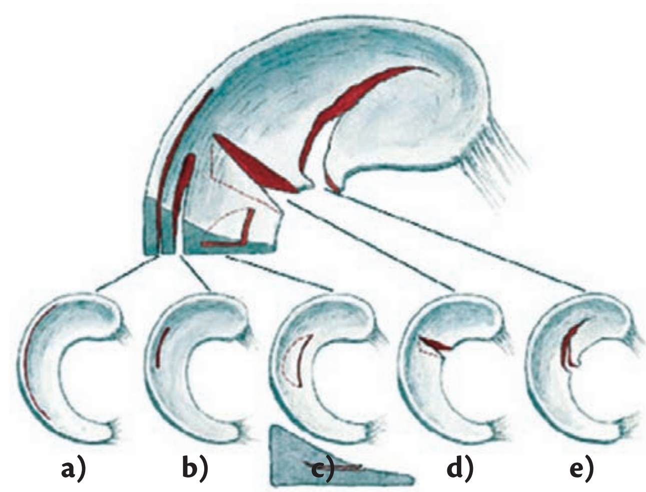


Figure 19.48 Types of meniscal tears. a) Capsule tear; b) vertical tears of red-red zone; c) horizontal tears in the red-white zone; d) radial tears through most of the meniscus; e) flap tear of the posterior horn.

movement such as deep knee bends, because of decreased strength due to degenerative changes.

Since injuries to the meniscus are caused by trauma, tears usually go vertically through the meniscal tissue; in older people horizontal tears are more frequent (Figs 19.48, 19.49). A suspect meniscus or knee injury should be examined by a physician who will do a stability test so that ligament damage can be excluded.

Medial meniscus injury

Symptoms and diagnosis

- Pain on the inside of the knee joint during and after exertion of the knee.
- 'Locking' phenomena happen when the torn part of the meniscus is lodged in the joint, forming a 'bucket handle' (Fig. 19.50), blocking mobility so that full extension or flexion is impossible. The joint can lock momentarily of its own accord in certain positions.
- Pain, located in the medial joint space, caused by hyperextension and hyperflexion of the joint as well as with outward rotation of the foot when the knee is bent.
- Sometimes there is effusion (hydrops) in the knee joint, especially when it has been strained.

The diagnosis of an internal meniscus injury is considered to be fairly certain if three or more of the following findings are present (Fig. 19.51):

- Point tenderness over the medial joint line.
- Pain located along the medial joint line when hyperextending knee.
- Pain located along the medial joint line when hyperflexing the knee.

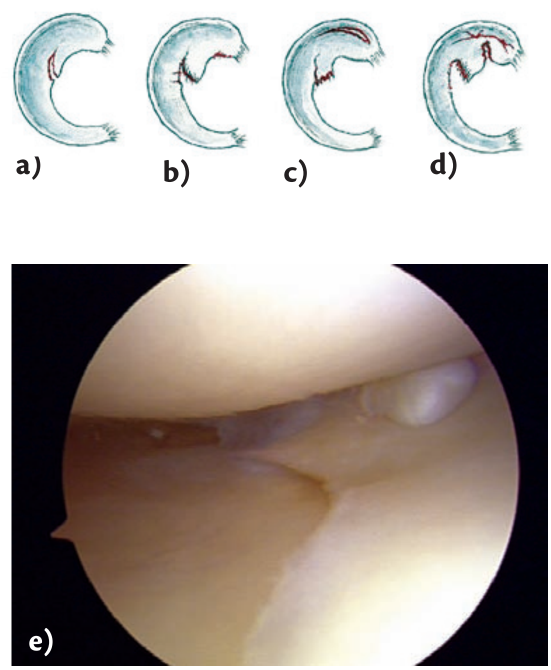


Figure 19.49 Development of 'flap' injury to the meniscus. a) Initial flap injury in the white zone; b) initial flap injury as dissecting into the red–white zone; c) initial combined with tear of the posterior horn in red zone of a degenerate meniscus; d) progress of degenerate meniscus with multiple ruptures; e) arthroscopy image of a meniscus posterior horn flap tear (courtesy of Björn Engström, ArtroClinic, Stockholm).

- Pain when outwardly rotating the foot and lower leg with the knee bent in a 70–90° angle; this examination is best performed in the prone position.
- Weakened or hypotrophied quadriceps.
- MRI can confirm the diagnosis (Fig. 19.52).
- Arthroscopy of the knee is the most certain way to diagnose a meniscal injury (Fig. 19.53).

Tip

The most frequently described symptoms of a meniscus injury are 'locking' or catching, stabbing pains, crepitations, pain and swelling, typical symptoms that are related to an unstable meniscus component.

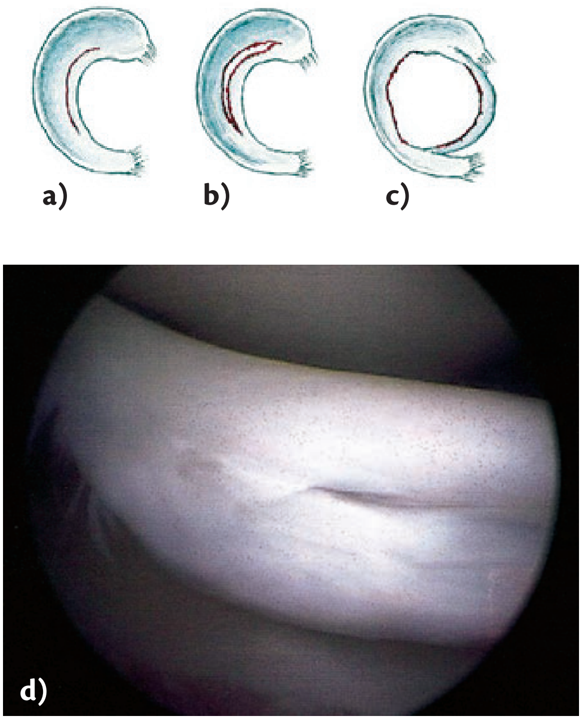


Figure 19.50 Meniscus rupture known as the "bucket handle". **a)** Development of "bucket handle" tear of the border between the red and white zone; **b+c)** progress of separation of bucket handle. Lodging of the "bucket handle" in the joint; **d)** arthroscopic image of a loose bucket handle tear. (courtesy of ArtroClinic, Stockholm.)

Lateral meniscus injury

Symptoms and diagnosis

- Pain on the lateral aspect of the joint that occurs in connection with exertion of the knee joint. In many cases the pain appears consistently after a specific amount of exertion.
- 'Locking', catching occurs (see above).
- Pain in the lateral joint line occurs on hyperextension and hyperflexion of the knee and also on internal rotation of the foot and the lower leg in relation to the femur when the knee joint is flexed to 70–90° (Fig. 19.54).
- Sometimes there is an effusion of fluid in the joint.

The diagnosis of a lateral meniscus injury is considered to be fairly certain if three or more of the following findings are present:

- Point tenderness over the lateral joint line.
- Pain located along the lateral joint line when hyperextending knee.
- Pain located along the lateral joint line when hyperflexing knee.
- Pain on internal rotation of the foot and lower leg with the knee bent at different angles.
- Weakened or hypotrophied quadriceps muscle.
- An MRI examination or arthroscopy confirms the diagnosis.

Treatment

The athlete should:

- If a meniscal injury is suspected, static (isometric) exercises of the quadriceps should be initiated. It is important that the thigh muscles are exercised regularly and daily when waiting for knee surgery. This prevents an unnecessary weakening of the muscles, and recovery time can be considerably shortened.

The physician may:

- Operate via arthroscopy, where the damaged part of the meniscus is removed or sewn back in place. In an acute 'locked' knee the injury should be treated surgically as soon as possible. The younger the patient the more important to sew back in place and preserve the meniscus.
- It is only when the menisci have become so damaged that they have lost their function and the injury triggers local pain, locking phenomena and recurrent effusions that the damaged meniscus is removed completely or preferably just the damaged portions. The damaged portions of the meniscus are either cut or punched out with small knives or pliers and removed during arthroscopic examination of the joint.

Figure 19.51 Examination for injury to the medial meniscus. **a)** Tenderness may be present along the joint space in about 50–75%; **b)** pain from injury to any of the menisci can be indicated by hyperextension of the knee joint; **c)** hyperflexion of the knee joint; **d)** rotation test meniscus rupture. If injury to the medial meniscus, pain can occur in 60–85% of the cases when the foot/lower leg is rotated outward with the knee bent at a 70–90° angle. This examination is best performed in the prone position. This test is equivalent to a McMurray's test.

Surgical possibilities

- Partial meniscectomy: it is well established that it is preferable to retain as much of a stable, well balanced meniscus as possible to protect the articular cartilage from further stress and degeneration than to perform a total meniscectomy. The amount of degenerative change in the joint is directly proportional to the amount of meniscus removed. The benefit of a partial meniscectomy via arthroscope is that the load on the joint can be reduced, the time of disability is less after such an operation and the postoperative effect on stability is not as bad; additionally the articular cartilage will have fewer degenerative changes leading to osteoarthritis in the long term.
- Surgical repair: in such repair of the meniscus the goal should be preserving as much as possible of the meniscal tissue. If possible, the damaged portion is sutured or anchored in some manner. Repair of a meniscus injury should be strongly considered if the tear is peripheral, i.e. in the outer part of

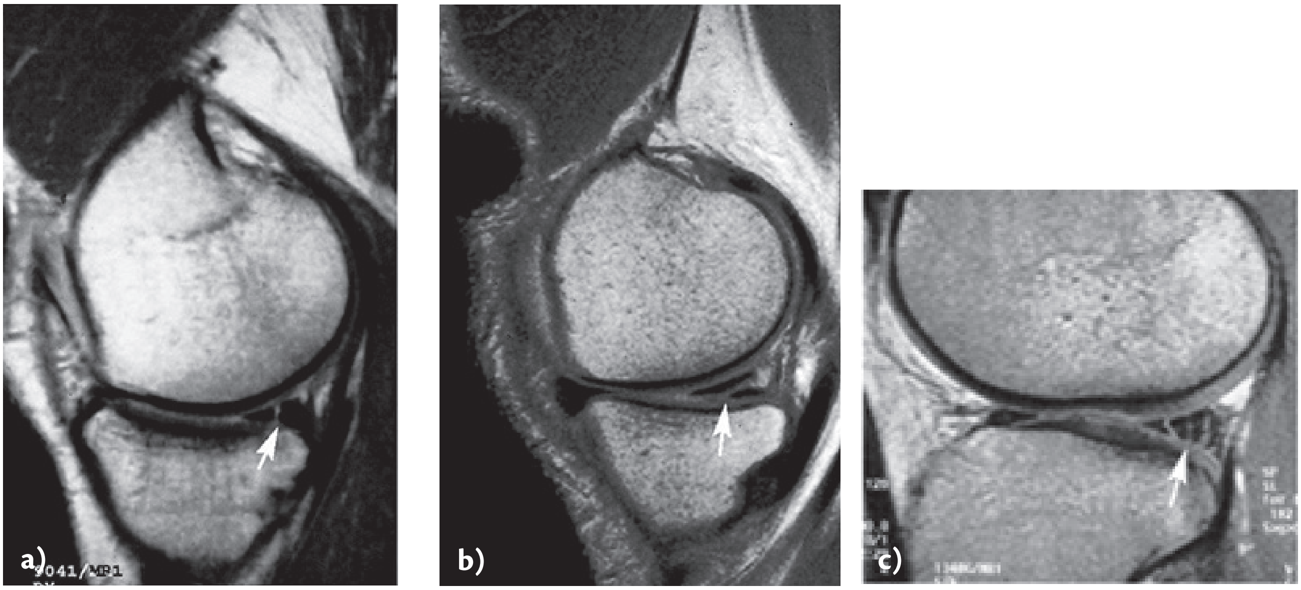


Figure 19.52 Magnetic resonance imaging can confirm the diagnosis, ruptured meniscus (see arrows). **a)** Vertical meniscus rupture; **b)** horizontal meniscus rupture; **c)** meniscus ruptures caused by degeneration.

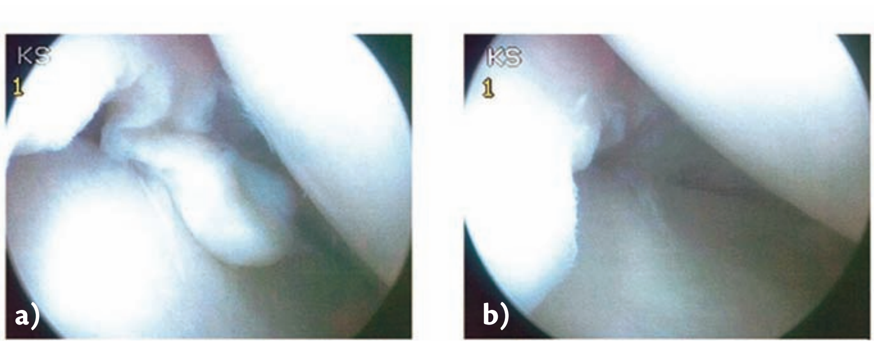


Figure 19.53 An arthroscopy clearly shows meniscal injuries. **a)** A meniscal fragment, a 'flap' injury before treatment; **b)** meniscus after the fragment, i.e. the flap is removed via arthroscopy.

the meniscus red–red zone or longitudinal, in combination with a simultaneous ACL rupture and in younger athletes. Best healing potential is in the best vascularized portion closest to the joint capsule. Clinically good results do not correlate well with the mechanical strength of the surgical reparation technique. However, biological factors are of greater importance than the surgical technique. Care should be taken when increasing the degrees of flexion of the knee joint too quickly after such a surgical repair. A repair of the meniscus improves the chances of preventing osteoarthritic development, but the healing and rehabilitation can take a considerably longer time.

- A renewed interest in the surgical repair of meniscus tears has been established and good clinical results have been reported (Figs 19.55–19.57). It is better to make an unstable traumatic or degenerative meniscus stable than to perform a partial meniscectomy.
- Meniscal transplants from deceased donors (allografts) offer new opportunities with encouraging results, particularly in terms of the medial meniscus, but the method is still under clinical development. Partial replacement of parts of the meniscus with an artificial material is subject to surgical evaluation and may be a future treatment (Fig. 19.58).

Tip

The indication for surgery for a meniscus injury will always be based on the overall clinical history. Meniscus surgery, based on MRI findings, can sometimes be unnecessary.

Figure 19.54 Signs of a lateral meniscus rupture. **a)** Tenderness palpating over the lateral joint space; **b)** pain can be experienced when hyperextending; **c)** when bending over; **d)** with an injury to the lateral meniscus, pain can occur when the foot/lower leg rotates inward at the knee bent at a 70–90° angle. This examination is best performed in the prone position.

There is a certain debate about the value of arthroscopic surgery, although most patients currently experience benefits from an arthroscopic procedure, which is a simple and relatively straightforward procedure. Treatment should normally be based on evidence-based medicine; however, there is unfortunately a lack of high qualified science such as randomized trials in this area. There is an ongoing policy discussion in many places and hopefully this will bring further clarity in problems associated with meniscus injuries and their treatment.

Tip

It should be noted that most experts today believe that there should be some restraint to performing arthroscopic knee surgery and that MRI findings by themselves cannot be the sole indication for meniscus surgery, but that the history and clinical findings are indicative and the key to making a proper decision.

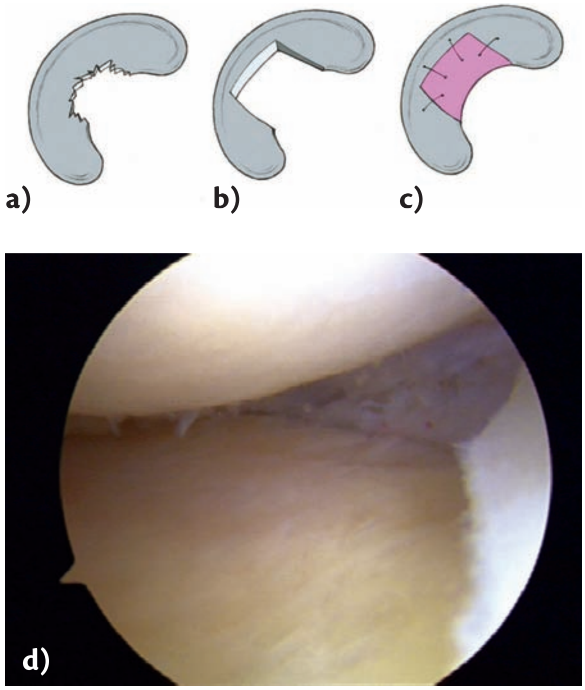


Figure 19.55 Partial meniscectomy, i.e. removal of the damaged portion of the meniscus and replacement with artificial tissue. **a)** Partial rupture of the inner edge of the meniscus; **b)** partial meniscectomy removal (resection) of ruptured area and trimming the edges; **c)** filling the defect in the meniscus with artificial tissue, which is in turn sutured to the surrounding tissue. This may be biodegradable or not; **d)** artificial tissue implanted in the defect of the meniscus, viewed at arthroscopy.

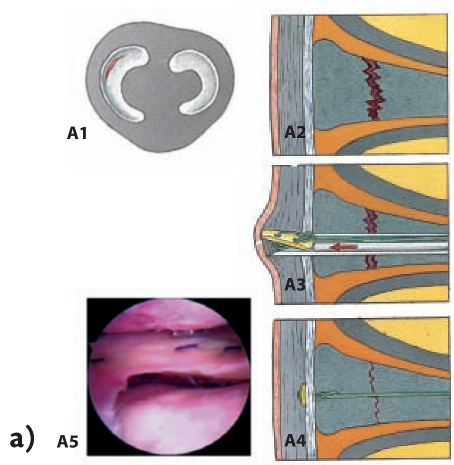


Figure 19.56a Some examples of meniscus repair techniques. A: All inside technology i.e. both insertion and fixation is performed from within the joint; A1. A2. Rupture has been identified in the red-white zone; A3. A needle loaded with T-fix anchor penetrates the meniscus and the fibrous capsule; A4. When pulling the suture inside the joint the transverse anchor is fixed against the outside of the fibrous capsule. Another parallel T-fix anchor is inserted and the two sutures are linked within the joint; A5. Meniscus repair done seen during arthroscopy.

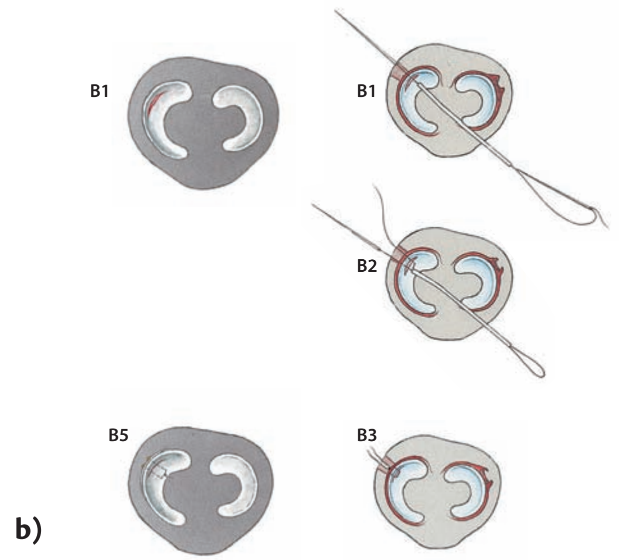


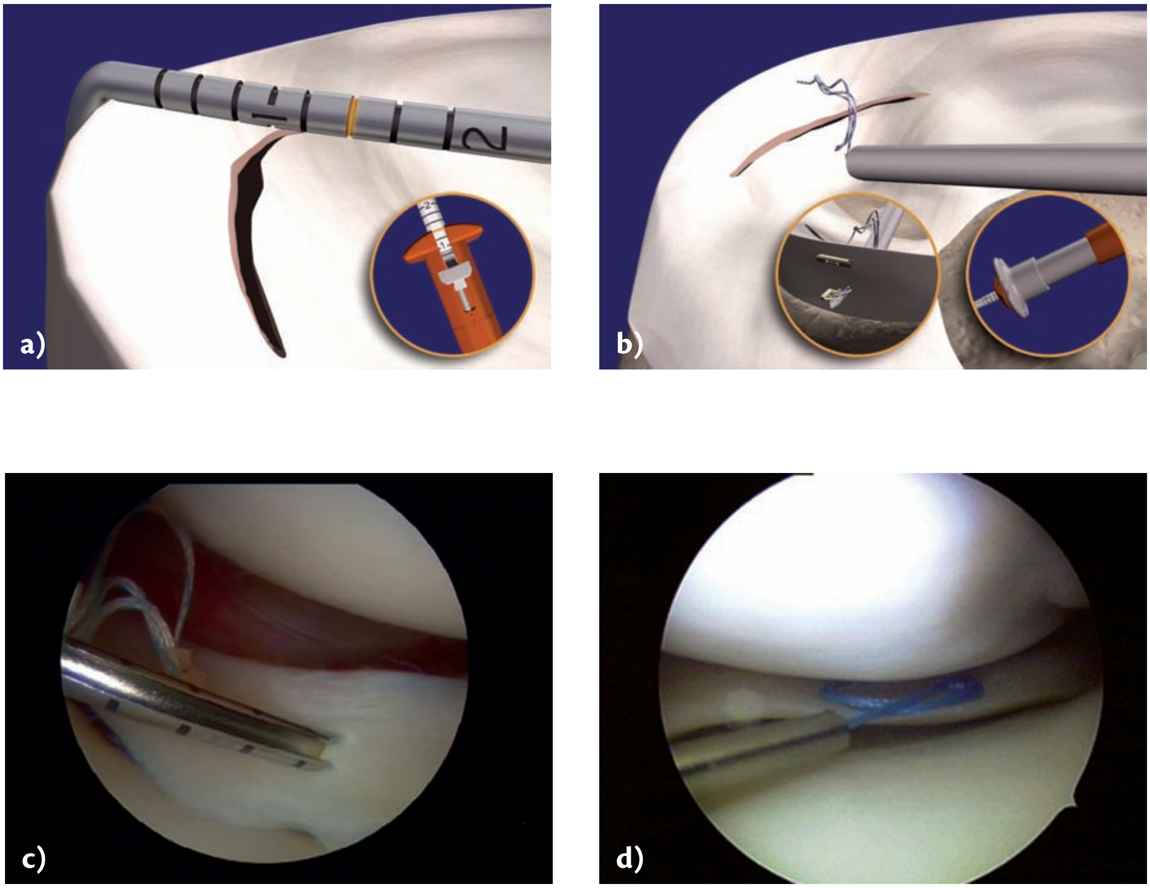
Figure 19.56b Inside–out alternative technique of meniscal suturing with a needle threaded with a double suture forming a loop in the end. B1. Rupture has been identified in the red-white zone; B2. The needle penetrates the injured meniscus and out through the fibrous capsule through a small incision in the skin. One suture end is pulled out of the needle outside the joint; B3. The needle is withdrawn into the joint and moved aside from the first suture end to penetrate the meniscus parallel to the first suture and out through the skin incision; B4. The two suture ends are pulled out so the loop catches tight to the meniscus surface and compresses the rupture surfaces as the sutures are tightened to the fibrous capsule; B5. The meniscus repair all done.

After surgery, the physician may prescribe exercise of the quadriceps and hamstring muscles (see p. 468 Table 19.3; see programs on pp. 464–5). The rehabilitation should begin soon after the operation. Crutches, at times, may be needed for 1–2 weeks, so that the operated leg is less weight bearing. This is especially true if the meniscal injury was sutured back in place. Weight bearing to the pain threshold should be allowed.

Tip

The goal should be to retain as much as possible of the meniscus and if possible attach the rupture in place.

It is an important established fact to retain as much as possible of a stable and well balanced meniscus, as articular cartilage must be protected from further compressive and degenerative injuries. There is a direct correlation between the degree of degenerative joint damage and the



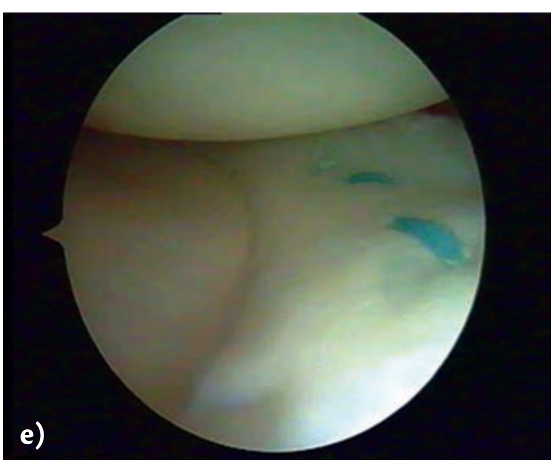
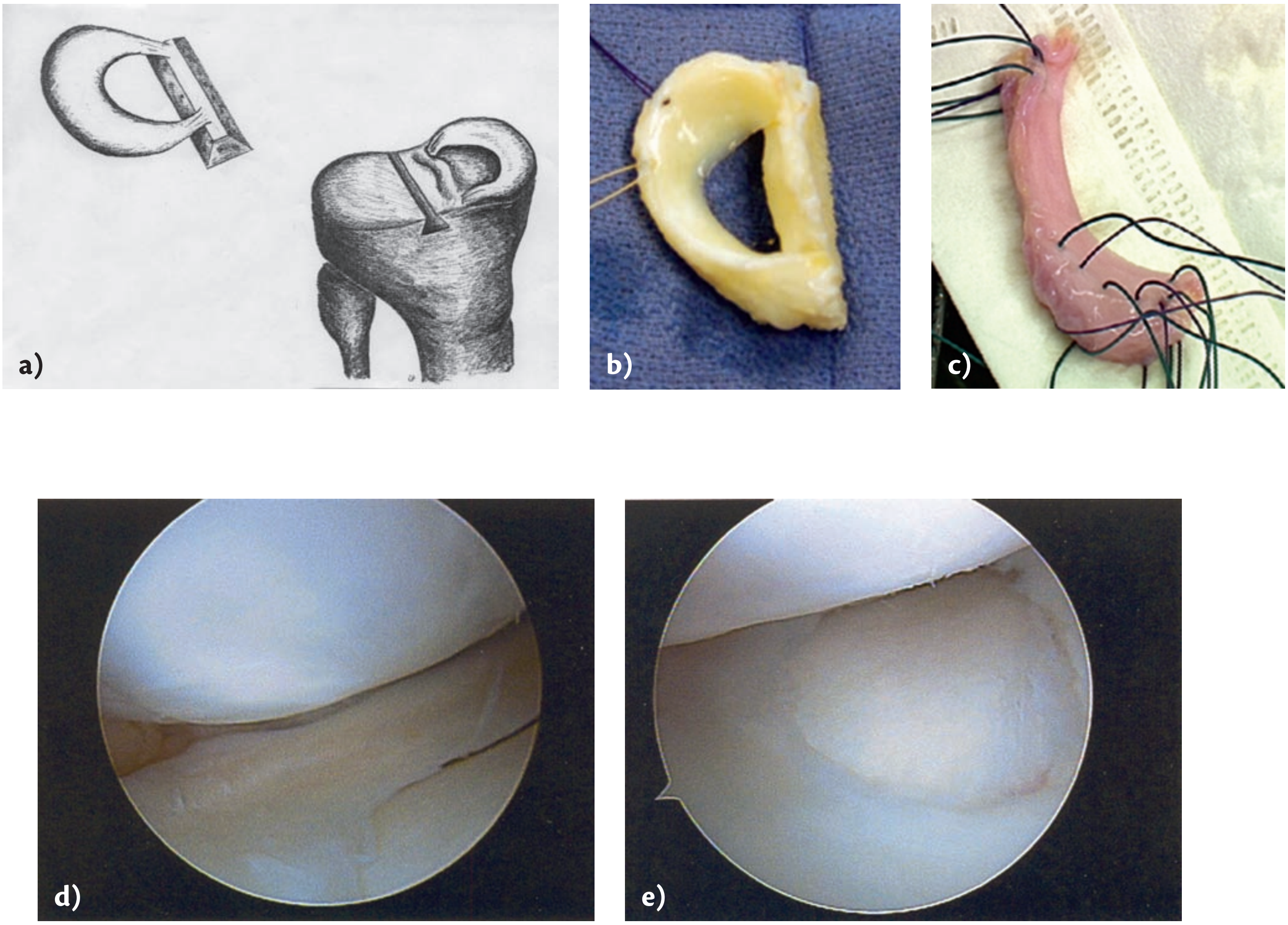


Figure 19.57 Another technique of repair (suture) of a meniscus rupture is a modification of the technique shown in 19.56. The method includes a suture on either side of the meniscus i.e., a suture madras with two sutures which are implanted with an injection needle penetrating the meniscus above and below the rupture. It can be carried out through the arthroscope. **a)** The damage is located and measured; **b)** sutures with anchors are passed through the meniscus above and below the rupture. Small picture shows the position of the upper and lower anchor on the outside of the capsule. The suture is provided with a running knot which can be tightened with a special instrument; **c)** arthroscopy image shows the entry of the needle with suture anchors through the meniscus; **d)** arthroscopy image shows the entry of the tightening with the special instrument; **e)** completed procedure with suture fixated. (Courtesy of ArtroClinic, Stockholm, Sweden.)

amount of meniscus removed. The degree of force on the tibiofemoral joint's contact surfaces increases the more of the meniscus that is removed and the more of the meniscus structure that has been damaged. Even damaged menisci can distribute force as long as the peripheral edge is intact throughout its length. Even after a partial meniscectomy, the uninjured meniscal peripheral surface can disperse a sizable load, if no abnormally high pressure is exerted on the remaining repaired edges. An uncomplicated bucket handle rupture usually results in plenty of meniscus periphery left untouched.

Good results are achieved with these small ruptures when they occur in the meniscus vessel-rich outer periphery.



Picture 19.58 Some variants of meniscal transplantation, which are becoming increasingly common practice. **a)** The meniscus with its bone insertion is fastened in an open bone channel; **b)** allograft prepared for transplantation; **c)** allograft meniscus without bony insertion prepared for transplant; **d, e)** meniscus graft in place. (Courtesy of Wayne Gersoff, MD., Denver, Colorado, USA.)

Tip

It should be noted that non-operative conservative treatment is possible with meniscal tears if the rupture is stable, vertical and longitudinal and especially if the tear is quite small and the symptoms are within reason.

Return to sport

An athlete who has been operated on for a meniscus injury should not return to ordinary training until almost full mobility and strength of the knee joint has been regained. This usually takes 2–6 weeks after arthroscopic surgery, depending on the size and location of the tear. When there is a large posterior horn tear, return to sport can take up to 12–16 weeks or even longer. Return to sport after a meniscal suture or anchor repair usually takes 4–6 months because of the healing process (see rehabilitation protocol p. 469 Table 19.4).

Tip

Even after returning to sporting activity, the athlete should continue training the quadriceps and hamstring muscles. The menisci should be preserved as far as possible.

Discoid meniscus

A discoid (disc-shaped) meniscus is a thickened, enlarged and abnormal meniscus that is covering most of the tibia condyle. It can cover the entire tibial condyle joint surface or part and may vary in thickness (Fig. 19.59). The entire posterior horn of the meniscus may be hypermobile. Discoid menisci usually occur on the lateral side of the knee. Their incidence varies, but is reported to be 1.4–16.6%.

Symptoms and diagnosis

- The diagnosis of discoid meniscus can sometimes be made from the clinical history. The athlete may describe a large snap during flexion or extension of the knee, which can be heard and felt on examination.
- There may be a 'catching' or a 'giving way' feeling. This history may be present in children as well as adolescents.
- The diagnosis is verified by arthroscopy or MRI.

Treatment

- Treatment methods vary. An intact discoid meniscus is found as an incidental finding and requires no specific treatment. It is not known how many cases of untreated discoid meniscus will eventually develop tears.
- Treatment is individualized. If there is a tear in the discoid meniscus that produces pain or snapping in the knee, or if there is a hypermobile posterior segment, the best treatment is arthroscopic subtotal meniscectomy (removal of part of the meniscus). The younger the patient, the more of a normal meniscus size should be preserved.
- Instability in the discoid meniscus (the posterior horn) can lead to surgical repair or removal of the meniscus. Removal of the meniscus should be avoided by stabilizing the meniscus and saving the functional portion, especially in younger athletes.
- The time it takes to return to sports activity is usually the same as for conventional meniscus surgery.

Articular cartilage injuries

Injuries to the articular cartilage (chondral) surfaces can affect the joint surfaces of the femur, the tibia and the patella. Cartilage injuries are often overlooked because they are difficult to detect. These injuries may be limited to cartilage damage or have progressed to a widespread osteoarthritis, i.e. extending down to bone by continued mechanical abrasion and tissue degradation by enzymes released from damaged cartilage cells (see p. 165 onwards, which describes the background to the osteoarthritic problem).

They may result from direct impact against the knee joint, but can also occur in association with meniscal and ligament injuries. A meniscus injury can lead to cartilage damage that may progress to osteoarthritis of the knee, but this can also lead to spontaneous meniscus rupture by degeneration and the weakening of the meniscus structure, especially in the elderly. Cartilage damage can cause major crack formation and defects in joint surfaces,

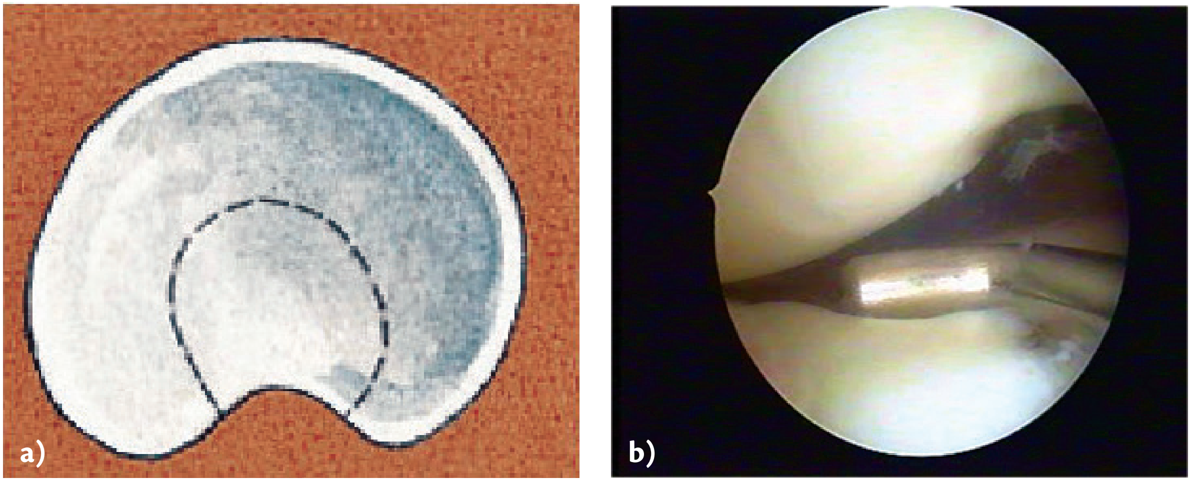


Figure 19.59 Discoid meniscus. **a)** Size of an enlarged discoid meniscus; **b)** arthroscopic image of a discoid meniscus (courtesy of Prof. Björn Engström, ArtroClinic, Stockholm, Sweden).

which then leads to a progressive decay of the articular cartilage. The end result may be a premature wear of the joint. Because cartilage damage often affects young active individuals, they predispose for osteoarthritis at a relatively young age.

Tip

Meniscal injury, ACL injury and cartilage damage is present in combination in 40–70%.

Symptoms and diagnosis

- Swelling of the knee joint due to recurrent effusions.
- Pain is felt during and after activities.
- 'Locking' or 'catching' mimics meniscal injury.
- Crepitations are heard and felt during weight-bearing activities.
- Loose bodies may be felt.
- The injury can be diagnosed by arthroscopy (Fig. 19.60) and by MRI.

Treatment

The athlete should:

- Avoid activities that provoke symptoms.
- Strength train the thigh muscles.
- Use a knee brace and heat retainer.

The physician may:

- Recommend a change to a sport that makes fewer demands on the knee joints.

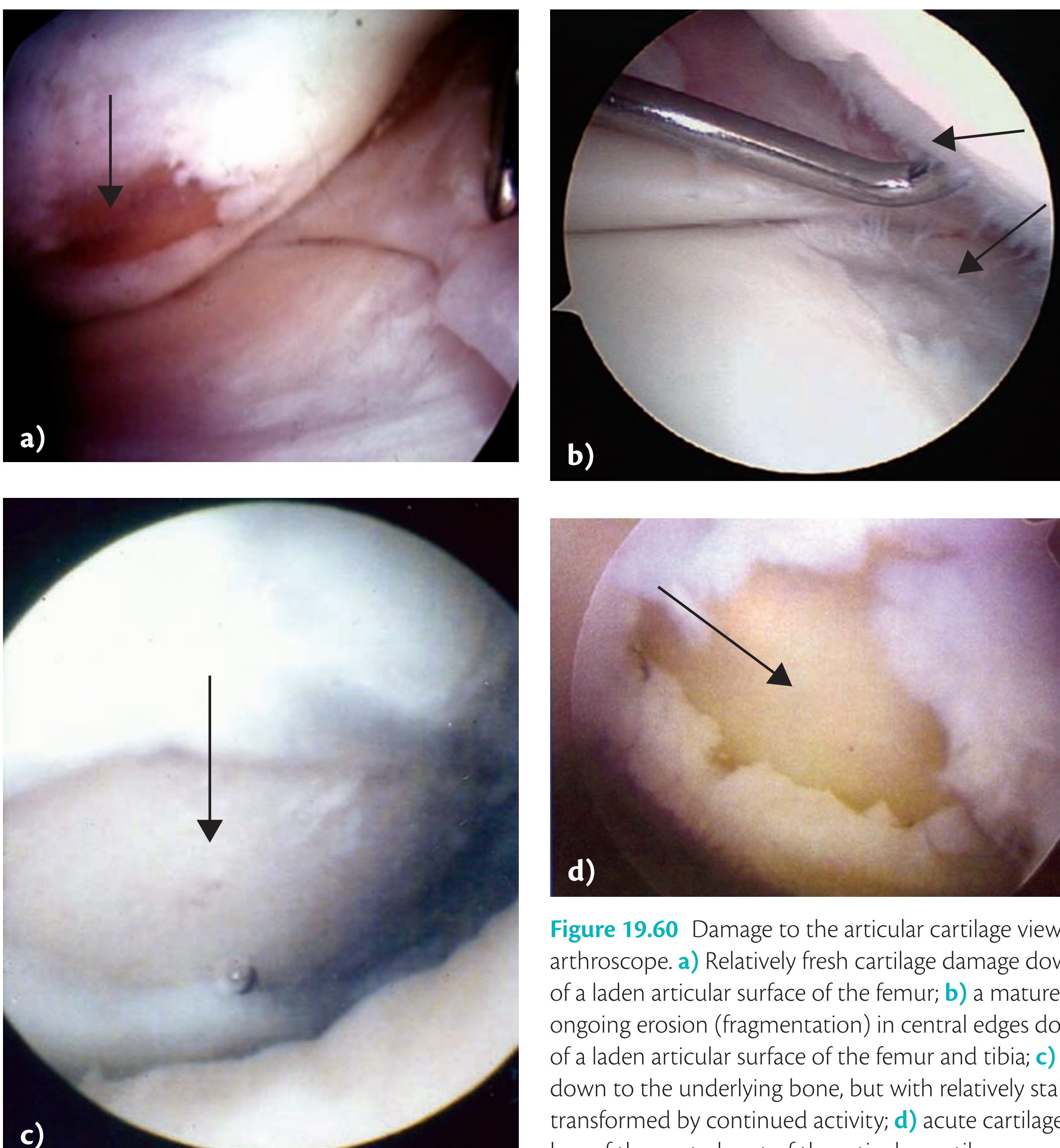


Figure 19.60 Damage to the articular cartilage viewed through an arthroscope. **a)** Relatively fresh cartilage damage down to the underlying bone of a laden articular surface of the femur; **b)** a mature cartilage injury with ongoing erosion (fragmentation) in central edges down to the underlying bone of a laden articular surface of the femur and tibia; **c)** a mature cartilage damage down to the underlying bone, but with relatively stable edges that have been transformed by continued activity; **d)** acute cartilage lesion down to bone with loss of the central part of the articular cartilage.

- Refer the athlete to an experienced physiotherapist for mobility and specialized thigh muscle training.
- Give injections into the joint of rooster comb extract, hyaluronic acid or similar preparation.
- Inject a small amount of cortisone in older people, which may have a good effect especially if there is some swelling with fluid in the knee joint.
- Perform surgery to remove the damaged cartilage surface, which eventually either could be replaced during the healing process by less elastic fibrous (connective tissue) cartilage or, which is most common over time, wears down to the underlying bone with osteoarthritis as a result. When knee function is restricted by pain or swelling after isolated articular cartilage damage, the physician may use one of the newer surgical techniques as described below.

Surgical techniques

Several new techniques have been developed to treat small, isolated articular cartilage defects. Although they are still under evaluation, early results are promising.

- Bone marrow-stimulating techniques such as abrasion, piercing, micro-fracturing or drilling are some of the methods used. The aim is to make a raw area or drill into the bone under the cartilage and thereby stimulate the ingrowth of new stem cells from the underlying bone marrow. The migrating cells can infiltrate the blood coagulate that forms in the area so that gaps and defects are filled by fibrous (connective tissue) cartilage. There is as yet few long-term results and few comparative studies showing the outcome of this intervention.
- Another method of bone marrow stimulating technique is described on p. 161. Some of these methods have been able to show new formation of mostly fibrous tissue, sometimes with elements of cartilage tissue, but large and multiple injuries with defects in joint surfaces are still a difficult orthopedic problem.
- Damage up to about 3 cm^2 has successfully been treated with autologous osteochondral cylinders of bone cartilage taken from a non-weight-bearing area of the joint and then used to fill the holes in the damaged area. Good long-term results and return to sporting activity level have been reported.
- Endogenous (autologous) chondrocyte transplantation has been used for more than 20 years for the treatment of both small (over 2 cm^2) and larger cartilage damage in the knee joint and is used also in other joints such as ankles. When damage is detected arthroscopically small cartilage biopsies are taken from a minor weight-bearing area of the joint for the cultivation of cartilage cells *in vitro*. A few weeks later the damaged cartilage is removed from the joint. The damaged area is then covered with a membrane of periosteum or artificial material under which the cultured cells are injected or seeded under the membrane. Long-term results are good even for large and multiple lesions in the same stage. Return to sports like soccer and hockey can be achieved after about 12–15 months (see p. 116).

Osteochondritis dissecans

Osteochondritis dissecans (OCD) is the detachment of fragments of bone and cartilage. In the knee joint it often afflicts young people between the ages of 12 and 16 years. This permanently affects the articular surface of the femur. The location of the injury is often obvious (Fig. 19.61). The condition causes cartilage and bone to dislodge in an area often as large as a hazelnut or larger. The detached part can either heal or become partially or completely detached forming a free body in the joint. This may cause locking and/or catching of the knee and recurrent effusions (see p. 164). The bony part can become necrotic and die, while the cartilage portion can initially survive, but risks eventually disintegrating. The bone necrosis impedes the fragment from healing into place and the more or less loose fragment dislodges sometimes completely and become a loose body.

The cause of OCD is not known, but hereditary and traumatic reasons can exist. Sports active children and youth are affected more often and would

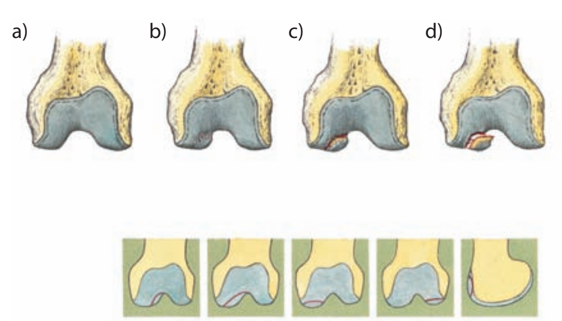


Figure 19.61 Usual injury location for osteochondritis dissecans (OCD) in the knee joint. Left to right: **a)** Grade 1; softening in the area. Articular cartilage surface intact; **b)** Grade 2; unstable fragments with initial stage of separation to the surrounding cartilage-bone; **c)** Grade 3; full separation of the fragment; **d)** Grade 4; displaced osteochondral fragment with mechanical irregularities and formation of loose bodies in the joint. Lower image row shows the usual injury areas of OCD.

indicate a traumatic cause. OCD is common in the knee joint, 75% of cases being localized to the medial femoral joint surface. Individuals from 5–10 years and up towards 40 years of age can be affected, but it is most frequent for 10–20 year olds and it is three times more common in men.

OCD can be divided into a juvenile and an adult form. The juvenile form affects growing individuals until the growth plates (epiphyseal plates) in the long bones have reached complete ossification, usually at 15–17 years old. The earlier OCD is detected and the younger the individual is, the better the prognosis and treatment results. If detection is delayed in the older individuals, the prognosis worsens, and if the fragment has loosened and been removed the risk of osteoarthritic development is almost 100% within 20–30 years.

Symptoms and diagnosis

- Diffuse pain over the joint and often aching pain after exertion.
- ‘Catching’ and direct locking of the knee is common especially if unstable fragments are present, often with joint swelling due to effusion.
- The diagnosis is confirmed with an X-ray and MRI (Fig. 19.62).
- Bone scan (scintigraphy) can provide additional information about circulation in the area.
- Arthroscopic assessment can be critical for treatment. Free bodies or unstable fragments can be removed or if possible fixated.

Treatment

Juvenile form with stable fragments:

- Initially, rest and simultaneous strength training.
- Sometimes a knee brace to protect the healing area.
- Operative treatment with fixation of the fragment can be an option, possibly after refreshing the bone surfaces of fragments and the surrounding bone to stimulate bone healing.
- Healing should be monitored by X-ray or MRI prior to return to sport.

Adult form:

- Conservative treatment rarely gives a good result. This can be attempted if the fragment is stable and not too deformed or necrotic.
- Operation can be performed on unstable fragments. Sometimes bone surfaces and edges have to be roughened and bone is transplanted between these. The fragment is then fixated and, at least for younger patients, healing can take place. When there are minor defects where the fragment is necrotic, loose or removed, damaged cartilage can be replaced by transplantation of autologous cylinders or attempt endogenous (autologous) chondrocyte transplantation. For large bone defects, transplantation of the body’s own bone into the defect and implantation of chondrocytes into the joint surfaces, the ‘sandwich technique’, can be used.
- After conservative treatment and rehabilitation return to activity should take place gradually after healing has been verified by X-ray or MRI. After surgical repair the healing process should be monitored with MRI and arthroscopy before the decision to return to training and competition or work. This assessment is highly individual.

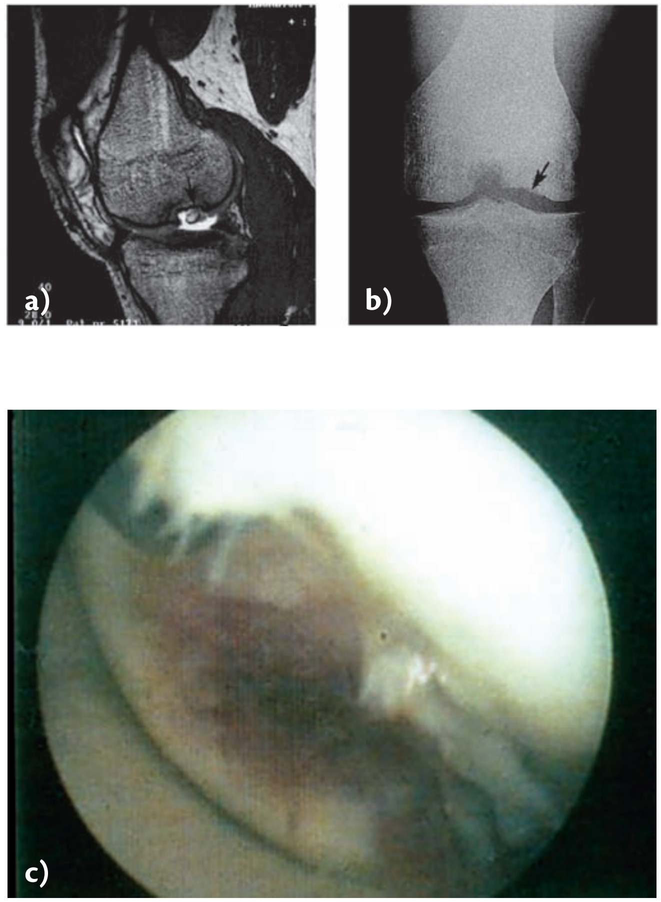


Figure 19.62 Examination techniques of the knee joint to verify the existence of osteochondritis dissecans (OCD). **a)** Magnetic resonance imaging of knee; large osteochondritis dissecans of the femur outer joint surface; **b)** X-ray of femoral condyle with defect after removing osteochondritis dissecans fragments; **c)** arthroscopy of OCD after the fragment has loosened and has become a free body.

The prognosis in the juvenile form of OCD is more favorable than in the adult form. Individuals with an untreated OCD risk developing osteoarthritis after 20–30 years and since most patients that have an OCD are between 10 and 40 years old they are at high risk of early disability, which may require joint replacement (arthroplasty).

Osteoarthritis

Post-traumatic osteoarthritis involves degradation and wear of particularly articular cartilage after traumatic injuries, which can eventually lead to changes even in subchondral bone. Primary osteoarthritis of the knee is especially common in the elderly and affects about 3% of the population over the age of 55 years. The cause is not known. Women are affected twice as often as men. Post-traumatic osteoarthritis can occur in people as young as 25–35 years old, as a result of knee injuries, such as fractures, cruciate ligament or meniscus and cartilage damage.

Football/soccer players have an increased risk of osteoarthritis to the hips and knees. Even asymmetric load on the joints, such as in elderly joggers, may be a contributing factor. Infections, rheumatoid arthritis (RA) and prolonged cortisone treatment are other reasons for developing osteoarthritis.

Symptoms and diagnosis

- Pain that usually comes slowly and increases with exertion. In athletes, the pain may go away during warm up to then re-occur after activity.
- Swelling due to an increased amount of fluid in the joint and thickening of the synovial membrane.
- Morning stiffness, that causes difficulty in getting started with everyday movements. The movement itself can also cause pain.
- Crackling (crepitations) in the joint.
- Pain at rest. This symptom occurs, however, only when the disease has reached an advanced stage and leads to among others things sleep disorders. This type of ache is less frequent in osteoarthritis of the knee joint.
- Deformities, mainly due to breakdown of the articular cartilage, which decrease the joint space and laxity of ligaments as a result. The deformation becomes pronounced by the formation of bone spurs (osteophytes), which can be significant and change the joint contour.
- Early diagnosis can be performed with arthroscopy.
- X-ray examination shows more pronounced changes, such as reduced joint space due to degradation of articular cartilage, increased bone density (sclerosis), osteophyte cyst formation; signs of increased secretion of synovial fluid and thus swelling can often be seen on the X-ray (Fig. 19.63).
- MRI can provide very detailed description of arthritic character and structure. In recent years, a marked development of technology has taken place for MRI to study the osteoarthritic change and development with the use of contrast (dGEMRIC technique, i.e. delayed gadolinium MRI of cartilage). This technology increases the sensitivity for detecting articular cartilage damage.

Tip

Osteoarthritic changes may exist in the joint for a long period of time before symptoms appear, but can sometimes be detected early in the bone tissue. These changes increases with time, and can even accelerate the greater the degree of loading on the affected joint.

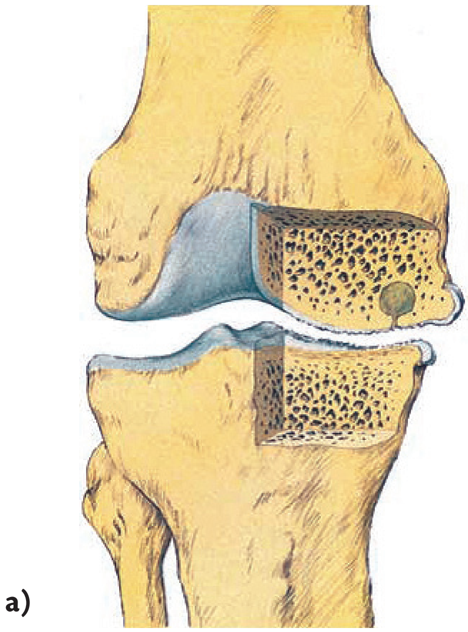
Treatment

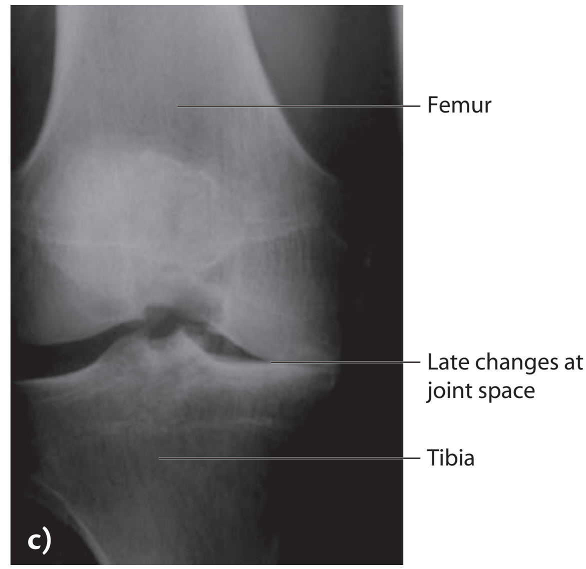
The athlete can:

- Ensure pain relief through a good acute treatment.
- Maintain or improve joint mobility and muscle function over the joint. Osteoarthritic affected joints are sensitive to strain and an important part of the treatment is to reduce the load.
- Start active mobility training without weights. This can sometimes be performed with a reduced strain in water. Passive movements, i.e. movements in which someone stretches the patient's joints, should be avoided due to the risk for increased degradation and increase in symptoms. All forms of stretching should be performed with caution.
- Heat treatment and heat retainers can reduce symptoms and facilitate active muscle training.

The physician may:

- Prescribe medicine for pain and inflammation, such as paracetamol (acetaminophen) and anti-inflammatory drugs (non-steroidal anti-inflammatory drugs, NSAIDs).
- Try glucosamine supplement and injections of hyaluronic acid.
- Provide support braces where the load is taken up on the non-affected side of the leg. The goal is to change the load pattern (Fig. 19.64).
- Perform arthroscopy in severe cases of osteoarthritis. The physician can remove loose cartilage fragments, cartilage flaps, free bodies, removing symptomatic changes in the menisci, osteophytes and reduce thickened joint capsule. Arthroscopy is often indicated





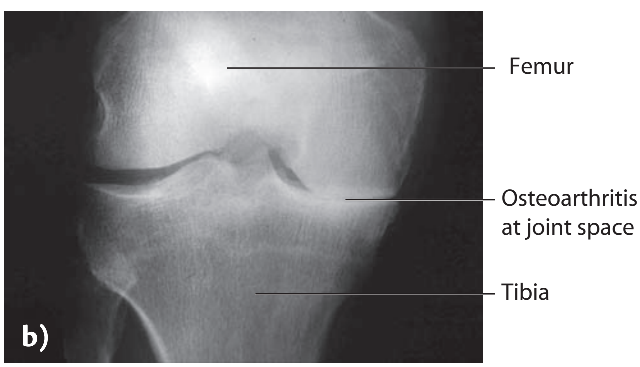


Figure 19.63 Osteoarthritis, 'worn out joints'. **a)** Diagram of the knee from the front showing internal structures. The picture shows the changes that occur at a later stage of osteoarthritis such as reduced joint space with cartilage erosion (wear), denser bone (sclerosis), cyst formation and osteophytes; **b, c)** osteoarthritis on the medial side of the knee is clearly visible on x-ray with a clear reduction of the medial joint space and osteophytes.

in cases of cartilage and meniscus damage combined with an apparent mechanical catching element and it is too early for a total joint (prosthetic) arthroplasty.

- Discuss major surgery, especially in elderly athletes. In middle-aged active people under 60 years with osteoarthritis limited to one joint compartment a wedge procedure (osteotomy) can be discussed. This technique is used when the malalignment of a knee being bowlegged (genu varum) or knockkneed (genu valgum) is corrected by a changing the direction of the force load to relieve the worn joint area.
- Perform arthroplasties which replace the worn out joint surfaces with artificial material of metal and plastic in patients over 60 years (total joint arthroplasty).
- There are various kinds of prostheses (partial or total):
  - ✓ Unicompartmental knee replacement (also called a partial knee replacement) is used for patients with osteoarthritis that is limited to just one part of the knee. In such a case the articular surfaces of the femur and tibia are replaced either in the medial or lateral compartment (Fig. 19.64).
  - ✓ Total knee replacement (TKA) when all joint surfaces in the medial and lateral compartments are replaced by artificial joint surfaces (Fig. 19.65).
  - ✓ The third compartment is the joint between the patella and the articular surface of the femur towards the patella. Prostheses replacing only the patella and the corresponding joint surface of the femur exist, but there is limited experience and can be considered a unicompartmental knee replacement if it is the only replacement.
- Hip resurfacing has been developed for the hip joint as an option to total replacement. There is much less bone loss, and has been increasingly used in younger patients in early stages of osteoarthritis.

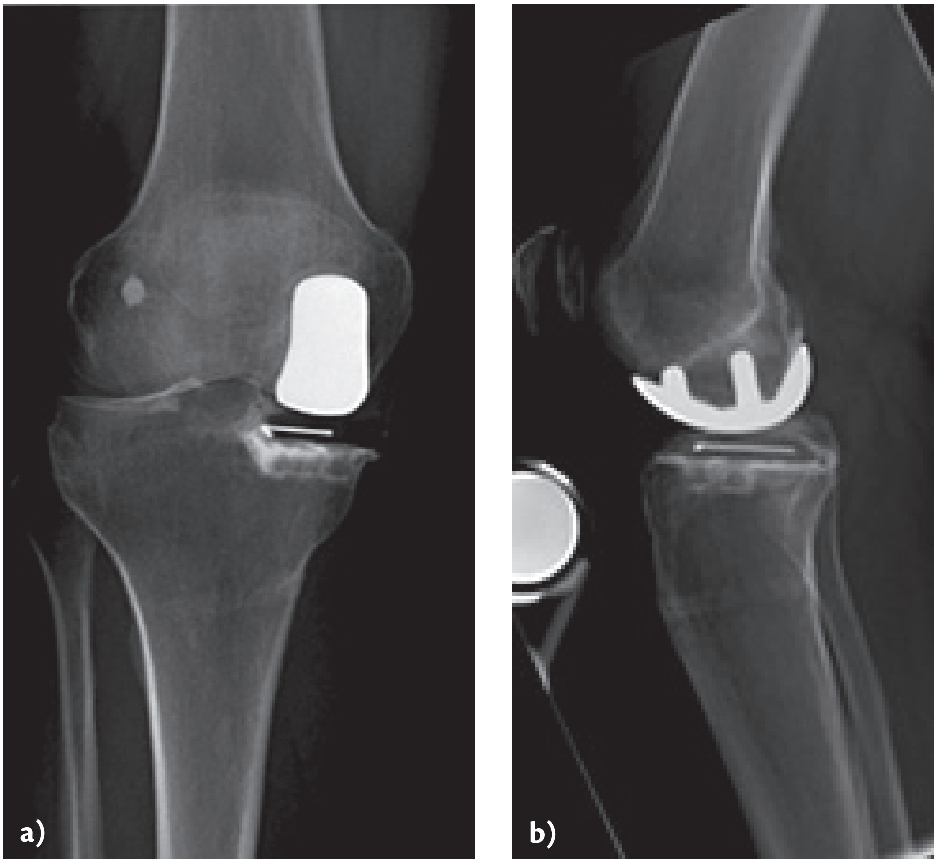


Figure 19.64 Unicompartmental knee replacement (also called a partial knee replacement) in the medial compartment of the knee joint. **a)** X-ray, front view; **b)** X-ray, side view.

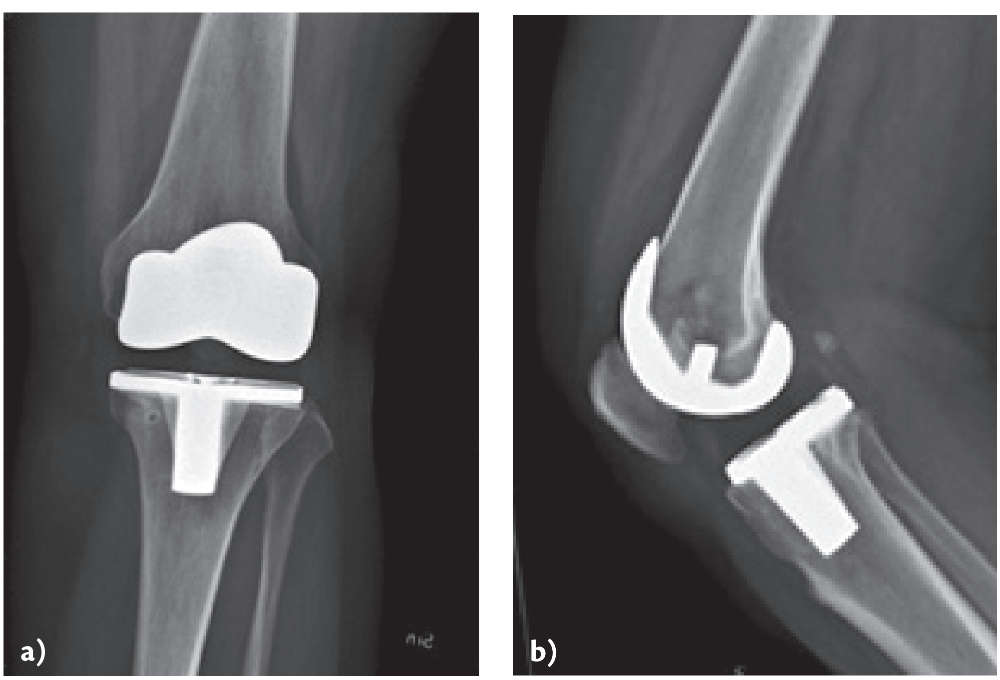


Figure 19.65 Total knee replacement. **a)** X-ray, front view; **b)** X-ray, side view.

The patient should be kept in hospital after a joint replacement surgery until he/she can cope walking on a level surface with support, walking stairs using the banister and crutch or walker and ROM between 5 and 70° (if possible 90°).

Research shows that over the past 20 years, the mean duration of hospitalization has decreased for patients who underwent arthroplasties from approximately 14 to 2 days. This is due to many factors such as improved surgical techniques with less soft tissue damage, improved pain management, early mobilization, more active rehabilitation techniques, etc. Joint replacement surgery can now even be done as an outpatient procedure.

The main goal of rehabilitation is walking without aid indoors and outdoors as well as a ROM of 0–110° or more. Younger patients often want to be able to ride a bicycle, which requires at least 110° of flexion. Theoretically modern knee prostheses can allow flexion up to 120–130°. Surgical results are good in terms of both function as well as duration.

There is some risk of complications, even if today it is quite limited. These can be classified as either early complications such as infection, thrombosis, embolism, pneumonia, luxation or late complications including loss of fixation of the prostheses, wear, dislocation, and bone or prosthesis fracture. Treatment of osteoarthritis can at best give freedom of symptoms.

Athletes who suffer from arthritis are advised to primarily engage in sports causing less load to the affected joint. In osteoarthritis of the knee disciplines such as cycling, swimming and cross-country skiing cause less strain on the joint than running events. Severe osteoarthritis may rule out participation in certain sports. Early onset of osteoarthritis is more common among athletes in contact sports like soccer, football, handball and ice hockey than in the general population.

Return to sports after joint replacement surgery should always be done after consultation with the surgeon. Sports having less impact on the knee should be considered. Cycling and swimming are the most natural fitness activity after a total knee arthroplasty. If the knee has 120° of flexion this facilitates these activities. Cross-country skiing may be possible for a few very stubborn athletes, but caution is required. Tennis, golf and table tennis are otherwise sports that can usefully be performed. In tennis, there exists great opportunities to play doubles and be invincible at net for many years after a joint replacement surgery!

Plica syndrome

Synovial plica syndrome is a controversial condition that is not very common but occasionally can cause pain in the knee joint. A plica is a normal partition in the synovial capsule (or a thickened fold in the capsule of the knee) which sometimes can become inflamed and thereby cause pain. 20–60% of the population has such a crease, plica, in the knee joint. The plica crossing the area proximal to the patella is the suprapatellar plica. There is also occasionally a lateral patellar plica. The area below the kneecap is filled up by the infrapatellar plica, which anchors the fat body against the notch's (intercondyle incisure of the femur) anterior area. The most involved plica is the mediopatellar plica, which runs from the medial side of the suprapatellar area to the anterior fat pad.

Symptoms and diagnosis

- Pain is felt with activities such as running, skiing, and cycling.
- Sometimes the athlete complains that it snaps in the knee joint and that is mimics the knee locking up. This happens often in flexion and the inflamed plica runs over the joint surface and because of the increased friction it causes a localized thickening and inflammation in the synovial membrane and can be pinched between the femur and patella.
- Sometimes a plica is palpated as a thick band at the edge of the articular surface.
- Ultrasound has been shown to be of value to identify plica in the knee joint.

Treatment

- Conservative treatment consists of rest and avoidance of painful movements. The athlete should gradually increase their activity level to pain tolerance.
- Anti-inflammatory medication may be of value.
- Arthroscopy can confirm the diagnosis. Removal (resection) of the plica has a good result in 70–90% of athletes.
- Return to sporting activity is possible within 2 weeks.

Knee extension mechanism injuries

The knee extension mechanism includes the quadriceps and its tendons, the patella, the patellar tendon, and its insertion into the tibia. Injuries can occur in all these structures.

Quadriceps tendon injuries

The lower part of quadriceps tendons attaches to the patella and its adjacent connective tissue band (retinaculum). These structures play an important part of the extension mechanism. The tendon is very strong and tears only in exceptional cases, e.g. senior athletes participating in explosive and fast moving ball games, or when a golfer falls on a slippery grass surface, or when weightlifters lift too much weight over a hyperflexed knee. Repeated squats can also cause overuse injuries among weightlifters (Fig. 19.66). Medications such as cortisone and doping substances such as anabolic steroids can weaken the tendon.

Figure 19.66 The risk for injury increases when the playing surface is slippery. **a, b)** Risk moments for injury of knee joint tendons and muscles (with permission, by Bildbyrån, Sweden); **c)** the finger shows the location where the quadriceps tendon inserts into the patella. This is a common location for an injury.

Ruptures

The typical description of a rupture of the quadriceps tendon is that the athlete experiences a sudden bang when the extension mechanism described above is exposed to too much strain. When the athlete tries to extend the knee and lift the leg from the surface the knee stays in a flexed position and they are not able to lift the leg off the ground. When the rupture is complete there is loss of function immediately and the athlete cannot rely on the injured side. Often the patella sinks downward in an unnatural position. These injuries are most often complete ruptures, and therefore pain is not the most prominent symptom.

Symptoms and diagnosis

- Tenderness and swelling in the transition between the muscle and tendon above the patella or at the junction between tendon and patella.
- A gap is felt where the rupture has occurred.
- The injured athlete cannot tighten the quadriceps muscle or straighten the knee and lift the leg.
- MRI confirms the diagnosis (Fig. 19.67).

Treatment

The physician:

- When the rupture is between the muscle and tendon, treat it with supportive bandaging and gradually increase the strength and mobility training.
- Should not operate on a partial rupture, since the injury usually does not lead to any noticeable functional deficits in the long term.
- Can initate X-ray examination to see if the patella has an abnormal position.
- Can operate when larger ruptures include an avulsion injury where the tendon is torn from the patella.
- Can operate in symptomatic older injuries of this type (Fig. 19.68).
- Early mobility training is important, however return to athletic activity is not possible until at the earliest 4–6 months after the injury.

Overuse injuries

Chronic overuse injuries of the lower (distal) portion of the quadriceps tendon is not common. This injury affects most often weightlifters, but can also occur in sports such as basketball and team handball, where repetitive jumping is involved during the game. The athlete complains of pain when they push off for a jump, or on rising from

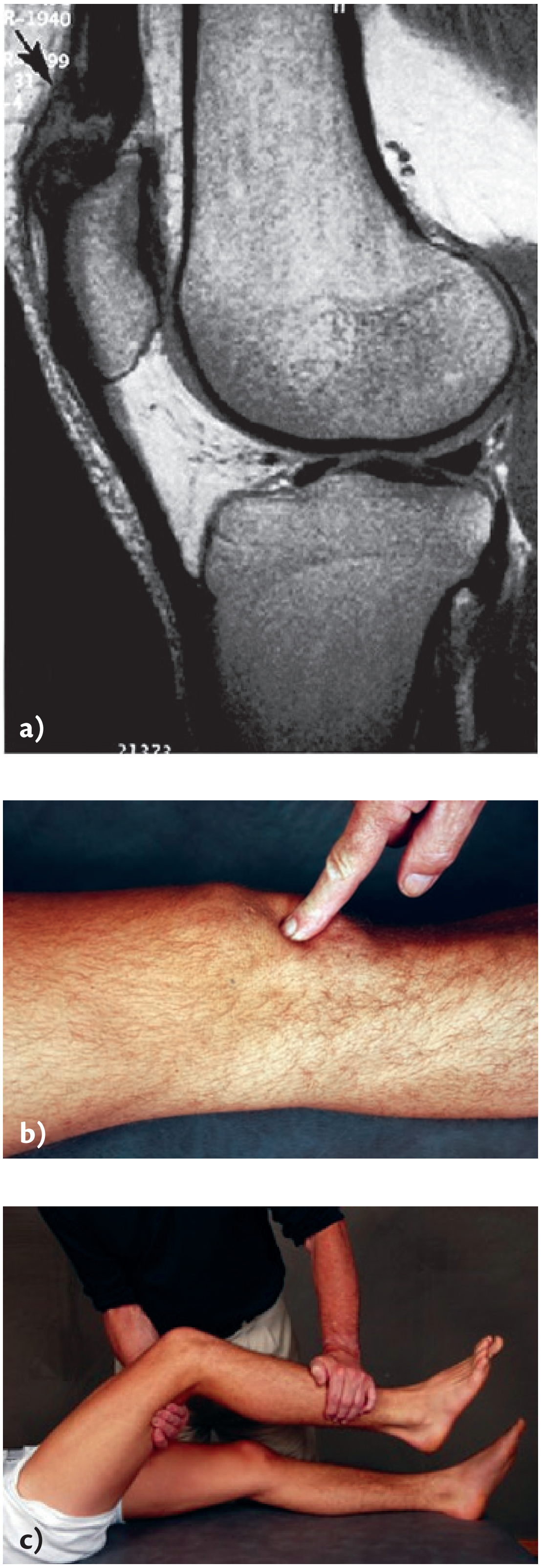


Figure 19.67 Examination of the knee joint. **a)** Magnetic resonance imaging of patella tendon. The arrow marks a partial rupture of the quadriceps tendon; **b)** the finger shows where the tenderness may be localized with an injured patella tendon; **c)** inability to actively extend the knee against resistance.

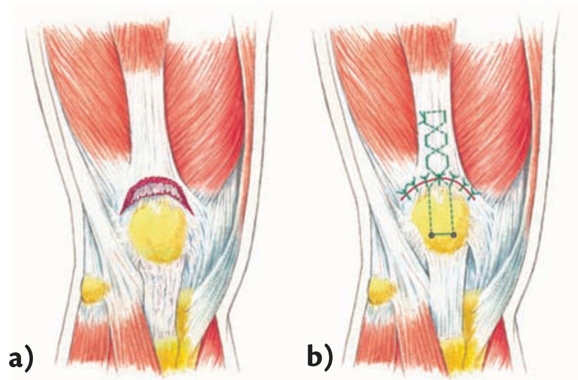


Figure 19.68 Surgical treatment of a ruptured quadriceps tendon. **a)** Total rupture of the quadriceps tendon from the patella; **b)** suture technique attaching the tendon to a raw bone surface made on the patella.

squatting or kneeling positions (Fig. 19.69). There is localized tenderness over the proximal area of the patella where the quadriceps tendon inserts. Sometimes there is discomfort when contracting the quadriceps, especially against resistance or when the extended knee is lifted against resistance. The treatments of these overuse injuries are designed according to the principles on pp. 463–5. The prognosis is often reasonably good and gradual return to activity may follow a rehabilitation period that includes stretching and strengthening exercises.

Sports injuries to the patella

In sport, pain in and around the kneecap (patella) is common. Patella pain syndrome known as patellofemoral pain syndrome, or chondromalacia patellae, occurs in most sports especially in growing individuals and most often young females. Dislocated patella (patella luxation) is common in children between 9 and14 years of age and has a recurrence rate of 30–50%.

Patellofemoral pain syndrome (chondromalacia patellae)

Anterior knee pain around the patella/femur area, i.e. the patellofemoral joint is common in all ages. The causes of the pain syndrome, which occurs in a number of conditions, is not yet fully understood. It is therefore important that the diagnosis is made as accurately as possible; otherwise the treatment may be ineffective.

Functional anatomy

Normally the patella has a wedge shape, with a medial and a lateral facet and a central crest. The patella has the thickest articular cartilage of any joint. The patella slides during extension and flexion in the groove (sulcus) of the trochlea, the upper part of the femur's two condyles, which provides stability of the joint.

Figure 19.69 a, b) Sports that involve large loads on the knee joint, tendons and other structures. (With permission, by Bildbyrån, Sweden.)

Etiology

Injury to the articular cartilage on the back of the patella usually appears in individuals between 10 and 25 years old. The condition called chondromalacia patellae is common and causes pain doing activities such as walking up and down hills or stairs, as well as squatting or with a bent knee.

It is common for pain to occur in the knee when walking up and down hills. Compared with the normal flexion of the joint on flat ground, knee flexion increases considerably during these activities, increasing compression between the patella and the femur. Walking uphill causes less pain than walking downhill, because during ascent the knee joint is flexed at an angle of about 50° under load, while on descent it is flexed at an angle of about 80° under strain. The body does not lean forward when walking downhill, so knee flexion is controlled by the quadriceps muscles alone, increasing the compression forces between the patella and the femur.

The cause of anterior knee pain may not always be found (idiopathic pain). Possible causes are trauma, overuse, malalignment or instability (Fig. 19.70).

Idiopathic anterior knee pain

Anterior knee pain is often present in growing individuals and often there is no cause to be found (idiopathic). Before the pain is labeled as idiopathic, other pathological causes must be excluded, such as bursitis, fat pad syndrome, plica syndrome and meniscus problems. Some nerve endings are not found in the cartilage, but the pain can be induced when the kneecap slides and is pressed against the surface of the femur after the articular

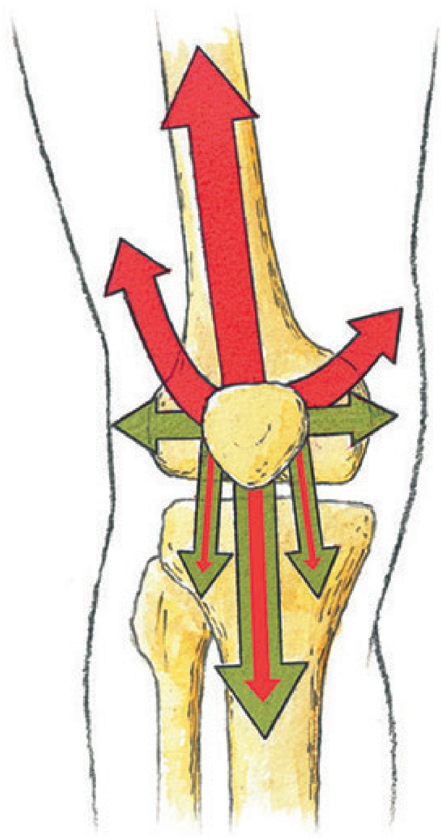


Figure 19.70 Forces acting on the knee. Red arrows represent active stabilizers; green/red arrows represent active and passive stabilizers; green arrows represent passive stabilizers.

cartilage's protective function has deteriorated. This is the primary source of pain in patellofemoral pain syndrome. Pain can also occur due to inflammation when the synovial lining of the joint is irritated by mechanical stress or by enzymes and fragments from deterioration of articular cartilage. Biomechanical disorders of the articular cartilage affect the distribution of force to the underlying subchondral bone. The bone can thicken, which can be a contributory pain factor. Improperly functioning extension mechanisms in the knee joint can also contribute to pain arising, among other causes, from muscle imbalance.

Trauma

Athletes often feel pain in the front part of the knee after receiving a blow to the knee. Direct hits can damage the joint's cartilage and the underlying bone and cause pain. The patella can totally dislocate (luxate) or partially dislocate (subluxate) laterally.

There is no consensus about which structures in the joint capsule are damaged by a luxation. The medial patellofemoral ligament (MPFL) is identified as the structure that primarily prevents a dislocation. The MPFL originates on the medial femoral condyle and goes to the medial edge of the patella. Adults injure this ligament usually at the origin on the femur. The MPFL injury has identical ruptures of the transverse connective tissue band (retinaculum) and is combined with weakness in the vastus medialis obliquus (VMO) portion of the quadriceps. Osteochondral (bone and articular cartilage) fractures may occur on the lateral femoral condyle or patella due to instability. This occurs in about 75% of dislocation cases.

Predisposing factors that likely contribute to the instability of the patella are a high-riding patella in relation to the femur (patella alta), hypermobile patella, general laxity of ligaments, increased Q-angle (see below) and changes in relation to the femur and tibia, hypotrophy of the thigh muscles, valgus deformity of the knee, abnormally-shaped patella and patella slipping out of place, caused by among other things a ground groove (sulcus, trochlear dysplasia) of the femur and/or weak connective tissue on the inside of the knee. A patella dislocation/luxation is caused in 15–45% of the cases involving the above factors.

Malalignment/instability of the extensor mechanism

Instability is considered a common cause of patellofemoral pain. Impaired function in the patellofemoral joint is very common in the general population, and symptoms associated with the knee extension mechanism are the most common among sports-related injuries. About 30% of all overuse injuries can be attributed to the knee, and 35% include the extension mechanism. In sporting events that are dependent on leg strength, such as running, jumping, gymnastics or ballet, the prevalence of patellofemoral pain is as high as 75%. Instability and malalignment of the knee joint are important background factors in these disorders.

The patellofemoral joint's passive (skeletal) stability is dependent on the joint surface congruity between the trochlea and patella. The anatomy of the intercondylar sulcus, especially in the proximal part of the articular surface of the trochlea, is important for the stability of the patella, when the joint is close to extension 0–30°. Other passive structures stabilizing the patellofemoral joint are the lateral and medial transverse and longitudinal retinacula, active during flexion and extension both in weight-bearing and non-weight-bearing movements, when they perform as tendons to VMO and vastus lateralis (Fig. 19.71).

The lateral and medial patellofemoral ligaments or the transverse retinacula run from the medial and lateral epicondyle of the femur and insert on the medial and

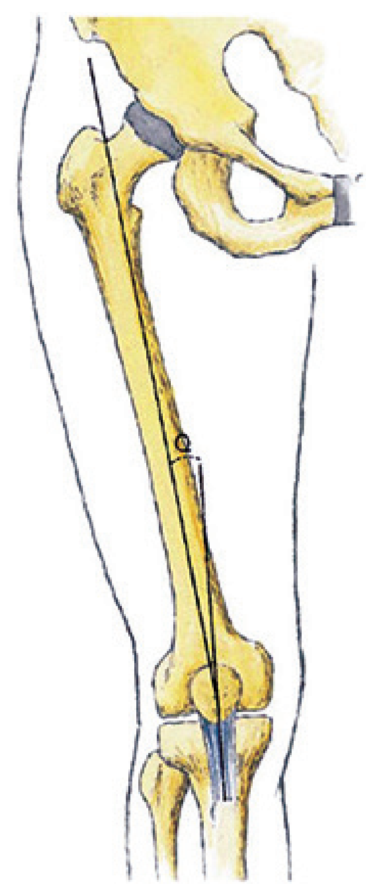


Figure 19.71 Quadriceps angle (Q-angle), i.e. the angle between a line through the rectus femoris longitudinal axis and a line through the patellar tendon/ligament.

lateral aspects of the proximal patella and provides passive stability to the patella. The medial and lateral longitudinal retinacula are tendinous connections between the VMO and the vastus lateralis muscles and insert on the medial and lateral aspect of the proximal tibia. The longitudinal retinacula provides both passive and active stability to the knee.

The patellar ligament has also both passive and active functions. It acts as a ligament in stabilizing the patella for proximal traction, and acts as a tendon via the patella to the quadriceps muscle. The active stability of the patella is controlled by the quadriceps muscles: the VMO exerts medial traction, the vastus lateralis lateral traction, and the rectus femoris and the vastus intermedius axial traction on the patella.

The quadriceps angle (Q-angle) is the angle formed between the lines through the longitudinal axis of the rectus femoris muscle and through the patellar ligament (Fig. 19.71). These lines meet in the center of the patella. An increased Q-angle will cause lateral tracking of the patella during quadriceps contraction.

Even slight deviations in the passive and active stability of the patella may give rise to patellofemoral symptoms and patellar instability. Recurrent patellar instability can be caused by the patellofemoral joint that has not developed normally (trochlear dysplasia) or the existence of a high-riding kneecap (patella alta). Defects in the soft tissue may also be present, such as a rupture or insufficiency of the medial patellofemoral ligament (retinaculum) or a weakened portion of the quadriceps, VMO. Instability of the patella due to underdevelopment (trochlear dysplasia) in the patellofemoral joint seems to be an important contributing factor for patellofemoral pain. Patellofemoral dysplasia is probably due to a genetic or developmental abnormality.

For the joint to develop normally the trochlea is stimulated by the tracking of the patella to form the sulcus between the condyles of the femur, and thus a well-fitted joint. Without such stimulation the trochlea becomes a shallow sulcus, flat or even convex surface, especially in its proximal portion. The surface of the patella has then the tendency to becomes flat and may lose its wedge shape with the dominance of the lateral facet.

Dysplasia of the patellofemoral joint, and especially in the femur trochlea, may be associated with patella alta, an increased Q-angle or genu valgum (lower leg angled outwards, knockkneed); as well as abnormal rotation of the tibia and femur (tibial and femoral torsion). The lack of a normal sulcus (dysplasia) with an increased Q-angle will create patellar instability and could be increased by muscular imbalance, especially due to weakness of the VMO.

Grading of patellar instability

- **Grade I, lateral compression syndrome**: owing to an increased Q-angle, the patella will move laterally before moving proximally on quadriceps contraction. This causes a lateral patellar compression syndrome where there is a small area of contact between the lateral trochlea and patella with increased pressure on the articular surfaces of the patella and lateral trochlea (Fig. 19.72). The patella is not dislocated but during quadriceps contraction when extending the knee, the patella will constantly be in contact with its lateral facet against the lateral trochlea. Apprehension test is negative (see p. 452 Fig. 19.76).
- **Grade II, patellar subluxation**: subluxation of the patella could either be a straight lateral subluxation or a tilt of the patella. Both conditions could be defined as subluxations with only a part of the articular surfaces in contact. The diagnosis is confirmed by computed tomography (CT) scan:
  - ✓ patellar lateral tilt is observed in chronic knee pain. Shortening and thickening of the lateral retinaculum and capsule occur, and the medial soft tissues are stretched out and as a result, the lateral facet is forced into the femoral trochlea during knee flexion, causing a lateral compression and a tilt. Over time, however, the patellar lateral tilt will cause cartilage damage. The diagnosis is confirmed by X-rays or CT scans;
  - ✓ patellar lateral subluxation is described as a subluxation of the patella elicited by quadriceps contraction on an extended knee. Recurrent

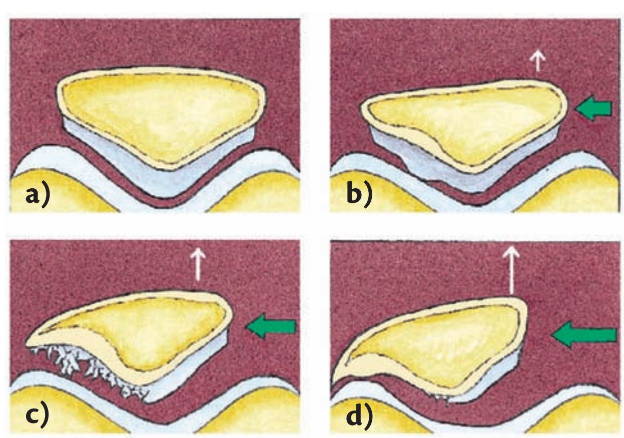


Figure 19.72 Patella position. **a)** Normal position; **b)** lateral compression syndrome with some consequences to the patella lateral angle due to tilting, which causes the patella to articulate against the lateral ridge of the femur (trochlea) increasing pressure on the articular surface; **c)** subluxation with a certain amount of patella tilt, which provides additional damage to the articular surface; **d)** subluxation and severe patella tilt.

subluxation of the patella will cause articular cartilage damage to both the patella and the trochlea with time. Sometimes there is a combination of patellar lateral subluxation and patellar tilt, which will increase the instability. The diagnosis is confirmed by CT scan during quadriceps relaxation and contraction.

- **Grade III, dislocation/luxation of the patella**: this is a severe condition with frequent recurrences (Fig. 19.73). Because of the instability and increasing damage to the articular cartilage, athletes suffer more often from'giving way'. It is a severe dysfunction of the joint and should be corrected as soon as possible. On examination a quadriceps contraction could cause a subluxation or even dislocation and there is a positive apprehension test. Patellar luxation in a normal knee can be caused by trauma, such as a fall on, or an acute blow to, the patella with a lateral dislocation injuring the medial retinacula, i.e. the MPFL and articular cartilage. It can also occur in an athlete with trochlear dysplasia and an increased Q-angle. In such cases surgical repair of the medial retinaculum ligament and the possibility to correct the other defect background factors is appropriate.

Classification of patella cartilage damage according to Outerbridge: (Fig.19.74)

Grade I: Softening and blistering; grade II: continued softening with cracking formation; grade III: cracking that reaches down to underlying bone and undermining of the surrounding cartilage tissue; grade IV: the total destruction of the cartilage and exposed bone (two examples are shown here). (For the general classification of the bone–cartilage damage see Fig. 8.13 p. 160.)

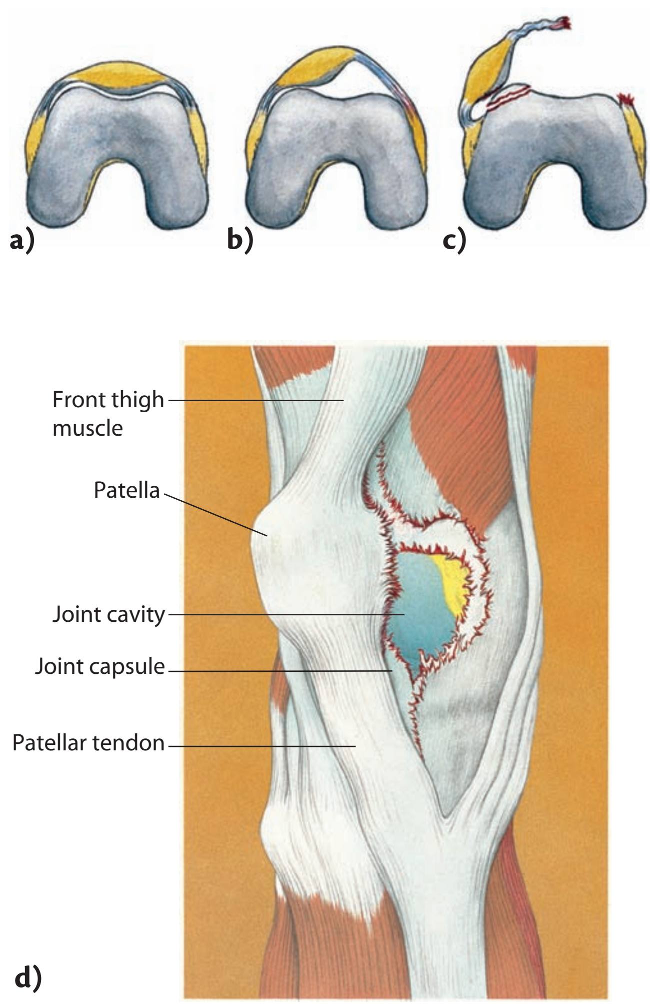


Figure 19.73 Dislocation of the patella can cause damage to the femur bone–cartilage surface or only on the cartilage surface. At the same time damage can occur to the patellar cartilage. **a)** Normal position; **b)** subluxated patella with elongation of the medial structures; **c)** dislocation of the patella with avulsion of the lateral part of the articular surface of the femur due to complete tear of the medial joint capsule, ligaments and tendons; **d)** dislocation of the patella laterally, front view. Note the extent of damage in surrounding soft tissue with rupture of the knee joint capsule, internal ligaments between the patella and the femur (medial patellofemoral ligament) and the tendon to the vastus medialis obliquus.

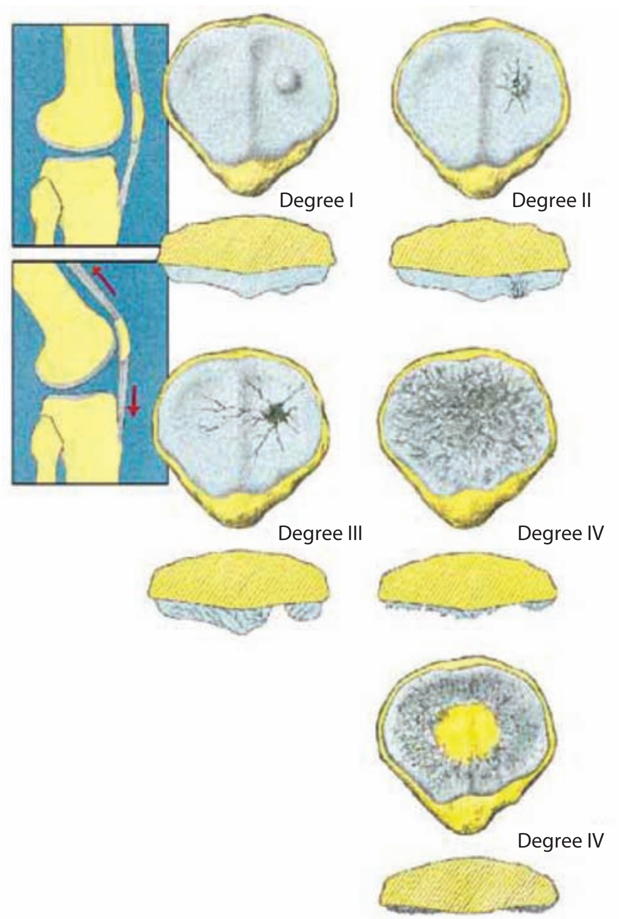


Figure 19.74 Chondromalacia patellae. **Above left** Shows the patella's location relative to the femur in extension and **Lower left** image shows at knee flexion the patella is being pressed harder against the femur. **Right**. Patella figures to the right refer to the Outerbridge classification of chondromalacia patella. See text below.

- Sometimes a slight swelling is found in the knee joint.
- It may be of diagnostic value to measure the Q-angle. The Q-angle should be measured: at 30° of flexion, the angle is normally less than 10° in men and less than 15° in women, and at 90° of flexion it is less than 8°. When measured in the extended position an angle of 15–20° is considered in need of correction.
- Malalignment of the lower limb including increased pronation of the foot, malrotation of the tibia or the femur (femoral anteversion), genu valgum and tight lateral retinaculum may be significant factors, which also increase the Q-angle and may cause recurrent dislocation of the patella (Fig. 19.75).
- Active and passive tracking of the patella should be evaluated.
- The apprehension test is positive. This test is performed with the knee in 0° of flexion. The examiner fixes the patella laterally with the hand. When the athlete bends the knee, the patella tries to sublux and thereby causes pain (Fig. 19.76).
- The passive patella tilt test evaluates the tension of the lateral retinaculum structures.
- Plain X-rays of the knee should be taken. The patella in relation to the joint line can be evaluated by lateral plain views. The Merchant infrapatellar view can be valuable, i.e. X-rays of the patella with the knee flexed at 40°.

A CT scan is effective in evaluating different malalignment patterns as well as assessing bone lesions and patellofemoral relationships (Fig. 19.77). The CT scan is also valuable for diagnosis of recurrent patellar subluxation in adolescents. This scan should be carried out in an extended position and at 30° of flexion with and without quadriceps contraction to assess the degree of instability and troclear dysplasia.

- MRI in this context is of less value, because it is difficult to perform with the knee bent at more than a 30° angle. MRI can be used, however, to provide a picture of the joint cartilage surface and underlying trabecular bone.

dGEMRIC technology has been developed for use in the early examination of cartilage lesions and follow-up of the healing after cartilage repair and osteoarthritis (Fig. 19.68B). This is a technology that is under development and is therefore used mainly for research purposes at some university clinics. As a part of the examination a contrast agent is injected to enhance the MRI image, whereby it is possible to evaluate the level of glucosaminoglucan, a substance in the cartilage which is essential for cartilage biomechanical properties. Even at the early stages of osteoarthritis, there is a reduced level of glucosaminoglucan.

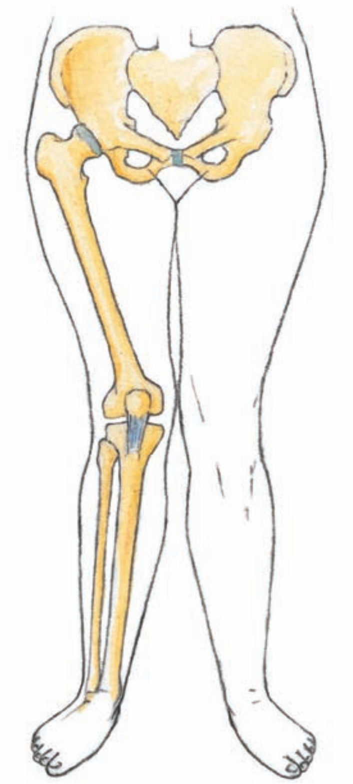


Figure 19.75 Abnormal position of the lower extremities, 'miserable malalignment syndrome'. These deformities can cause overuse problems.

- A bone scan (scintigraphy) is increasingly rare but can be used in cases with prolonged symptoms and anterior knee pain. The diagnosis is confirmed by low isotope uptake of nuclide (radioactive agent) by both patella and femur, and indicates a poor prognosis.
- Arthroscopy can evaluate the extent of the patella and trochlea articular damage and confirms the clinical and radiographic alignment and establishes whether synovitis is present.

Treatment

The athlete can:

- Actively rest.
- Apply ice in the acute phase.
- Use a brace with an opening and support for the patella.
- Try taping, which in some cases can be helpful (see p. 74 Fig. 5.19).
- Try stretching, but the effect is not verified.
- Activate the quadriceps with a straight leg. Straight leg lifts with gradually increasing load is of value.
- Exercise using squats to 90° of knee flexion; initially only using the athlete's own body weight as resistance and then gradually increasing the load and standing on one leg.

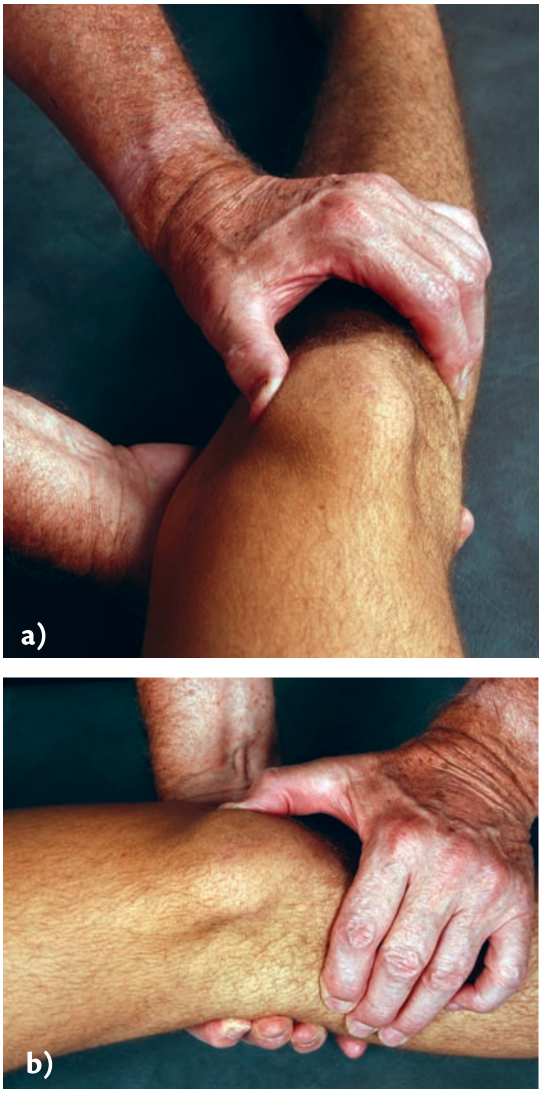


Figure 19.76 a, b) Apprehension test of the knee. The examiner pushes the patella outward laterally and fixates it. When the athlete bends his/her knee the patella tries to partially dislocate (subluxate), causing pain.

The physician may:

- Explain the cause of the pain and involve the parents if necessary. This should be done at the first visit to the clinic.
- Carry out the examination and tests necessary to secure a correct diagnosis.
- Prescribe active rest and physical therapy treatment. The athlete often needs to be educated by a knowledgeable physical therapist and by the physician. The athlete must really understand the nature of the injury in order to accept it, and must realize that, with a conservative exercise program, 80% of athletes with idiopathic patellofemoral pain usually improve over a period of 6 months.

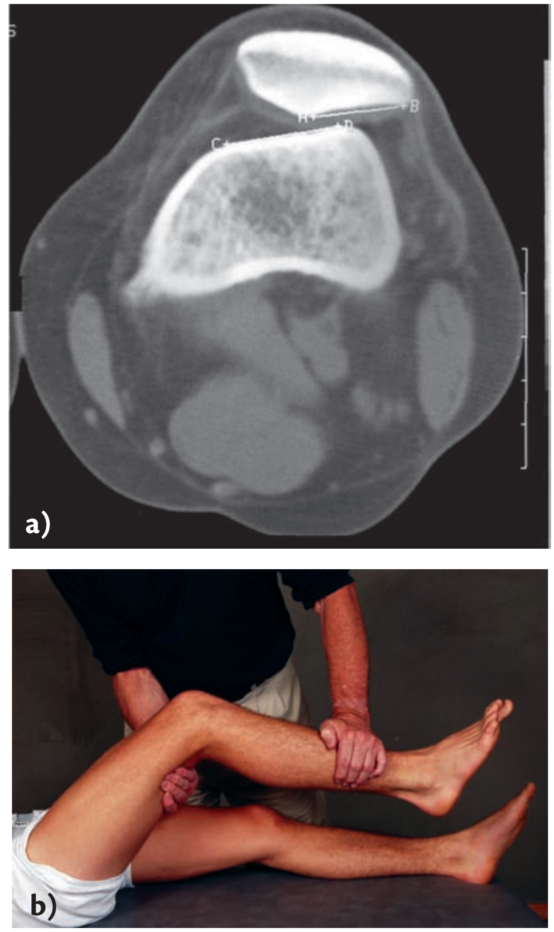


Figure 19.77 Computed tomography of the patellofemoral joint during contraction of quadriceps muscle. **a)** Cross-section of the knee, showing the patella subluxating relative to the femur with a flattened surface (throchlea); **b)** during a quadriceps contraction the patella lateralizes on both sides.

Tip

It should carefully be explained and be stressed that this injury may take time to heal.

- Prescribe anti-inflammatory agents during the acute phase. Even if there are no major objective symptoms the goal of the treatment is to regain homeostasis (metabolic equilibrium).
- Sometimes perform arthroscopy to confirm the diagnosis and assess the articular cartilage of the patella and trochlea.
- Operate in cases of prolonged symptoms. There are more than a hundred surgical procedures for the treatment of patellofemoral disorders, addressing the different malalignments. Surgery can also include treatment of the articular cartilage lesions (p. 161).

Treatment of lateral patellar tilt

The athlete should refrain from activities that cause pain and the use of a knee protection is recommended. In order to stabilize the patella, functional bracing/orthosis with reinforcement along the sides is used, or taping (Fig. 19.78). It is important to perform eccentric strength training, particularly of the VMO muscles.

The physician may:

- Advise the athlete to avoid pain triggering activities.
- Prescribe physical therapy, and place an emphasis on the training of the vastus medialialis muscle of the quadriceps; this should be performed with simultaneous electrical stimulation to be effective.
- Prescribe anti-inflammatory agents.
- Perform arthroscopy and occasionally release tight lateral structures. If there is damage to the joint in the form of loose cartilage fragments or if the articular cartilage has been softened and deformed with mechanical locking or catching as a result, the surgeon can easily remove damaged tissue (debridement). If other background factors are present, such as increased Q-angle and patellofemoral dysplasia, additional corrective interventions can become necessary.
- If the patellofemoral symptoms are caused by lateral tracking of the patella and the articular cartilage has remained intact, conservative treatment has a good prognosis.

Treatment of patellar tilt

If no articular cartilage damage exists conservative treatment, for example a patellar stabilizing brace and strength training of the VMO, offers a good prognosis; in the long term however, surgery may be necessary. In chronic conditions, both the retinaculum and joint capsule laterally can be taut and thickened. If only the lateral retinaculum is taut, it can be solved surgically, and thereafter by strength training of the VMO. If necessary, a medial patellofemoral ligament surgery can be performed. If there are other contributing factors, additional surgery may be required to restore the patella in its right position.

Figure 19.78 Braces/orthoses for different patellofemoral problems can often give some relief.
A lightweight brace for adult patients with mild subluxation, maltracking, and patella arthritis. (With permission, from DJO, LLC. All rights reserved).

Treatment of lateral patellar subluxation

Treatment should be initiated early. Initially conservative methods should be used, such as a patellar stabilizing brace, taping, strength training of the VMO and a change in the athlete's exercise routine. If conservative treatment fails, surgical stabilization measures are taken so that all defective background factors are corrected.

Treatment of patellar dislocation/luxation

The diagnosis is confirmed by MRI or CT with or without simultaneous quadriceps contraction. Arthroscopy should be performed if cartilage damage is suspected. Conservative treatment is generally preferred initially. Training programs and a patellar stabilizing brace are used. Surgery is resorted to if the conservative treatment fails. The patellofemoral ligament (MPFL) should be carefully examined and repaired if rupture or insufficiency exists.

The prognosis is good as long as no articular cartilage damage exists in the patellofemoral joint. Treatment of cartilage damage is described on p. 161. It should be noted that the recurrence rate of conservatively-treated patella luxations is 50%.

Healing and return to sport activity

The symptoms from an injury to the patella may disappear spontaneously, especially in younger athletes. The athlete must therefore change their workout routines and avoid activities that trigger pain, such as running in uneven terrain. Surgery should be avoided if possible or delayed. To be successful, the background factors should be identified and addressed.

Tip

Patellofemoral pain syndrome is one of the most difficult sports injuries to treat; partly because of the length of rehabilitation, this problem requires enormous patience of the athlete.

It is vital to teach the athlete about the character of the injury.

Background factors that can predispose to symptoms should be diagnosed and taken into account in both conservative and operative treatment.

Fractures of the patella

The patella can be cracked with transverse or longitudinal fractures or shattered into stellate fractures. The injury often occurs as a result of a fall on the knee. When the fragments are displaced, surgery is required followed by casting or a stabilizing brace for about 4 weeks. When there is no displacement a plaster cast or orthosis will usually suffice. A longitudinal patellar fracture often requires no more than bandaging if there is no displacement. The patient should be instructed in isometric thigh muscle training. Healing time is usually 6–8 weeks, depending on the fracture type.

Patellar tendon rupture

The patellar tendon is very strong (almost the strongest soft tissue in the whole body); it originates from the patella and inserts in the prominence on the anterior proximal part of the tibia (tibial tuberosity). This tendon is essential for the knee extensor mechanism, i.e. it is impossible to extend the knee unless this tendon is intact. It also acts as a ligament limiting the proximal movement of the patella during the whole ROM, therefore some call it the 'patellar ligament'.

Ruptures of the tendon can be complete or partial. A complete patellar tendon rupture is not very common as the tendon is so strong. Biomechanical studies have shown that a patellar tendon rupture may occur during weightlifting in deep knee bending, when the patellar tendon tension at the time of failure was equal to approximately 17.5 times the lifter's body weight. The patella tendon may rupture with an unexpected forceful extension, e.g. slipping on a wet golf course, where the injured athlete cannot extend their leg or constrict the quadriceps (Fig. 19.79).

A predisposing risk factor for tears of the patellar tendon is if the athlete has received a cortisone injection earlier.

Symptoms and diagnosis

- At the time of injury the athlete experiences a sudden 'pop' with intense pain, typically when pushing-off or landing after a jump.
- Disability will be immediate and the athlete cannot support weight on the injured side.
- The patella will be proximally displaced and there will be a palpable gap at the rupture site. There will be tenderness over that area and some swelling, but usually only moderate pain.
- An X-ray will show a patellar bone that is proximally retracted.
- MRI confirms the injury.

Treatment

Total rupture of the patellar tendon (proximal or distal) should be treated surgically. Usually it is sufficient to suture the tendon back to bone, but occasionally it has to be reinforced by addition of tissue such as the hamstring tendon or artificial degradable net. A KO protects the knee joint for approximately 6–8 weeks. Rehabilitation is slow, with a gradual increase in ROM and thereafter strengthening. Return to sports may be possible after 6–8 months. Cycling and sports such as golf may be possible to return to before then.

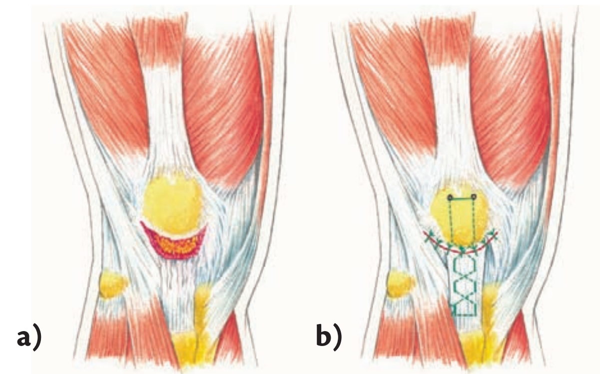


Figure 19.79 Complete rupture of the patellar tendon and how it can be treated. **a)** Total rupture at the distal point of the patella; **b)** operative technique for re-attachment of the tendon to the patella. The tendon must be attached to a raw bone surface and fixated with sutures through channels drilled in the patella.

Patellar tendinopathy 'jumper's knee' (patellar tendon overuse injury)

Overuse injuries to the patellar tendon are common since it plays a central role in almost all sporting activities. Tendinopathy is a clinical syndrome which, often but not always, is indicative of an overuse injury in the tendon. This is characterized by a combination of pain, diffuse or localized swelling and impaired functional ability. Tendinopathy can also occur without signs of overuse and is then usually related to more general medicine conditions.

The incidence of tendinopathy has gradually increased due to increased participation in sports but also because the intensity of these activities has increased. Injuries can be associated with the high demands on the extensor mechanism, and also with the load on the patellar tendon in explosive jumping and running, which may result in partial tears caused by local minor tears of collagen fibers or bundles or chronic overload of the tendon (tendinopathy). The injury risk increases if there is age-related degeneration of the tendon. Patellar tendinopathy is common in sports where jumping is prominent, such as volleyball (14%), team handball (13%) and basketball (12%). This condition is also common in track and field (see Fig. 19.80).

Figure 19.80 High jumping creates great stress on the patellar tendon. **a)** Patella tendinopathy has only been known as an entity since the late 1960s. The picture is from 1951 when the Swedish champion in the high jump, jumped a series of consecutive high jumps using the scissors jump technique on the streets of Stockholm during a student carnival. He thereby incurred an injury to the patellar tendon, which could not be properly diagnosed at the time (with permission by Prof. Arne Ljungqvist, Karolinska Institutet, Stockholm, IOC and WADA); **b)** the 'Fosbury flop' designed by Dick Fosbury in 1965 is still the dominant technique in modern high jump. This technique also causes large stress on the knee joint. (With permission, Bildbyrån, Sweden.)

The mechanism behind this injury is debated. There may be an impingement between the distal point of the patella and the tendon itself during flexion. Most injuries, especially partial tears, are located in the proximal posterior aspect of the tendon, indicating that the impingement may well be the main reason for these injuries.

Symptoms and diagnosis

- Pain at or near the lower patellar apex. Typical for this injury is that it occurs when jumping and landing in such sports such as volleyball, basketball and team handball. It has been shown that differences in landing technique may be of importance.
- Tenderness over the tendon, often in the bracket on the bottom tip of the kneecap. The tenderness is often local and distinct, suggesting a partial rupture or an inflammatory condition in the tendon. The soreness becomes more pronounced when pressure is applied over the top of the patella when the knee is actively in full extension.
- The upper portion of the patellar tendon may be thickened.
- Muscle hypotrophy is frequently seen with this injury along with a tense quadriceps muscle.
- Limited dorsiflexion of the ankle is a proven risk factor for the development of patellar tendinopathy for basketball players etc., because this is compensated by increased strain on the patellar tendon.
- MRI or ultrasound can confirm the injury. These examinations can be used to investigate degenerative changes (tendinosis) and chronic partial ruptures (Fig. 19.81).

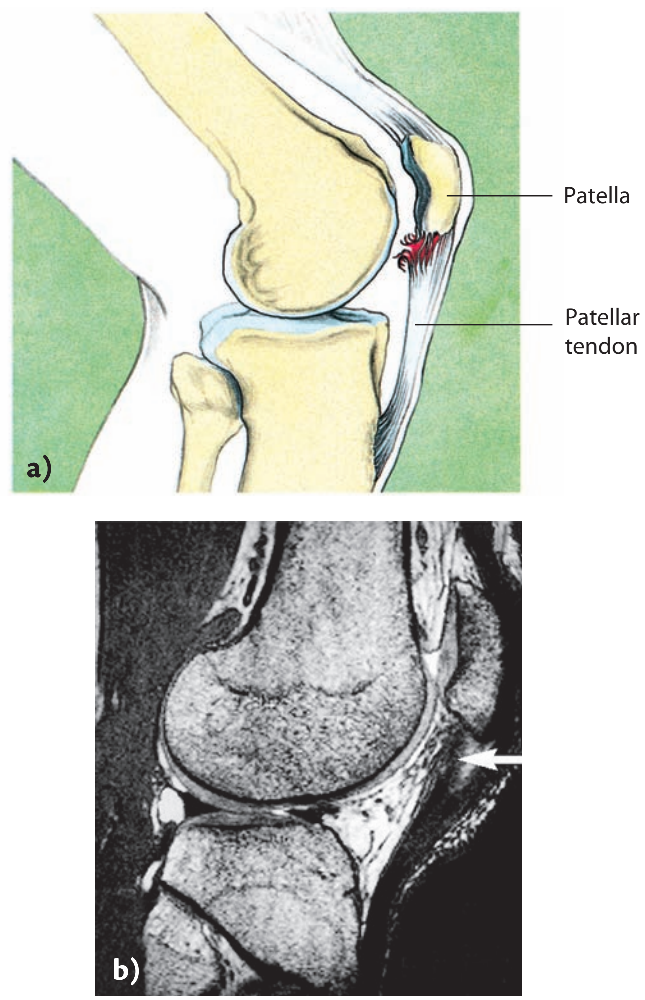


Figure 19.81 Patellar tendinopathy, overload, of the patellar tendon. **a)** Damage to the patella tendon's upper posterior portion at the attachment to the patella; **b)** Magnetic resonance imaging shows the same damage (arrow).

Treatment

The athlete can:

- Rest until the pain while exercising is relieved.
- Train the extension mechanism muscles through strength exercises and stretching. Cycle.

The physician may:

- Prescribe anti-inflammatory medication (this has limited effect).
- Correct malalignments.
- Prescribe physical therapy, because these injuries require expert help. Patient education is very important.
- Recommend strength training that includes eccentric exercises, which gradually increase in accordance with the principles on p. 200 and mobility exercises described on p. 463; a 6-week program has been shown to give very good results and improvements for over 85% of cases (Fig. 19.82).

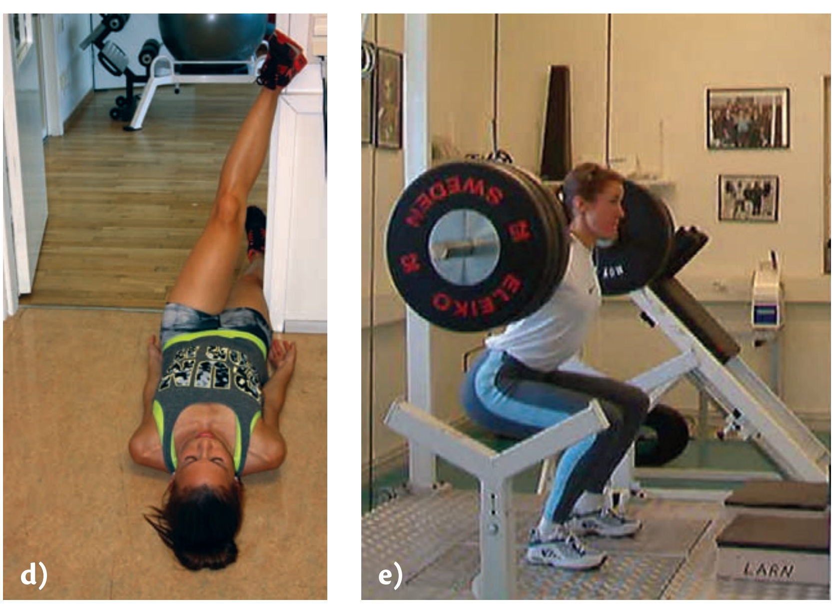


Figure 19.82 Rehabilitation for the patellar tendon. **a, b)** The quadriceps muscle of the injured leg should be loaded eccentrically, i.e. works while lengthening the muscle during a squat; squat training is performed with a straight back on a 25° tilted table. Load the injured leg on the way down and both legs on the way up. Increase load by 5 kg when the pain decreases. Squats movement should be performed slowly (3–5 s) down to 90°, 3 sets × 15 reps (repetitions), 2 times/day for 12 weeks (photos, Heijne/Frohm); **c)** exercising the medial and **d)** lateral and posterior thigh muscles is important; **e)** eccentric exercise can be practiced using varying loads under controlled conditions, and has since been shown to have good effect; sometimes called the Bromsman squat[5] (photo, Anna Frohm).

- Send the athlete to a physiotherapist for rehabilitation training since it is often too difficult to manage alone.
- Prescribe an infrapatellar strap that encircles the tibia at the level of the patellar tendon and compresses it (Fig. 19.83). This may alter the mechanical stress within the tendon in a similar way that straps are used in tennis elbow (p. 271 Fig. 12.12); 77% of patients using such a strap experienced enough relief from pain to resume 'normal' activity. These results are, however, controversial. The treatment should be individualized, as these straps have a variable effect.
- Recommend patella taping to reduce the patella travel. This technique is effective in some but not in others and should be performed by experts.
- Prescribe modern conservative treatment, such as extracorporeal shock wave therapy, and low intensity pulsed ultrasound (LIPUS). Initially, there were reports of relatively good results, especially in chronic cases, but these have not yet been fully verified in well-controlled clinical studies.
- Prescribe sclerosing injections that have been reported to counteract increased vascularity, i.e. the increased number of blood vessels, which sometimes can be seen in the injured tendon; initially relatively good results have been reported, but again more clinical studies are needed as the good results have not been verified.
- Inject platelet-rich plasma (PRP) to stimulate healing by the growth factors added; it should be noted that this is a much used treatment technique that may be a future success, but there is not yet any high quality long-term clinical scientific support for substantial treatment effects of this method.
- Avoid cortisone injections. Such an injection reduces the strength of the patellar tendon and thus increasing the risk of rupture.
- If conservative therapy is not enough, surgical treatment either arthroscopic or open with removal of the pathological area is indicated. Arthroscopy is performed today using ultrasound so that the changes may be well identified and removed (Fig. 19.84).

Tip

A well-formulated training program with eccentric strength exercise stimulates healing and is often effective in the treatment of this chronic painful condition in the patellar tendon.

This overuse injury is difficult to treat and may require a lot of rehabilitation work and take a long time.

Have, therefore, great respect for this injury!

Rehabilitation usually takes a long time and the athlete needs plenty of patience. Return to activity depends on the sport, but it is usually possible to resume strenuous sports within 4–8 months, depending on the character of the injury.

Figure 19.83 Relief support of the patellar tendon for patella tendinopathy and Osgood–Schlatter's disease. **a)** Taping can often be effective (courtesy of the Swedish Football Association); **b, c)** a strap tightened over the patellar tendon can help many athletes. (**b)** courtesy of NEA International; **c)** courtesy of Otto Bock/Rehband.)

Figure 19.84 a, b) Arthroscopy of the patellar tendon can now be carried out using the support of ultrasound. This allows for any changes to be identified and subsequently removed. (Courtesy of Lotta Willberg, ArtroClinic, Stockholm.)

Conditions from patellar tendon attachments due to overload/overuse

Sinding–Larsen–Johansson disease

Sinding–Larsen–Johansson disease is an inflammation of the tendon attachment at the distal patellar apex. The condition can be caused by repeated micro-trauma due to overuse. It is seen in growing individuals, who have pain at the distal patella apex in association with running and jumping. Local tenderness over this area is a typical clinical finding, along with swelling, decrease in ROM and limping. X-ray shows fragmentation and ossification of the patellar apex at the tendon attachment.

The treatment is relief of symptoms, because the disease is self-healing. Within 12 months, the athlete recovers. During this time, restrictive activity prevails. Strength training and stretching are important parts of rehabilitation, as well as the athlete understanding the condition. In adult athletes there are generally no residual symptoms. It should be remembered that the differential diagnosis could be stress fracture of the patella.

Osgood–Schlatter's disease

Tendinitis in the distal attachment of the patellar tendon on the tibia (tibial tuberosity) due to overuse is known as Osgood–Schlatter's disease (Fig. 19.85). This condition is common among young athletes, occurring in 13% of those seeking a consultation with a sports physician for knee pain. It affects the young athlete, who may have grown quickly, has begun to be seriously involved in a sport, e.g. jumping or running or ball games, that taxes the contraction ability of the quadriceps muscle.

In Osgood–Schlatter's disease the tibial attachment of the patellar tendon becomes a seat of inflammation and degradation of bone (apophysitis of the tibial tuberosity). The attachment of the patellar tendon pulls loose small cartilage fragments from the tibial tuberosity. The cause of this injury is unclear; possibly it is local overload. It is mainly 10–16 year olds who are primarily affected, and the symptoms disappear when the athlete is fully grown.

Symptoms and diagnosis

- Pain at the tendon attachment of the tibia during and after exertion.
- Pain may be triggered by contraction of the quadriceps against resistance.
- Local tenderness and soft tissue swelling over patellar tendon attachment to the tibia.
- The skin may be hot and red, with a prominence at the affected area.
- Muscle tightness is often present.
- X-ray examination shows fragmentation of the bone in the tendon junction. Eventually swelling and thickening of the lower portion of the patellar tendon can be seen.

Treatment

The athlete can:

- Refrain from movements that trigger pain, such as jumping and running, but can otherwise be active.
- Use heat treatment locally and use heat retainers before and during activity.
- Use ice treatment locally after activity.
- Carefully train the quadriceps muscle.

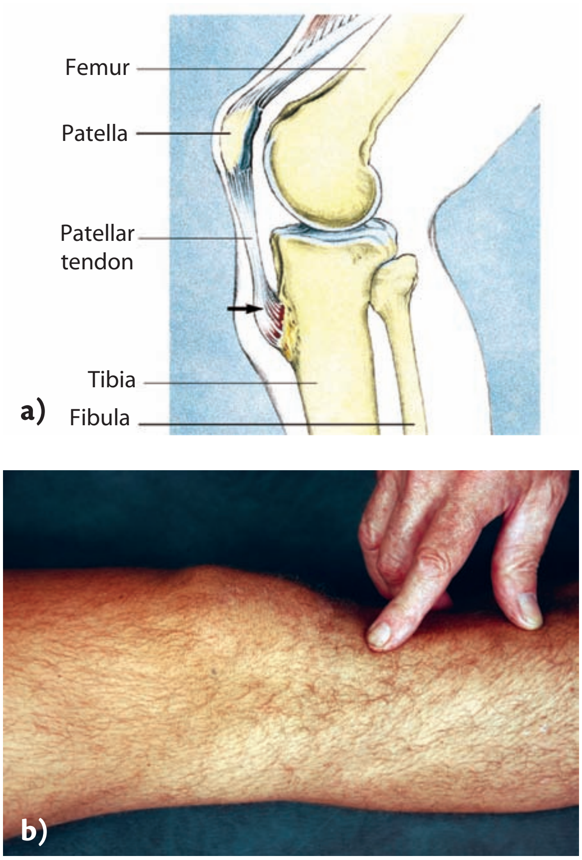


Figure 19.85 Osgood–Schlatter's disease. **a)** Arrow shows where the tendon attaches to the tibia; this is the area where the tissue breaks up, fragments form and become sore; **b)** the finger points to where the tendon attaches and tenderness occurs.

The physician may:

- Teach athletes and parents about the consequences of the condition; i.e. inform the young person that the condition is self-healing, provided that the activities are regulated to a pain free level.
- If severe pain is present apply a leg cast for 2 weeks, which can lead to pain relief.
- Prescribe an infrapatellar strap/orthosis or brace while participating in sports activity.
- Refer to a physical therapist, which provides further education about the disease.
- In rare conditions with persistent pain, perform surgery to remove small bone fragments.

Healing and complications

Osgood–Schlatter's disease heals spontaneously. Symptoms may, however, return when a new overload occurs to the patellar tendon, but this rarely occurs after the athlete's bones are fully grown at the age of 17–18 years. Problems in older athletes may be caused by loose bodies formed at the site of the insertion of the patellar tendon or even at the bursa beneath the patellar tendon. These can be removed surgically with good results.

Bursitis in the knee joint

Around the knee joint are a number of bursae. Treatment principles for bursitis are discussed on p. 185.

Inflammation of the bursa on top of the patella (prepatellar bursitis), 'housemaid's knee'

The prepatellar bursa is located anterior and distal to the patella. Its location makes it vulnerable to traumatic bursitis (Fig. 19.86). Team handball, American football and soccer players, wrestlers and gymnasts have an increased risk. One study reported that 9.5% of wrestlers had prepatellar bursitis some time over a 6-year period.[6]

Acute traumatic bursitis is caused by a single direct blow to the area resulting in hemorrhagic bursitis. Diagnosis and treatment are described on p. 186. Healing may take 1 week. Return to sport is possible as soon as the symptoms have disappeared, the swelling and inflammation have subsided, and there is a more or

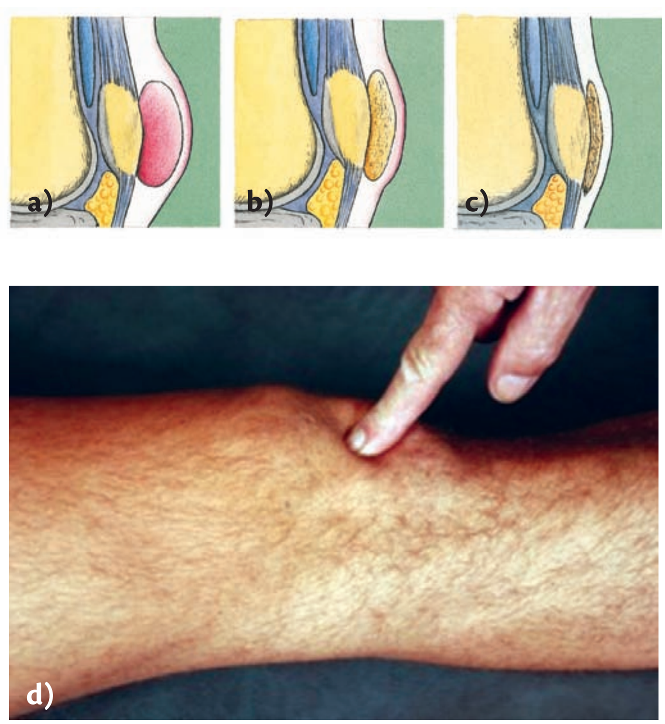


Figure 19.86 Inflammation of the bursa in front of the patella (prepatella bursitis). **a)** Acute bleeding into the bursa (hemobursa) above the knee; **b)** untreated bleeding, adhesions and loose bodies; **c)** residual condition with adhesions, scar tissue and loose bodies; **d)** the finger is pointing to where the damage and the tenderness are localized.

less normal ROM. Protective padding is important to prevent recurrence.

Recurrent bursitis can result from recurrent trauma. This chronic situation is more difficult to treat. Aspiration is usually necessary and then cortisone can be injected into the area. A compression bandage is helpful. Immobilization for a short period may be necessary. Sometimes surgical excision of the bursa is indicated when there are multiple recurrences, or the inflamed bursa extends beyond the patella. Return to sport after surgery is possible within 2–3 weeks. The surgery can be performed arthroscopically.

Bursitis due to infection (septic bursitis) requires aggressive medical treatment as detailed on p. 186.

Inflammation of the bursa beneath the patella (infrapatellar bursitis), 'clergymen's knee' 'maid's knee'

A small bursa is located under the distal part of the patellar tendon and the proximal anterior part of the tibia. Pain in this area can be a residual problem after Osgood–Schlatter's disease. Bursitis may be combined with the presence of a small bone fragment. The symptoms include local pain and tenderness and discomfort when the knee is bent under load. Treatment is conservative; occasionally surgery is needed. In sports and work where the person kneels, a superficial (subcutaneous) bursa can occur with painful swelling in the tendon insertion area (tibial tuberosity). Treatment is as above.

Pes anserinus bursitis

The pes anserinus is the tendinous insertion of the hamstring muscles (sartorius, gracilis, and semitendinosus) on the anterior medial aspect of the proximal tibia. There is a bursa between the aponeurosis of these tendons and the MCL approximately 6 cm below the medial joint line. This bursa may be inflamed by overuse friction. Occasionally there may be a direct contusion. Since the diagnosis of this injury is not easy, it is probably more common than previously thought.

Symptoms are localized pain during activity. Physical examination shows localized tenderness, swelling, and sometimes crepitus.

Treatment is conservative, including anti-inflammatory medication and restricted activity. Occasionally corticosteroid injection and ultrasound treatment have been successful. If conservative therapy does not help, surgery to remove the bursa will usually give good results.

Baker's cyst (popliteal cyst or bursitis)

An enlarged bursa in the hollow behind the knee (the popliteal space) is a relatively uncommon condition that manifests itself as a swelling of the posterior joint capsule of the knee joint (Fig. 19.87). The bursa is connected with the knee joint, and when an irritant condition is present with effusion in the joint, synovial fluid may be pressed out into the bursa so that it becomes enlarged.

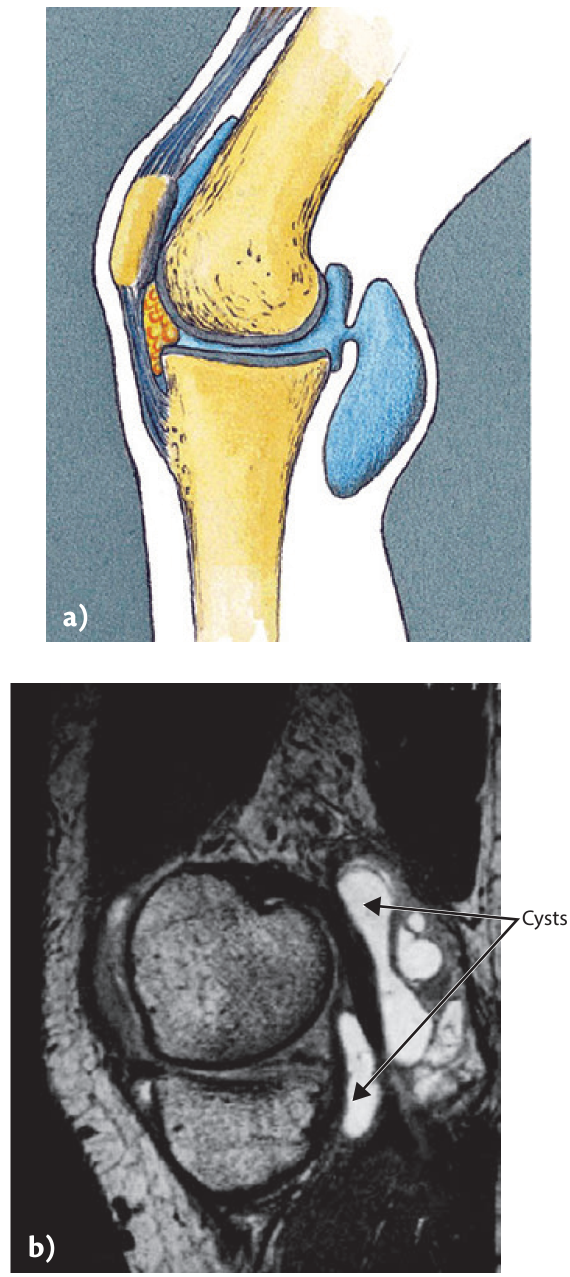


Figure 19.87 Demonstrating Baker's cyst s.c. multilobular cyst formation. **a)** Schematic drawing of the bursa in the posterior space of the knee, a Baker's cyst; there is often a communication with the knee; **b)** magnetic resonance imaging demonstrating a Baker's cyst (arrows).

Symptoms and diagnosis

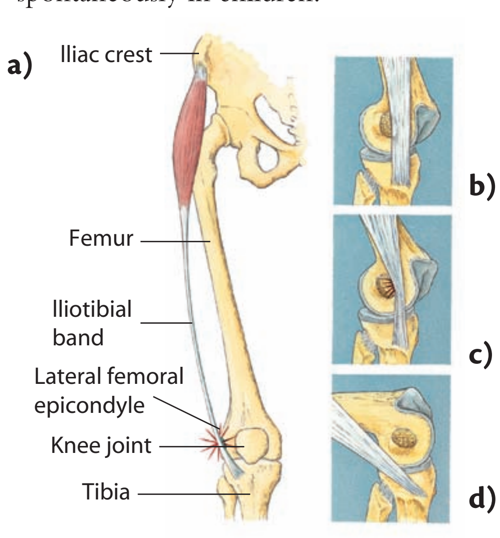
- A sensation of pressure mainly affecting the popliteal space is experienced, especially on bending. This feeling may also be transmitted to the calf muscles.
- It is difficult to bend and straighten the knee joint completely.
- Aching and tenderness are felt after exertion of the knee joint.
- The distended bursa appears as a rounded, fluctuant swelling, usually the size of a golf ball but sometimes as big as a tennis ball, when the knee joint is held in extension.
- Ultrasound or MRI of the knee (Fig. 19.87B) can show the elements of the bursa.
- Arthroscopy may reveal the cause of the effusion in the knee joint.

Treatment

The athlete should rest; the symptoms may then disappear.

The physician may:

- Treat any cause of the effusion in the knee joint.
- Remove the bursa surgically if it is causing problems.
- The injured athlete can return to sporting activity 4–8 weeks after surgery. Baker's cyst often disappears spontaneously in children.



Runner's knee (iliotibial band friction syndrome)

This painful condition is localized on the lateral side of the knee joint. It is particularly common in athletes who run often and long. This injury occurs regularly in runners participating in extreme runs, such as the so-called 'comrades' marathon' in South Africa, which is over 89 km, i.e. more than twice the length of a normal marathon. It can also affect cyclists, skiers and weightlifters.

The iliotibial tract originates from the tensor fasciae latae, and passes the greater trochanter and runs distally on the lateral side of the leg. It inserts into the lateral tibial condyle. When the knee is in extension, the iliotibial band lies anterior to the lateral epicondyle of the femur. When the athlete flexes the knee, the iliotibial band passes over the condyle at 30° of flexion, increasing friction. Inflammation of the iliotibial band occurs over the prominent epicondyle secondary to this friction. There may be associated bursitis. After 30° of flexion the iliotibial band is posterior to the epicondyle (Fig. 19.88).

Kinematic evaluation, i.e. body movements, suggest that runners with this syndrome have less hip adduction and limited hip movement in the frontal plane. They also have lower maximum flexion velocity in the hip and

Figure 19.88 Iliotibial band syndrome, 'runner's knee'. **a)** Damage caused by friction to the iliotibial band; **b)** when the knee is extended the iliotibial band lies in front of the lateral femur's epicondyle; **c)** when the knee bends to 30° the iliotibial band rubs against the lateral femur's epicondyle; **d)** when the knee bends more than 30° the iliotibial band goes behind the lateral femur's epicondyle; **e)** long distance running on a paved road can cause these symptoms (with permission, by Bildbyrån Sweden); **f)** local palpation tenderness can be felt over the lateral epicondyle on the femur.

maximum knee flexion velocity as well as early hip and knee flexion. Other conditions usually associated with this condition are excessive foot pronation, genu varum (bowlegged), rotation of the tibia and excessive tightness of the iliotibial band. 'Runners knee' is also seen in athletes running on cambered roads, which gives rise to a functional leg length discrepancy (Fig. 19.88).

Symptoms and diagnosis

- Pain localized to the lateral side of the knee may limit mobility.
- The pain may radiate upward or downward.
- This pain may start after the athlete has run a certain distance and then increases so that further running becomes impossible; after a short rest the pain may disappear, but it recurs if running is resumed.
- Running downhill or climbing stairs may aggravate the symptoms, as these activities cause excessive friction of the iliotibial band on the lateral condyle.
- Localized tenderness on the lateral condyle is felt approximately 3 cm proximal to the lateral joint line (Fig. 19.89).
- A compression test (Noble's test) can reproduce the typical pain. With the patient supine, the examiner's thumb is placed over the condyle and active extension/flexion is performed. Maximum pain occurs at 30° knee flexion.

Figure 19.89 Local palpation tenderness over the biceps femoris muscle insertion in the fibula on the lateral side of the knee joint.

Treatment

The athlete can:

- Modify their athletic activity to avoid situations that cause pain, such as running downhill or on the side of the road.
- Consider shortening the running step length, which some consider may be of value, but it has never been proven in any study.
- When training resumes, alteration of the training program may be helpful.
- Apply heat locally and use heat retainers.
- Ice can be applied immediately after activity.
- Practice static stretching of the tissues on the lateral aspect of the thigh.
- Work out to improve the mobility of the hip by stretching hip abductors and also the hamstrings, calf muscles and hip flexors.

The physician may:

- Prescribe anti-inflammatory medication.
- Prescribe a period of rest.
- Prescribe a lateral wedge orthosis, which may help an athlete with a tight iliotibial band.
- Administer a local steroid injection.
- Operate if conservative therapy fails. A small incision can be made from posterior in the iliotibial band over the lateral condyle with knee at 30° of flexion. Return to sports may be possible within 3–4 weeks.

Popliteal tendon overuse injury

Overuse injuries to the popliteal tendon are relatively uncommon. They cause pain on the lateral side of the knee joint. The popliteal tendon has its wide origin on the posterior aspect of the tibia above the attachment of the soleus muscle; it courses supralaterally and anteriorly and runs beneath the lateral collateral ligament to insert in front of it on the femur. The major function of the popliteus muscle and popliteal tendon is to initiate and maintain internal rotation of the tibia on the femur and to assist the PCL in its actions. This injury usually occurs in runners but can also occur in hikers while hiking downhill.

The injury is usually either peritendinitis (inflammation of the tendon sheath) or tendinosis (degenerative pathological changes in the tendon). Ruptures are rare, and occur mostly with major trauma.

Symptoms and diagnosis

- The characteristic symptom of overuse of the popliteal tendon is that the pain is located at the lateral femoral condyle. It usually occurs during weight bearing with knee flexion at 15–30°.

- The onset of pain is often insidious and there is no history of acute injury. The pain occurs when walking or running downhill or downstairs.
- Local tenderness is noted on palpation over the tendon attachment and lateral aspect of the femur just anterior to the LCL insertion. This tenderness is most apparent if the injured athlete sits holding the knee joint of the injured leg at an angle of 90° with the foot placed on the healthy knee.
- Pain can occur while rotating the lower leg inwards.
- Before the diagnosis is made, the physician should check that there is no injury to the lateral meniscus.
- The physical examination may often be normal. The patient should therefore be examined immediately after running.

Treatment

The athlete can:

- Avoid situations causing pain: it is often possible to continue running on even surfaces, cycling or cross-country skiing.
- Apply local heat before activities and ice after activities.

The physician may:

- Prescribe anti-inflammatory medication.
- In persistent cases, administer a local injection of steroids around the tendon, followed by activity restriction for 1–2 weeks.
- Send the patient to a physical therapist for education and treatment.
- Encourage stretching.
- Operate in cases of prolonged and severe problems.

Injury to the distal biceps femoris muscle–tendon at the knee

The symptoms and treatment for this injury are the same as described on p. 391 for injuries to the thigh muscles.

Rehabilitation programs for knee injuries

Rehabilitation of knee injuries currently emphasizes an early onset of mobility, balance and neuromuscular training, early balanced load/weight training and on an individual basis, recovery, controlled return to activity (see p. 210). An effective rehabilitation program for patients with knee injuries requires a good knowledge of the surgical procedure, the knee joint anatomy, nature of knee injuries as well as knowledge of basic training theory.

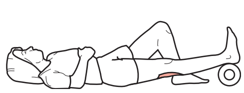
Tip

Weight lifting exercises can include both open and closed chain, with respect to the athlete's individual needs.

- An assessment of the patellofemoral relationship should be done both statically and dynamically.
- Patella position, mobility and travelling path are essential to restore proper function to the knee joint and surrounding muscles.

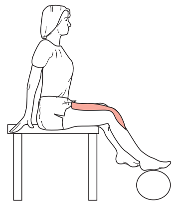
Mobility training for the knee joint

Knee extension using gravity



- Lie on your back with the foot of the injured leg resting on a rolled towel. Be sure that the leg is off the floor, especially the knee.

- Relax your leg and let gravity pull the leg to an extended position. Hold for 10–15 minutes.
- This elongation can be combined with quadriceps activation (innervation) and even straight leg raises.

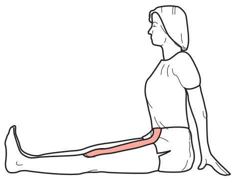


Knee flexion using gravity

- Sit on the edge of a table or high chair, let the injured leg lie against a Bobath ball.
- Bend the injured knee to its limit by rolling the ball. Keep the leg relaxed throughout the exercise.
- Hold for 20–30 seconds, relax, repeat 10 times.

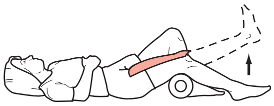
Training for lower extremity

Each exercise should be done slowly and controlled. Resistance can be added with the help of ankle weights or elastic bands. Do 2–3 sets of 10–15 repetitions.



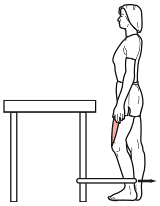
Isometric training of thigh muscles (quadriceps)

- Sit on floor with legs stretched, and tighten the thigh muscles by pressing the back of the knee down to the floor. Hold for 10 seconds, relax, repeat.
- This exercise can also be performed sitting on a chair with your heel on the floor.



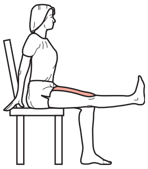
End extension (quadriceps)

- Sit on the floor with the injured leg straight and the healthy leg bent, place a rolled towel under the knee of the injured leg.
- Contract the quadriceps and lift the lower leg and foot upward. The back of the knee should constantly be in contact with the rolled towel.
- Hold for 10 seconds, return slowly. Repeat.



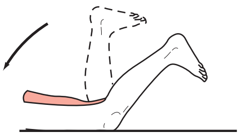
End extension standing (VMO, quadriceps)

- Attach the loop of an elastic band around a fixed object and around the knee of the injured leg. Take a step back so that the band is tensed.
- Keep the other leg straight and bend the injured leg slightly, then contract the thigh muscles and extend the leg.
- Hold for 5 seconds, relax, and repeat.



Full knee extension (quadriceps)

- Sit on the edge of a table or on a high chair, put a rolled towel under the back of the knee, with both legs hanging and femur resting on the surface.
- Slowly lift the injured leg to full extension. Hold for 5 seconds, then return slowly to the start position. Repeat.

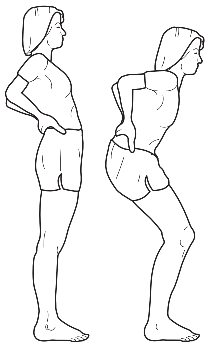


Full knee flexion (hamstrings)

- Lie on your stomach with your legs straight, slowly bend the injured leg, as far as possible, by using the hamstring muscles on the back of the thigh.
- Hold for 5 seconds and slowly lower. Repeat.

Climbing and descending 'step training' (quadriceps, hamstrings, gluteus)

- Start with a 5 cm high step and raise successively to 15 cm.
- Stand with your side to the step, with the injured leg's foot on the step. Raise your body with the injured leg and return slowly all the way down until the heel of the other leg reaches the floor. Raise yourself again from this position and repeat.
- Be sure to keep the knee joint of the injured leg in line with the foot and the hip and do not let your knee go forward in front of your toes. Repeat.



Squat (quadriceps, hamstrings, gluteus)

- Stand with your feet shoulder-width apart.
- Lean slightly forward and bend your knees to 45°. Hold for 5–10 seconds.
- Stand up again, but do not go up to full knee extension. In order to make this exercise more challenging a ball or rolled towel can be held between the knees. Repeat.
- This exercise can be made more challenging by going into a deeper squat than 45°, but it will continue to be a challenge for the muscles rather than painful for the joint. Be sure to keep the knee joint on the injured leg in line with the foot and the hip and do not let your knee go forward in front of your toes. Repeat.
- Closed chain exercises with a Bobath ball is good for stabilization of the knee joint as well as the rest of the body.

Rehabilitation programs for specific injuries

Rehabilitation programs for specific injuries are found in the following Tables:

- ACL reconstruction (patellar tendon), Table 19.1.
- Isolated MCL rupture, Table 19.2.
- Partial meniscectomy or arthroscopy, Table 19.3.
- Meniscus reconstruction, Table 19.4.
- Patellofemoral pain syndrome, Table 19.5.

Table 19.1 Standard rehabilitation protocol after anterior cruciate ligament (ACL) reconstruction using patellar or hamstring tendon)

	Rehabilitation phase/time frame					
	1. Preoperative	**2. Postoperative (first 7–10 days)**	**3. Return to weightbearing/full motion (up to 11 weeks)**	**4. Return to straight line activities (3–4 months)**	**5. Return to cutting activities (4–6 months)**	**6. Return to competition (6 months and beyond)**
Goals	• Reduce pain/swelling • Improve range of motion (at least 0–120°) • Improve strength (muscle torque) as able • Maintain overall strength/aerobic capacity as able	• Full extension (compared to non-operative knee) • At least 90° of knee flexion • Reduce swelling and pain • Improve quadriceps/hamstring function	• Normal gait without brace • No swelling • Full range of motion • Improved strength (hip/knee/ankle musculature) • Improved proprioception/balance/postural stability • Maintain overall strength/aerobic capacity as able	• Active quadriceps training against resistance without pain • Normal running gait • Maintain overall strength/aerobic capacity as able	• >90% of normal muscle torque (measured isokinetically) • All types of running without pain and in full control • Jumping without pain and in full control	Return to full unrestricted activity approved upon: • Full range of motion and muscular flexibility as compared to the opposite leg • Isokinetic strength >90% of opposite leg • No pain or swelling as a result of training • Good results of all functional testing
Methods	Prior to operation Measurements: • IKDC score • Knee laxity measurement (KT 1000) • Isokinetic concentric/eccentric measurement of quadriceps and hamstring strength • Proprioception/postural stability test (KAT 2000) Initial treatment: • Cold and compression • Passive knee extension exercises • Active knee flexion exercises OBS! For patients who have undergone rehabilitation with hamstring graft, start	Day of surgery, starting at the hospital Treatment: • Cold and compression (cryo-cuff) • Passive knee extension exercises • Active knee flexion exercises • Quadriceps control and straight leg raise exercises • Weightbearing as tolerated with brace and crutches as necessary	Upon realization of phase 2 goals Treatment additions: • Patellar mobilization (as needed) • Stretching of lower extremity (esp. hamstrings and gastrocnemius) OBS! For patients who have undergone rehabilitation with hamstring graft, the stretching of the hamstring muscle needs to be very slow and gentle. • Gait training (with a mirror and/or therapist) • Closed kinetic chain exercises • Hamstring strengthening exercises	Upon realization of phase 3 goals Treatment additions: • Submaximal isokinetic or isotonic quadriceps training (open kinetic chain, concentric/eccentric, full range of motion). OBS! For patients who have undergone rehabilitation with hamstring graft, continue working with strengthening exercises for hamstrings in low velocities however, be progressive in terms of external weights. Important to successively introduce the Nordic curl exercise. • Straightline jogging on even surface, flat or uphill only	Upon realization of phase 4 goals Treatment additions: • Jogging and running on uneven surfaces • Jogging with changes of direction (90°, 180°) • Zig-zag running with 45° cuts • Acceleration and deceleration training	Upon realization of phase 5 goals Measurements: • IKDC score • Knee laxity testing (KT 1000) • Proprioception/postural stability test (KAT 2000) • Isokinetic concentric/eccentric measurement of quadriceps and hamstring strength • Objective functional testing, such as single leg hop, triple hop test, and/or stairs hopple (hopping) test

contd...

Table 19.1 Standard rehabilitation protocol after anterior cruciate ligament (ACL) reconstruction using patellar or hamstring tendon) (*contd...*)

	Rehabilitation phase/time frame					
	1. Preoperative	**2. Postoperative (first 7–10 days)**	**3. Return to weightbearing/full motion (up to 11 weeks)**	**4. Return to straight line activities (3–4 months)**	**5. Return to cutting activities (4–6 months)**	**6. Return to competition (6 months and beyond)**
	strengthening exercises with light external weights, low velocity and very controlled. Preferable in supine position. • Quadriceps control and straight leg raise exercises • Weightbearing as tolerated, brace and crutches as necessary Note: Progress exercise and activity level, emphasizing pain free motion and strength and a gradual return to activities until a plateau is reached or surgery performed	• Home program instruction Notes: • Outpatient therapy to be done 2–3 times a week • No high-intensity training for other body parts • Crutches are required until gait is normal and painfree • Brace used for weight-bearing activities during first 3 weeks	• Proprioception, balance and coordination training • Exercise bicycle (when flexion > 100°) • Pool exercises (avoid frog kick/breast stroke) Exercises that may be added at week 5–6 (at the therapist's discretion): • Active dynamic quadriceps training, 90–40° of knee flexion • Functional exercises (jumprope, slideboard, etc.) • Specific eccentric lower extremity training (walking downstairs, jumping down on a trampoline) • Outdoor cycling • Outdoor exercise walking, flat or uphill (uneven terrain-use poles) Notes: Moderate intensity upper body/abdominal/ opposite leg training	• Progress towards normal general and sport-specific training for all other body parts	• Full-body sport-specific training with emphasis upon leg strength training	• Full speed field or court drills as appropriate to sport(s) involved

Table 19.2 Rehabilitation protocol for isolated medial collateral ligament (MCL) sprain (see p. 415)

	Early phase	**Intermediate phase**	**Late phase**	**Return to activity**
Goals	Reduce/control pain, swelling Protect joint Maintain ROM Prevent quadriceps atrophy	Increase ROM Protect joint Restore strength Increase function	Resolve remaining strength deficits Functional progression of activities	Prepare for return to activity
Weight-bearing status	To tolerance Stabilizing brace of choice	Full weight bearing	Full weight bearing	Full weight bearing
ROM, flexibility	PROM/AROM knee flexion/extension Hamstring stretching	Continue ROM exercises Hamstring stretch Standing hip flexor stretch	Continue if deficits remain	
Open kinetic chain strength training	Quadriceps sets Straight leg raises Short arc quads Hip strengthening exercises	Continue previous strength training Isotonic quadriceps/ hamstring strengthening through pain-free ROM	Full lower extremity isotonic/isokinetic program	Continue previous strength training
Closed kinetic chain strength training	Double knee bends 0–45° Terminal knee extension	Double knee bends 0–80° Straight-ahead lunge, jump, hop Step-up/down	Lateral lunges, hops, bounds Quick feet (forward, back) Squats	Carioca, hop, skip drills, plyometric drills
Functional/ proprioceptive	Maintain fitness: stationary cycling, swimming with flutter kick, deep water running	Double leg stance balance board Stork stands, balance drills Maintain fitness: cycling, swimming, stair climbing, pool running	Single leg stance balance board Slideboard, agility/ balance exercises Fitness activity: running, cycling, swimming	Functional running patterns Jump rope Sport-specific drills
Restrictions or recommendations	No jumping, cutting, or kicking sports; no frog kick in pool	No jumping, cutting, or kicking sports	Consider functional brace Consider strength test	

AROM: active range of motion; PROM: passive range of motion; ROM: range of motion.

Table 19.3 Rehabilitation protocol after partial meniscectomy or arthroscopy (see p. 425)

	Early phase (0–2 weeks)	**Intermediate phase (2–4 weeks)**	**Late phase (4–8 weeks) and return to activity**
Goals	Reduce/control pain, swelling Increase ROM Quadriceps recruitment	Increase ROM Restore strength Increase function	Resolve remaining strength deficits Functional progression of activities Return to activity
Weight-bearing status	To tolerance	Full weight bearing	Full weight bearing
ROM, flexibility	PROM/AROM knee flexion/ extension Hamstring stretching Patella mobilization	Continue ROM exercises Hamstring stretch Standing hip flexor stretch	Continue if deficits remain

contd...

Table 19.3 Rehabilitation protocol after partial meniscectomy or arthroscopy (see p. 425) (*contd...*)

	Early phase (0–2 weeks)	Intermediate phase (2–4 weeks)	Late phase (4–8 weeks) and return to activity
Closed kinetic chain strength training	Quadriceps sets Straight-leg raises Short arc quads Hip strengthening exercises	Begin isotonic quadriceps/ hamstring strengthening to tolerance	Full lower extremity isotonic/ isokinetic program
Functional/proprioceptive	Maintain fitness: stationary cycling, swimming, deep water running (when incisions are healed)	Double leg stance balance board Stork stands, balance drills Maintain fitness: cycling, swimming, stair climbing, pool running	Single leg stance balance board Slide board, agility/balance drills Functional running patterns Jump rope Running, cycling, swimming
Restrictions or recommendations	No sports	No jumping, cutting sports	Return to sports when 85% strength is reached compared to the healthy side

AROM: active range of motion; PROM: passive range of motion; ROM: range of motion.

Table 19.4 Rehabilitation protocol after meniscus repair (see p. 434)

	Time elapsed since operation			
	1–7 days	**7 days–4 weeks**	**4–12 weeks**	**12 weeks–4 months**
Goals	Reduce/control pain, swelling Prevent quadriceps atrophy	Increase ROM Protect joint Increase function	Increase ROM Initiate strength training	Resolve strength deficits Return to functional activities
Weight-bearing status	Partial weight bearing in long leg brace locked at 0°	Full weight bearing in brace set to 0–30°	Full weight bearing Brace remains on for walking until 6 weeks, then gradually discontinued	Full weight bearing
ROM, flexibility	Patella mobilization, limited range AROM if allowed by surgeon	Patella mobilization At 2 weeks: – AROM exercises 0–90° only – hamstring stretching	AROM exercises 0–120° only Hamstring stretching	Progress ROM exercises Hamstring stretching
Open kinetic chain strength training	Quadriceps sets Straight-leg raises Side-lying hip exercises	Brace remains on for exercises until 3 weeks: – quad sets – straight-leg raises – short arc quads – side-lying hip exercises – side-lying hip exercises with no weight	Brace removed for exercises Continue previous strengthening up to 4.5 kg (10 lb)	Continue previous strengthening exercises–may use weights up to 14 kg (30 lb) Leg extension 0–60°, up to 14 kg (30 lb) Leg curl Hip strengthening

contd...

Table 19.4 Rehabilitation protocol after meniscus repair (see p. 434) (*contd...*)

	Time elapsed since operation			
	1–7 days	**7 days–4 weeks**	**4–12 weeks**	**12 weeks–4 months**
Closed kinetic chain strength training	None	Toe raises, heel raises	At 8 weeks: – Double knee bends 0–60° only – step-up/down – straight-ahead lunges – double leg stance balance board – stork stand, balance drills	At 4 months: – carioca, hops, lateral lunges – plyometric drills
Functional proprioceptive	None	Standing balance on stable, flat surface	Gait training Fitness activity: swimming with flutter kick, cycling, cross trainer, pool running At 8 weeks: stair climbing	Jog, cycle At 4 months: – functional running patterns – jump rope – sport-specific drills
Restrictions or recommendations	No weight with exercises No sports	No weight with exercises	No jumping, cutting sports	Return to sport with physician's permission

AROM, active range of motion; ROM: range of motion.

Table 19.5 Rehabilitation protocol for patellofemoral pain syndrome (see p. 446)

	Early phase	**Intermediate phase**	**Late phase**	**Return to activity**
Goals	Reduce pain, inflammation Initiate medial quadriceps strengthening	Increase lower extremity flexibility Restore strength Improve patella tracking	Resolve remaining strength deficits Functional progression of activities	Prepare for return to activity
Weight-bearing status	Full weight bearing	Full weight bearing	Full weight bearing	Full weight bearing
ROM, flexibility	Hamstring stretching Hip flexor stretching Quadriceps stretching	Continue aggressive lower extremity stretching	Continue if deficits remain	
Open kinetic chain strength training	Quad sets Straight leg raises Short arc quadriceps Side-lying hip exercises	Continue previous exercises Isotonic short arc quadriceps/ hamstring strengthening if pain-free	Focused eccentric quadriceps strength training Full arc isotonic quadriceps/hamstring strengthening if no pain	Continue previous strength training
Closed kinetic chain strength training	Double knee bends 0–45° Terminal knee extension	Step-up/down Double knee bends 0–45° Terminal knee extensions	Straight-ahead lunges, hops Quick feet (forward, back) Squats	Carioca, lateral lunges, hops Light plyometric drills

contd...

Table 19.5 Rehabilitation protocol for patellofemoral pain syndrome (see p. 446) (*contd...*)

	Early phase	Intermediate phase	Late phase	Return to activity
Functional/ proprioceptive	Maintain fitness: stationary cycling, swimming, deep water running	Double leg stance balance board Stork stands, balance drills Maintain fitness: cycling, swimming, stair climbing, pool running	Single leg stance balance board Slide-board, agility/ balance drills Running, cycling, swimming	Functional running patterns Jump rope Sport-specific drills
Restrictions or recommendations	Avoid exercises that increase patellar compression	Avoid exercises that increase patellar compression		Return to sport if pain-free

ROM: range of motion.

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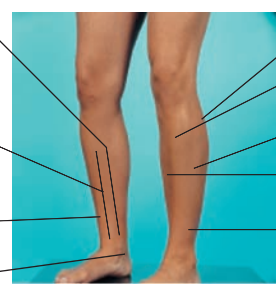
20

Lower Leg Injuries in Sport

Functional anatomy

The musculature of the lower leg is enclosed in four tight, inflexible compartments by fascias of connective tissue, which are anchored to the tibia and fibula. A cross-section through the lower leg about 10 cm (4 in.) below the knee shows that the four compartments are very well defined. In front, between the tibia and the fibula, there is an anterior compartment, which contains the toe extensors, the tibialis anterior muscle and the blood vessels and nerves that supply the anterior aspect of the lower leg and the dorsal aspect of the foot. At the back, the lower leg is divided into two compartments, one deep and one superficial. The posterior deep compartment, which is located between the tibia and the fibula and behind the tight connective tissue band (interosseous membrane) that connects the two, contains the long toe flexors (flexor digitorum longus and flexor hallucis longus) and the tibialis posterior muscle. Nerves and blood vessels pass to the back of the lower leg and the sole of the foot through this deep compartment. The posterior superficial muscle compartment at the

20.1



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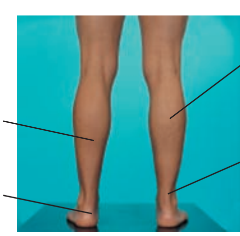


20.3

20.4

Figures 20.1–20.4 Injury location in the lower leg.

back contains the broad, deep calf muscle (the soleus) and the superficial calf muscle (the gastrocnemius). On the lateral aspect of the leg, around the fibula, there is a lateral compartment, which encloses the peroneus longus, the peroneus brevis muscles and the peroneal nerve (Figs. 20.1–20.4).

Fractures

Fractures of the lower leg occur most frequently in alpine skiers, and also occur in horse riders and participants in contact sports such as American football, football/soccer, rugby and ice hockey (Fig. 20.5).

In alpine skiing, the injury occurs most frequently in young skiers and there is no difference in incidence by sex. Snow conditions are an important consideration in tibial fractures: on icy or hard-packed surfaces the incidence of tibial fractures is much lower than on powder snow. A contributory factor may be the failure of the ski binding to release (p. 110). Tibial fractures are relatively unusual in cross-country skiing, but they do occur. Fractures in football/soccer can occur when the lower leg is hit by an opponent while the foot is loaded. Rugby tackles or an opponent tripping over an outstretched leg may also cause fractures. Lower leg fractures are not uncommon in motor sports.

Fractures of the tibia and fibula

The tibia and fibula may fracture simultaneously or separately. As a rule the injury is more serious if both bones are affected and dislocated, particularly if the broken ends penetrate the skin causing a compound fracture. The different types of fracture can be seen on p. 474 (Fig. 20.5A)

Symptoms and diagnosis

- Intense, instantaneous pain is felt in the injured area.
- Tenderness and swelling occur over the fracture.

Figure 20.5 a–e) Fracture of the tibia and fibula. This can happen in sports like football/soccer, American football and downhill skiing, when the foot is planted firmly onto the surface. The risk increases when the foot is in externally rotated position and the rest of the body rotates inward. (With permission, by Bildbyrån, Sweden.)

- The athlete is unable to use the injured leg.
- The normal contour and alignment of the lower leg may be altered by displacement of the fractured bones.

Treatment

When treating fractures it is important to remember that the soft tissues around the injury are also damaged. Guidelines for the proper management of fractures can be found in Chapter 8, p. 149. The injured athlete should not be given anything to eat or drink before transportation to hospital in case general anesthesia is required.

The physician may:

- Examine the injured area and nerve function and circulation distal to the injury.
- X-ray the injury.
- Realign the bones if necessary and put the leg in a walking boot, a brace, or a plaster cast, which for the first 4–8 weeks should include the foot, the lower leg and sometimes the thigh up to the groin. The treatment usually lasts for 8–12 weeks or sometimes longer.
- Operate if necessary. The bone ends can be realigned and fixed with a steel rod or a plate and screws. After surgery, external support may be applied for 4–12 weeks, but motion of the knee and ankle should be allowed as soon as possible.
- Realign the bones and use an external fixation instrument. This allows early range of motion (ROM) training. Acute compartment syndrome may occur and should be treated along with the fracture (see below).

Healing and complications

After the period of protection, mobility and strength are improved by continued training. A return to competitive sports is usually not possible for at least 6 months after the injury. In cases of tibial fractures there can be complications such as delayed union, nonunion or non-healing pseudarthrosis development. This condition is difficult to treat and may require surgery.

Fractures of the fibula

When the fibula alone is fractured, a simultaneous injury often occurs at the syndesmosis, which is a slightly movable articulation held together by the strong ligaments that unite the fibula and the tibia at the ankle joint. It is therefore important that the ankle joint is examined for stability by a doctor and X-rayed.

Symptoms and diagnosis

- Pain and tenderness are felt over the fracture.
- Pain occurs when the leg is under load.
- When the syndesmosis (p. 509) is damaged, the ankle joint shows swelling, tenderness and instability when tested with external rotation.
- An X-ray of the lower leg and the ankle joint confirms the diagnosis.

Treatment

An isolated fracture of the fibula without displacement often requires only rest and no immobility treatment, but when the syndesmosis is severely injured surgical repair of the ligaments may be necessary.

Healing

The healing time is 4–6 weeks, depending on the extent of the fracture. If an injury of the syndesmosis is present the deltoid ligament can be ruptured (p. 508).

Compartment syndrome

Compartment syndromes are painful conditions caused by increased pressure inside the different muscle compartments. They may be acute or chronic (Fig. 20.6).

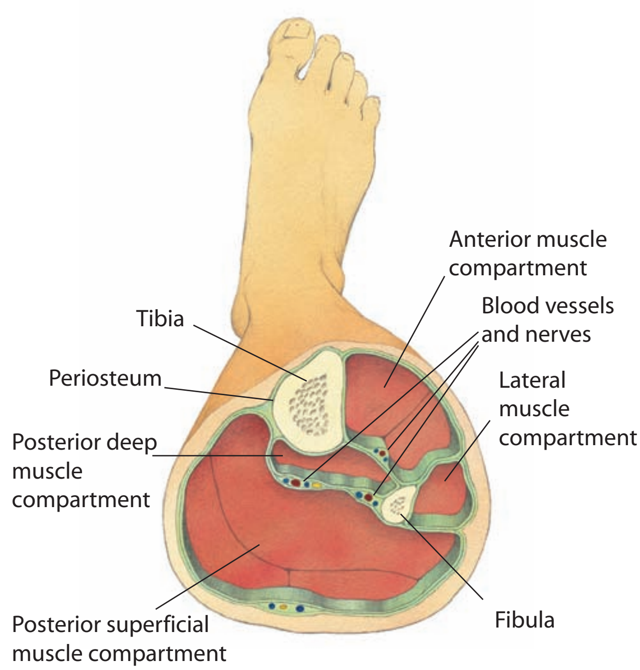


Figure 20.6 The lower leg is divided into four compartments surrounded by membranes of less elastic or firmer connective tissue (fascia). If the pressure inside one of the compartments increases, compartment syndrome may occur.

Acute compartment syndrome can arise as a result of:

- External impact that causes a fracture and/or soft tissue injury with bleeding inside a compartment.
- Muscle rupture with bleeding inside a compartment.
- Overuse, e.g. from running on a hard surface without adequate preparation or time for adjustment.

Chronic compartment syndrome can result from muscular hypertrophy (an increase in muscle volume) following prolonged training. The increase in volume causes the musculature to expand more than is allowed for by the surrounding fascia, since these tight membranes are not particularly elastic. When the muscles are at rest there is no problem, but during muscular work thousands of small blood vessels dilate in order to increase the blood flow, thereby increasing the intracompartmental pressure. The blood flow may be obstructed by excessive pressure, depriving the muscle of oxygen and leading to formation of lactic acid. This changes the cell environment, and fluid begins to leak from the capillaries, causing swelling (edema) within the muscle and further increasing the pressure in the muscle compartment, impairing the blood flow even more. This vicious cycle continues unless exercise ceases. Muscular contraction within the compartments can also exert traction on the periosteum, causing it to become inflamed (periostitis).

Compartment syndromes can occur at the front (anterior), at the back (posterior) and on each side (medial or lateral) of the lower leg.

Anterior lower leg pain

Anterior lower leg pain is caused by chronic compartment syndromes in the anterior (10–20%) and lateral (1–2%) muscle compartments, peroneal nerve syndromes (20%), muscle hernia (5%) or medial tibial stress syndromes (50%).

Acute anterior compartment syndrome

Acute anterior compartment syndrome can occur as a result of direct impact, such as a kick or a blow, to the tibialis anterior muscle. This is, however, uncommon, as the muscle lies well protected laterally to the tibia. Acute bleeding in the anterior compartment of the lower leg can lead to greatly increased pressure, which in turn impairs the blood flow of the vessels that pass through the muscle compartment. Of most importance is the artery supplying the anterior part of the dorsum of the foot, which can become completely blocked, causing an acute condition that requires surgery.

Acute anterior compartment syndrome can also be caused by overuse, triggered by the athlete training or competing too intensively, perhaps on a hard surface and without proper preparation.

Symptoms and diagnosis

- A characteristic symptom is acute pain that gradually increases until it becomes impossible to continue running.
- Weakness can occur when the foot is dorsiflexed (bent upwards).
- A sensation of numbness extending down into the foot may be felt.
- Local swelling and tenderness can be present over the tibialis anterior muscle.

Pain can be triggered when the foot or toes are passively plantar flexed (bent downwards).

Treatment

The athlete should:

- Rest actively.
- Cool the injured area.

The physician may:

- Prescribe diuretics.
- Prescribe anti-inflammatory medication.
- Check the effectiveness of the treatment by measuring the pressure in the muscle compartment.
- Operate to divide the fascia if the pressure in the muscle compartment is too high and does not diminish. Treatment should be started early, because the increased pressure can cause permanent damage to muscle and other soft tissues in the muscle compartment.

Chronic anterior compartment syndrome

Chronic anterior compartment syndrome mainly affects athletes who run long distances, or compete in specialized sports such as walking. These athletes have increased the volume of their lower leg muscles (by up to 20%) by extensive training, and the muscles have thus become larger than the surrounding fascias will allow. During exertion, as first the venous blood supply and then the arterial flow become obstructed, and the pain due to lack of oxygen and increased pressure gradually worsens until the athlete can no longer continue training, either because of the pain itself or because of weakness of muscular function.

Symptoms and diagnosis

Pain increases under load and finally makes continued muscle work impossible.

The pain disappears after a short rest but recurs when activity is resumed.

Local swelling and tenderness over the muscle belly on the antero-lateral side of the tibia is often present (Fig. 20.7).

- Pain and muscle weakness occur on dorsiflexing the foot after provocation by muscle work.
- Passive plantar toe flexion may provoke pain.
- A sensation of numbness in the space between the big toe and the second toe, weakness in the foot and marked difficulty in dorsiflexing the foot are experienced.
- The pressure in the muscle compartment can be measured at rest and during muscle work. Increased pressure is present in cases of chronic anterior compartment syndrome.

Treatment

The athlete should:

- Rest until pain has resolved.
- Stretch the involved compartment.
- Apply local heat and use a heat retainer.
- Analyze running surfaces, running technique, training, type of shoes, and so on.

The physician may:

- Analyze anatomical background factors.
- Treat the injured athlete with diuretics and anti-inflammatory medication.
- Perform compartment pressure measurements (pressure of more than 33 mmHg after effort suggests the diagnosis).
- Operate to divide the fascia and give the enlarged muscle more space (there are good results after surgery in over 90% of cases).

Figure 20.7 Anterior compartment syndrome. **a)** Area in front of the lower leg where tenderness can occur; **b)** local tenderness over the anterior area of the lower leg.

Tibialis anterior syndrome

An acute inflammation of the tendon sheath of the tibialis anterior muscle may arise from overuse of the ankle joint, e.g. in jumping and running (especially on a hard surface), in racquet sports, and so on. Dorsiflexion of the ankle joint precipitates the problem. It can also be caused by increased pressure from shoes or skates that are laced too tightly.

Symptoms and diagnosis

- Local pain is felt on dorsiflexing the ankle joint.
- Crepitus (creaking) occurs over the tendon on moving the ankle joint.
- Temperature increase, skin redness and swelling may be present over the lower anterior part of the tibia.
- Tenderness over the tendon and its sheath is felt on direct pressure over the lateral side of the tibia and also when the foot is bent up and down. If the hand is placed over the tendon, crepitus sometimes can be felt when moving the foot.

Treatment

The athlete should:

- Rest actively.
- Apply cooling both in the acute stage and later, when it may be alternated with heat treatment.
- Use proper footwear and equipment.
- Unload the anterior area from pressure and friction of a too tight shoe or skate.

The physician may:

- Prescribe anti-inflammatory medication.
- Prescribe crutches for 2–3 days to take the weight off the leg. Brace treatment is rarely needed in acute injury, but may be helpful in cases of prolonged symptoms.

Medial lower leg pain

Pain on the medial side of the lower leg can arise from medial tibial stress syndrome, a stress fracture of the tibia or from posterior deep muscle compartment syndrome.

Medial tibial stress syndrome – ‘shin splints’

Medial tibial stress syndrome (periostitis of the medial margin of the tibia or ‘shin splints’) is a common complaint in athletes, especially those who change from one surface to another in spring and autumn, change their type of shoes, alter their techniques or subject themselves to intensive training on hard noncompliant tracks, streets or floors. This syndrome can be triggered by running and other sports with elements of jumping, the main cause of the pain being repeated landing and take-off from the surface. Runners who run with forefoot strides or with externally rotated feet ('Charlie Chaplin runners') or who use spiked shoes can suffer from these complaints. Increased pronation or high arches can be a contributory cause. This injury is rather common and accounts according to current literature for approximately 13–17% of all running-related injuries. It can be even more common among dancers.

Symptoms and diagnosis

- There is diffuse longitudinal tenderness over the distal medial margin of the tibia, which can be intense. It can be local but also spreads diffusely longitudinally. The tenderness is usually pronounced over the lower half of the bone.
- A certain degree of diffuse swelling can be felt and seen.
- The pain ceases at rest but returns on renewed activity. The injured athlete can enter the pain cycle.
- Pain is triggered when the toes or ankle joint are bent in plantar flexion.
- Local tenderness occurs usually in the lower half of the tibia (Fig. 20.8). A certain degree of irregularity can sometimes be felt along its edge.
- An X-ray examination is needed when symptoms are prolonged, to exclude a stress fracture. Otherwise findings are normal, although there may be hypertrophy of the posterior cortex of the tibia.
- There is normal pressure in the compartment.
- A triple-phase bone scan may help to distinguish this syndrome from a tibial stress fracture. There is a moderate increase of activity along the posteromedial border of the tibia on the delayed images.
- Magnetic resonance imaging (MRI) can be of value to show bone edema, indicating that this condition may be a stress reaction of bone and a precursor to a stress fracture.
- There are many symptoms overlapping with other diagnoses. This may make a final diagnosis difficult. A correct diagnosis is important to determine the most appropriate treatment.

Prevention

- Every change of surface should be made gradually while the intensity of training is adjusted accordingly.
- Correct clothing and equipment should be used. Shoes should be chosen to suit the surface: shoes with cleats should be avoided when training on unyielding hard surfaces such as asphalt. Orthotic treatment may be required.
- The technique should be adjusted to the surface.
- Careful warm-up is essential.

Treatment

The athlete should:

- Interrupt training and competition and rest as early as possible. The sooner training is given up, the more rapidly the injury will heal. A chronic condition can then be avoided. Pain is a warning that should signal rest.
- Not start training again until there is no pain under load and the tenderness over the tibia is gone.
- Maintain physical fitness by cycling or swimming. If cycling, the pedal should be held under the heel rather than the front of the foot.
- Can apply local heat and use a heat retainer (Fig. 20.9). Sometimes alternating heat and cooling can be of value.

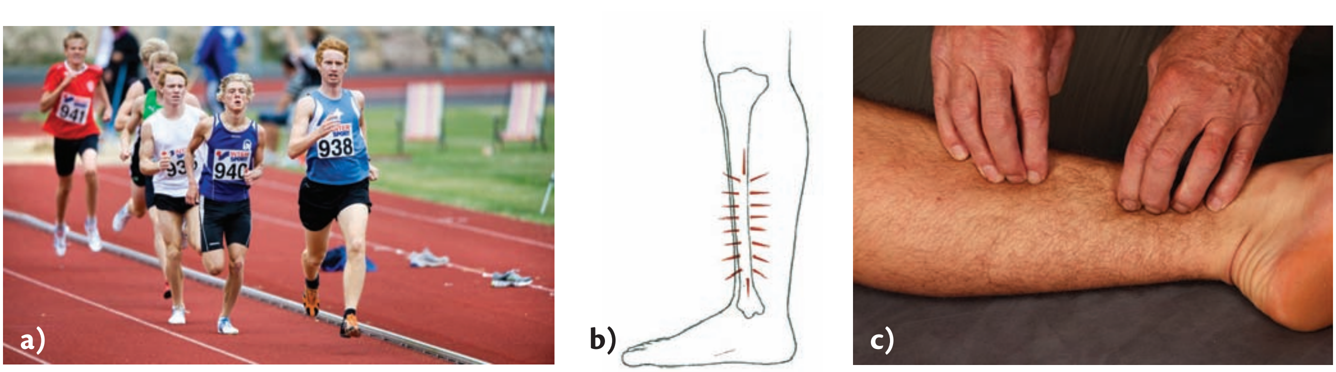


Figure 20.8 Medial tibial stress syndrome ('shin splints'). **a)** Young runners who train and run on very hard surfaces are at risk of getting pain in the lower leg (with permission, by Bildbyrån, Sweden); **b)** localization of pain in the lower leg; **c)** local tenderness occurs on the inside (medial side), usually of the tibia's lower half.

Figure 20.9 Heat retainer on the lower leg.

See a physician if the complaint persists.

The physician may:

- Prescribe anti-inflammatory medication.
- Measure the pressure in the posterior deep muscle compartment during provocation in cases of persistent complaints to exclude deep posterior compartment syndrome.
- Analyze malalignment as a cause: examine the anatomy of the lower extremity and the foot, particularly with regard to pronation and a high longitudinal arch, or genu valgum (foot orthotics can be effective in up to 30% of patients).
- Operate to divide the periosteum from the medial margin of the tibia.

Return to sport is possible within 2–4 months in most cases. It requires gradual increase of activity, education of athlete and coaches about the chronicity of this injury, and skilful teamwork. The athlete should consider return to running on softer surfaces such as grass. The prognosis is usually good, but the cause of the injury must be identified, whether it is a training error or a biomechanical deviation.

Medial tibial stress syndrome can occur as an isolated condition, but can also be a symptom of a chronic posterior deep compartment syndrome, and this can be treated with diuretics. If conservative treatment fails to relieve pain due to loading within 2 weeks, then a stress fracture should be suspected and excluded by X-ray or bone scan.

Lower leg stress fractures

Both tibia and fibula can be the site of stress fractures (p. 150), often after prolonged and repeated running and jumping. Skeletal asymmetry, leg-length discrepancy, variations in gait, poor running conditions, hard or cambered surfaces or prior injury can predispose to injury. Stress fractures are more common in women.

Different types of stress fractures

- Fibula stress fractures: these are usually located 5–7 cm (2–3 in.) from the tip of the medial malleolus. They are typical injuries of long-distance runners.
- Proximal and distal tibia stress fractures: these are most common in the proximal area and are usually located postero-medially. This part of the tibia is a compression site and these fractures develop slowly. They allow bone remodeling as response to functional demands of the mechanical loading. These fractures often heal well in 4–8 weeks. They are seen mostly in runners.
- Central and anterior tibial stress fractures: these are located in the anterior aspect of the tibia, which is called the tension side. They tend to heal very poorly and represent about 5% of tibial stress fractures. They need to be treated with special attention. These fractures typically involve the anterior tibial cortex and may be referred to as 'dreaded black-line fractures' because they generally have poor prognosis and a propensity to progress to complete fracture (Fig. 20.10). They are seen in sports that include running and jumping, such as volleyball, team handball, hurdles and long jump.

Symptoms and diagnosis

Stress fracture characteristics are described on page 150 (Fig. 20.11).

It is possible to differentiate a stress fracture from medial tibial stress syndrome by a triple-phase bone scan (Fig. 20.12). In medial tibial stress syndrome the scan is only positive on the delayed phase and covers a long segment, while in stress fractures the scan is positive on all phases, and has a focal location. MRI and computed tomography (CT) can verify the diagnosis. Bone edema (swelling) can be seen as a reaction to the stress fracture.

Treatment

- Rest and avoidance of abuse from painful activities.
- Crutches may sometimes be needed in the early phase if there is pain on weight bearing.
- Conservative treatment of these stress fractures can be combined with electrical stimulation.

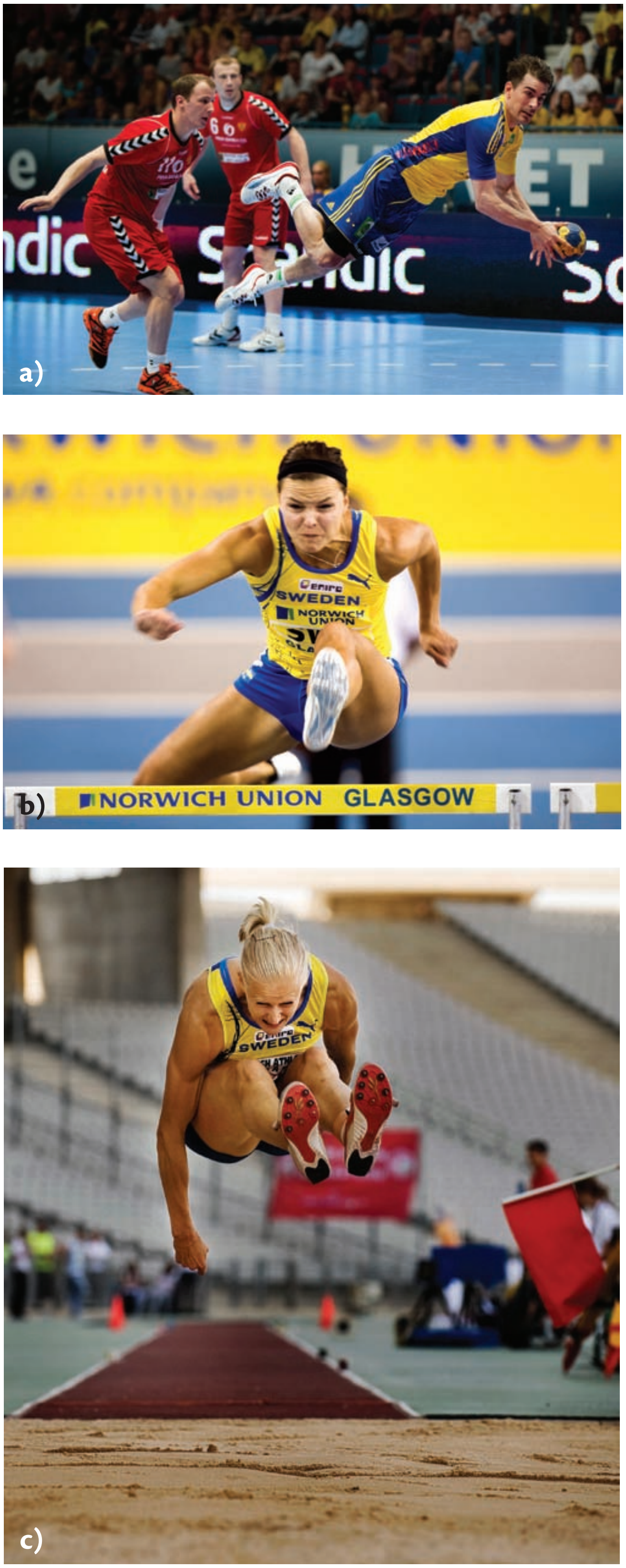


Figure 20.10 a–c) Training and competition of elite athletes that contains repeated forceful jump training, e.g. plyometrics, may increase risk of stress fractures. (With permission, by Bildbyrån, Sweden.)

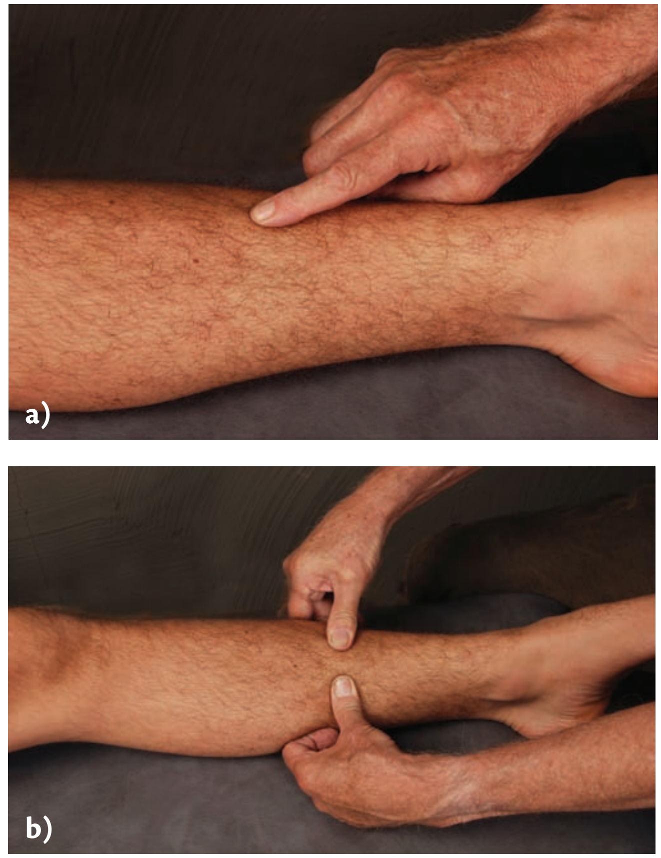


Figure 20.11 Usual localization of tenderness of an anterior lower leg stress fracture. **a)** Tenderness can usually be felt with a finger; **b)** tenderness certainly can be felt with a two hand investigation.

- For anterior tibial stress fracture of the central tibia a more aggressive approach has been advocated, since these fractures may take a long time to heal. Among the different alternatives are:
  - ✓ conservative management involving rest, possibly augmented by external electrical stimulation;
  - ✓ pneumatic lower leg brace with modified rest, which have in some hands been effective;
  - ✓ shock wave therapy: in some hands this has given good results, but the treatment, despite promising results, should still be considered experimental;
  - ✓ early surgery with excision of the excessive sclerotic (hard) bone of the delayed union, combined with drilling;
  - ✓ early surgery with intramedullary (marrow canal) nailing, which has allowed return to sports in a few months. The results of surgery have not been universally successful, with complications including persistent pain at the excision/graft site pain after nailing;
  - ✓ surgical treatment with laminofixation seems to work.[1]

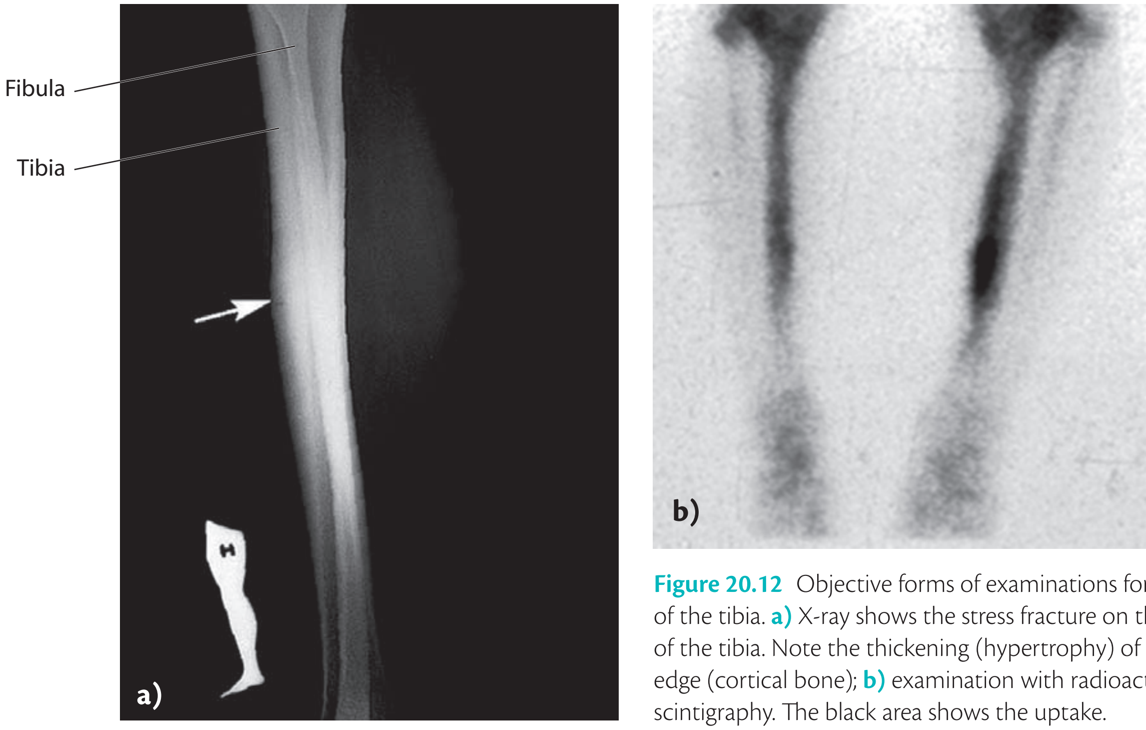


Figure 20.12 Objective forms of examinations for stress fracture of the tibia. **a)** X-ray shows the stress fracture on the anterior side of the tibia. Note the thickening (hypertrophy) of the anterior tibial edge (cortical bone); **b)** examination with radioactive isotopes scintigraphy. The black area shows the uptake.

Since stress fractures (especially those of the anterior central tibia) have a tendency to heal poorly, an early consultation with an orthopedic Sports Medicine specialist is recommended. Intense, repetitive training without variation and without time for tissue recovery and adaptation increases the risk of stress fractures.

Tip

A stress fracture on the anterior central tibia should be treated by a specialists in the field.

Posterior deep compartment syndrome

Acute posterior deep compartment syndrome can result from external impact or acute overuse of the muscles, e.g. during running and jumping (especially when taking-off). Such an injury may affect all the muscles simultaneously, or one (e.g. tibialis posterior, flexor hallucis longus, or flexor digitorum longus) in isolation. It can be difficult – sometimes impossible – to decide which muscles have been affected, but clues can be found if each muscle group is tested individually:

- If plantar-flexing the big toe against resistance triggers pain, the flexor hallucis longus muscle tendon is involved.
- If plantar-flexing the whole of the foot inward against resistance triggers pain, the tibialis posterior muscle is primarily involved.
- If plantar-flexing all the toes against resistance triggers pain, the long toe flexors are involved.

In chronic posterior deep compartment syndrome, increased pressure during activity in the muscle compartment, in addition to the increased muscle contraction, can cause increased pressure on the vessels and nerves in the compartment, as well as traction on the fascial attachment to the periosteum on the inside edge of the tibia. The result may be pain and inflammation of the periosteum (periostitis).

Symptoms and diagnosis

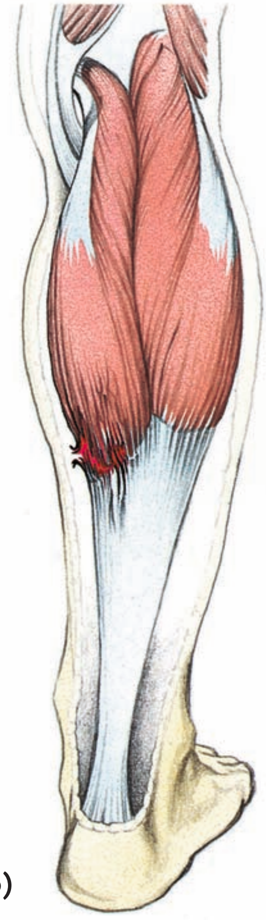
- The examination should if needed be performed after provocation (Fig. 20.13).
- Pain occurs on kicking or pushing-off from the ground and also on heel-raising. The pain starts insidiously and gradually intensifies until physical activity is rendered impossible.
- A sensation of numbness in the foot and weakness on taking-off are felt.
- The symptoms abate after rest but recur when there is renewed exertion.

Treatment

The treatment is the same as for chronic anterior compartment syndrome (p. 476).

Figure 20.13 Localization of discomfort for posterior compartment syndrome.

a)



b)

Figure 20.14 Partial rupture of the calf muscle (gastrocnemius) ('tennis leg'). **a)** A serve or a rush forward in tennis creates a risk of this injury; **b)** anatomic location of the injury that usually occurs at the transition on the medial side between the calf muscle (gastrocnemius muscle) and Achilles tendon.

Posterior lower leg pain

Posterior superficial compartment syndrome

Posterior superficial compartment syndrome is an uncommon condition affecting the muscle compartment containing the broad, deep calf muscle (the soleus) and the superficial calf muscle (the gastrocnemius). Symptoms, diagnosis, and treatment are in principle the same as for anterior compartment syndrome (p. 476).

'Tennis leg' (rupture of the gastrocnemius muscle)

Ruptures of the calf musculature usually occur at the point where the Achilles tendon merges with the inner belly of the calf muscle (Fig. 20.14). The injury occurs most frequently in tennis, badminton, squash, volleyball, basketball and team handball, and also in the jumping sports.

Table 20.1 Pain and discomfort from medial tibial pain, stress fractures and compartment syndrome

Symptoms and diagnosis

- There is a sudden pain in the calf which may feel like a blow on the leg from behind.

Table 20.1

Sign	Medial tibial syndrome	Stress fracture	Compartment syndrome
Pain during activity	500m	Immediate	3 km
Need to stop	No	Yes	Yes
Pain after activity	Yes	No	No

- There is difficulty in contracting the calf muscle and walking on tiptoe.
- Local tenderness occurs over the injured area (Fig. 20.15).
- Effusion of blood in the region of the rupture.
- A gap can be felt in the muscle–tendon junction over the injured area.
- In middle-aged and elderly individuals a muscle–tendon junction injury may be misinterpreted as thrombosis.

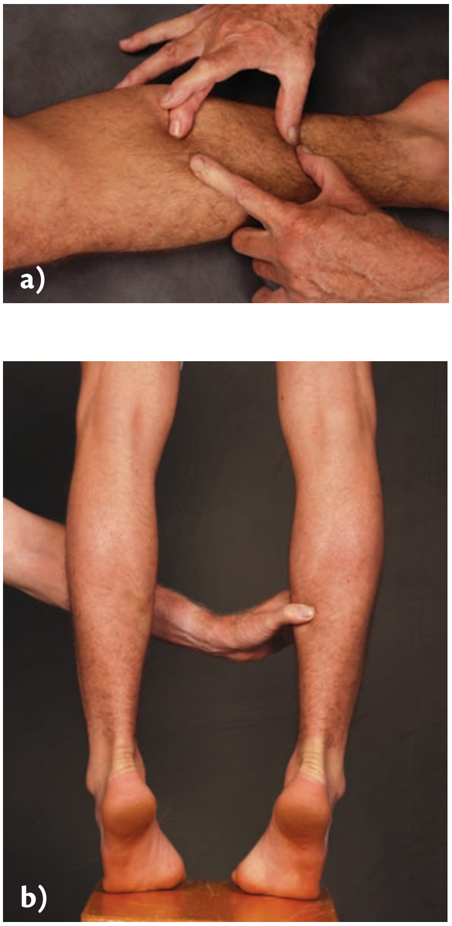


Figure 20.15 Rupture of the calf muscle (gastrocnemius) ('Tennis leg'). **a)** Localization of tenderness and pain of the injury; **b)** alternative method to find the tenderness.

Treatment

The athlete should:

- Treat the injury immediately by cooling, apply a compression bandage, and elevate the leg.
- Avoid any 'pushing-off' activity.
- Use crutches.

The physician may:

- In cases of minor ruptures and in elderly patients, prescribe a support bandage and early introduction of mobility and progressive strength training.
- Advise the athlete to wear a walking boot to keep the ankle stiff and prevent 'pushing-off' activity.
- Occasionally operate when the injury and the hematoma are extensive or risk for acute compartment syndrome in an active athlete.

Healing and complications

- Muscle rehabilitation should start within 3–5 days and increase progressively (p. 200). The injured athlete can return to training 2–6 weeks after a minor rupture. After surgery, rehabilitation will demand another 6–10 weeks.
- An untreated muscle rupture leads to scarring, which carries with it the risk of repeated discomfort if the muscle is overexerted.
- The risk for recurrent muscle tear is large and therefore optimal rehabilitation is of greatest importance.

Rupture of the soleus muscle

On vigorous take-offs or jump-ups the soleus muscle deep in the calf can be overloaded and rupture. Such ruptures are uncommon, and are usually only partial.

Symptoms and diagnosis

- Pain is located deep in the calf and recurs on repeated loading.
- Pain is triggered when the foot is plantar-flexed against resistance and also on attempting to walk on tiptoe.
- Bleeding most often makes itself felt only some 24 hours after the injury. Bruising becomes visible on the inner side of the proximal and middle parts of the shin.
- Deep local tenderness is felt over the rupture, often along the soleus at the tibial margin.
- In cases of long-term problems MRI may be helpful.

Treatment

The athlete should:

- Immediately treat the injury by cooling, apply a compression bandage, and elevate the leg.
- Start motion and strengthening gradually after 3–5 days.

The physician may:

- Prescribe further strength and mobility training.
- Prescribe anti-inflammatory medication if the leg is painful.

If the bleeding accompanying the muscle rupture is extensive, acutely increased pressure can occur in the posterior superficial muscle compartment (see p. 482).

Healing

The injured athlete should not return to regular training until there is no further pain during movements under load, which usually takes 2–4 weeks.

Lateral lower leg pain

In the lateral side of the lower leg, pain can occur in the fibula as a result of stress fractures (p. 150) and also in the lateral muscle compartment as a result of acute or chronic lateral compartment syndrome.

Lateral compartment syndrome

Acute lateral compartment syndrome can result from external impact or sudden overuse of the muscles. Symptoms, diagnosis and treatment are in principle the same as for cases of acute anterior compartment syndrome (p. 476).

Chronic pressure increase in the lateral muscle compartment occurs mainly in runners and is often associated with insufficient ligaments on the lateral aspect of the ankle joint. The muscle group of the lateral compartment acts to stabilize the lateral side of the ankle joint and can be overloaded in cases of instability of the joint. Symptoms, diagnosis and treatment are the same as for chronic anterior compartment syndrome (p. 476).

Muscle hernia

A muscle hernia is a defect in the muscle fascia. It exists in 40% of athletes with chronic compartment syndrome, compared with 5% of normal athletes. The muscle can herniate through this fascia defect. The hernia is characterized by localized muscle swelling. Pain and swelling increase with exercise. There are negative findings on X-ray and bone scan. Occasionally, pressure studies may be abnormal if there is an associated compartment syndrome.

As there may be increased intracompartmental pressure after fascia closure, the most common treatment is completion of the herniation with complete fasciotomy, where the fascia is cut. Occasionally, the fascia can be closed with the addition of transplanted fascial material.

Injury to the common peroneal nerve

Injuries to the peroneal nerve in its course down the lateral aspect of the upper part of the fibula can occur as a result of impact – a blow, kick or fall – and in combination with severe knee ligament injuries or as a result of external pressure from tape or plaster cast. This pressure is most common where the nerve goes around the proximal 2 cm (0.8 in.) of the fibula.

Symptoms and diagnosis

- The pressure on the nerve causes paralysis creating a weakness in dorsiflexion of the ankle joint and eversion (pronation) of the foot. The result can be a 'drop foot'.
- The skin in the area may lose some sensitivity.
- An electromyography (EMG) test may be used to analyze the injury.

Treatment

- Strength and mobility training.
- Taking the pressure off the injured area.
- A bandage or an extension orthosis to keep the foot in its normal position, if necessary.
- Electrical stimulation by a physiotherapist to reduce muscle wasting in cases of paralysis.
- Anti-inflammatory medication if needed.
- Surgical repair when necessary.

Healing

The function of the ankle joint usually returns after a period that varies from a few days to several months. The function usually returns if the nerve is damaged only by pressure.

Entrapment of the superficial peroneal nerve

The superficial peroneal nerve pierces the deep fascia 10 cm (4 in.) proximal to the lateral malleolus of the ankle. It is the most common nerve compression in the lower leg. The symptoms are vaguely localized pain at the lateral ankle and there may be foot pain. This pain is usually associated with exercise. There is a positive Tinel sign (tapping on the nerve gives discomfort) and a positive nerve conduction velocity test. Treatment is by surgical decompression and fasciotomy.

Lower leg neurological pain

In elderly athletes there can be neurological pain in the lower leg, which may have the following causes:

- Neuropathy or 'nerve pain', is not uncommon in middle-aged women with diabetes. The symptoms with pain are worse at night or at rest. This problem is best treated by the diabetician. Sometimes the use of orthoses are valuable.
- Nerve pain radiation (neuroradiculopathy), which is often associated with back pain, causes sensory pain spread according to the nerve distribution. There can be some muscle weakness present. The treatment is rest or occasional surgery.

- Spinal stenosis (a narrow spinal canal) can also give pain and weakness in the legs when walking or running, sometimes so severe that the patient has to stop or sit down. These patients can often exercise without pain with flexed spine and knee, and continue cycling and stair-climbing, but have pain with other activities. Associated back pain with exercise and spinal imaging will give the diagnosis (see p. 347).

Vascular pain in the lower legs

Elderly people may have problems with their circulation. Arterial insufficiency is characterized by claudication, which is pain in the legs with any activity. These patients should go through a vascular evaluation. Venous insufficiency is seen in older age groups. These elderly athletes may have distal pretibial bone pain, tenderness and swelling, which increases as the day progresses. Vascular examination is often normal in these patients, who should be evaluated by a physician. An exertional deep vein thrombosis (blood clot) is very rare in active individuals. It is characterized by constant pain localized to the posterior compartment. The pain is not associated with exercise.

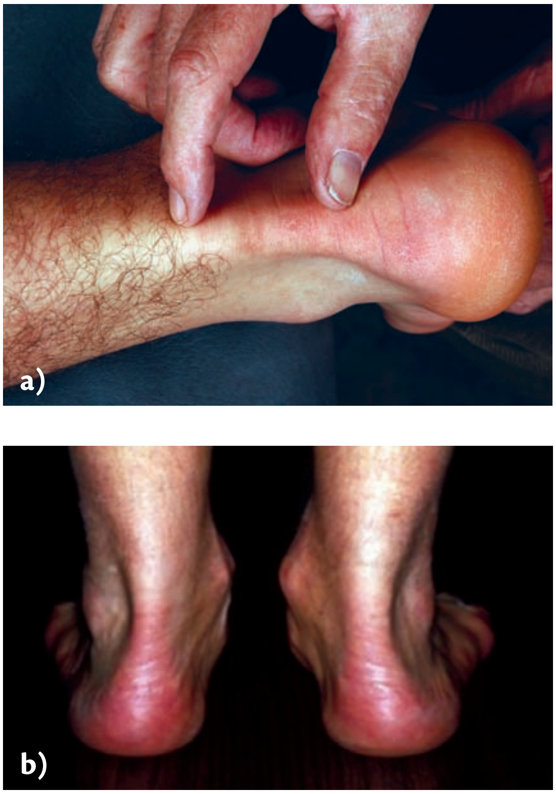


Figure 20.16 Injuries of the Achilles tendon. **a)** Achilles tendon injuries are usually located about 2–6 cm above the insertion on the heel bone (calcaneus); **b)** pronation of the foot of 10° increases the load on the medial side of the Achilles tendon by 20% compared with a normal foot/lower leg configuration. The load increase on the medial side can be explained by observing the joint axis between the talus and calcaneal bone around which most of the foot's pronation occurs; this axis is offset laterally relative to the Achilles tendon attachment.

Achilles tendon injuries

The principles of tendon injuries are discussed on p. 177. The main role of the Achilles tendon is to generate forceful plantar flexion activities as part of the soleus and gastrocnemius muscle–tendon complex. The gastrocnemius component of the tendon is longer (11–26 cm, 4.4–10.4 in.) than the soleus component (3–11 cm, 1.2–4.4 in.). The soleus component occupies the medial portion of the tendon at the level of its insertion and the gastrocnemius occupies the lateral aspect at this level. There is a spiral orientation of the most distal 2–5 cm (0.8–2 in.) of the tendon, which may contribute to injuries (Fig. 20.16). The Achilles tendon is extremely strong.

Etiology

Achilles tendon injuries may have many causes, both intrinsic (related to the body) and extrinsic.

Extrinsic factors

Probably the most common extrinsic factors are a sudden change in activity, excessive training, sudden change in training surface characteristics or sub-optimal footwear. Most Achilles tendon ruptures or injuries occur in transition from inactivity to activity. This is especially true in formerly active athletes: after a period of limited sporting activity, typically when marriage and careers take priority, many athletes resume strenuous exercise at the age of 35–45 years. A sudden change in activitiy type, e.g. from cross-country skiing or running to tennis, is also a factor. Excessive training, especially by middle-aged athletes, may cause Achilles tendon damage. Younger athletes are injured by a sudden, forceful overload such as push-off, jumps or quick starts, often in actions including deceleration–acceleration forces.

Particular movements in sports, such as the tennis serve or high-jump push-off, may cause Achilles tendon injuries. The tennis serve action includes a heavy push-off followed by lower leg rotation, which increases the load in the Achilles tendon and calf muscles. This motion may cause 'tennis leg' which is a partial tear of the muscle–tendon junction of the Achilles tendon and gastrocnemius (p. 482). A sudden change in direction that includes a sudden deceleration and then a major push-off, which forces the foot and the lower leg into major rotation, may also damage the Achilles tendon. This is the most likely cause for complete Achilles tendon tears in the middle-aged tennis player.

The sport surfaces may vary considerably. Unforgiving surfaces such as asphalt or concrete often have high friction and are fatiguing for the legs; this kind of surface will often produce an overuse syndrome in the Achilles tendon. More forgiving surfaces such as clay are less likely to result in tendon problems, as the deceleration load is decreased by gliding on the surface.

Shoes are an important support for the Achilles tendon. Modern jogging and tennis shoes have a high heel counter that supports Achilles tendon rotation, and may thereby protect the tendon from damage.

Intrinsic factors

Common intrinsic factors are malalignment, excessive pronation, gastrocnemius–soleus stiffness, muscle imbalance and age.

Functional hyperpronation can be physiologic, but can also be excessive, caused by malalignments such as tibia varus (outward angulation of the tibia) or forefoot varus. A forefoot varus (outward angulation of the forefoot) of more than 7° has been found in roughly half the runners with Achilles tendon problems. There are some indications that it may be a common cause of functional hyperpronation in the running population. Pronation is discussed on p. 476.

The biomechanical evidence for increased localized stress of the Achilles tendon with hyperpronation is lacking. Pronation of 10° increases the strain on the medial side by 20% compared with the neutral position. The increase of the load on the medial side may be explained by the fact that the subtalar joint axis around which the majority of the pronation occurs lies to the lateral side of the Achilles tendon insertion. The medial side is therefore eccentric to the axis. Thus, as the foot pronates, the fibers on the medial aspect will be expected to rotate further away, increasing the relative tension and stress (Fig. 20.16).

The tendons begin to show degenerative changes (p. 178) at the early age of 25–30 years. The changes bring about weakness in the tendons, but to some extent they can be prevented or at least delayed by regular physical activity.

Injuries to the Achilles tendon can be divided into complete Achilles tendon tears, partial Achilles tendon tears, tendinopathy, peritenonitis with or without tendinopathy, and insertionitis. Injuries may also occur around the Achilles tendon, such as Achilles bursitis.

Complete rupture of the Achilles tendon

A rupture of the Achilles tendon is one of the most common tendon injuries in sport and in society as a whole, affecting 1 in every 10000 inhabitants per year, with an incidence increasing with age. The ratio of men to women affected is 6:1 and the average age of sufferers is 35–40 years. The tear can be complete or partial. The injury mainly afflicts participants in football/soccer, team handball, volleyball, basketball, American football, rugby, tennis, squash and especially badminton, and also athletes such as runners and jumpers (Fig. 20.17).

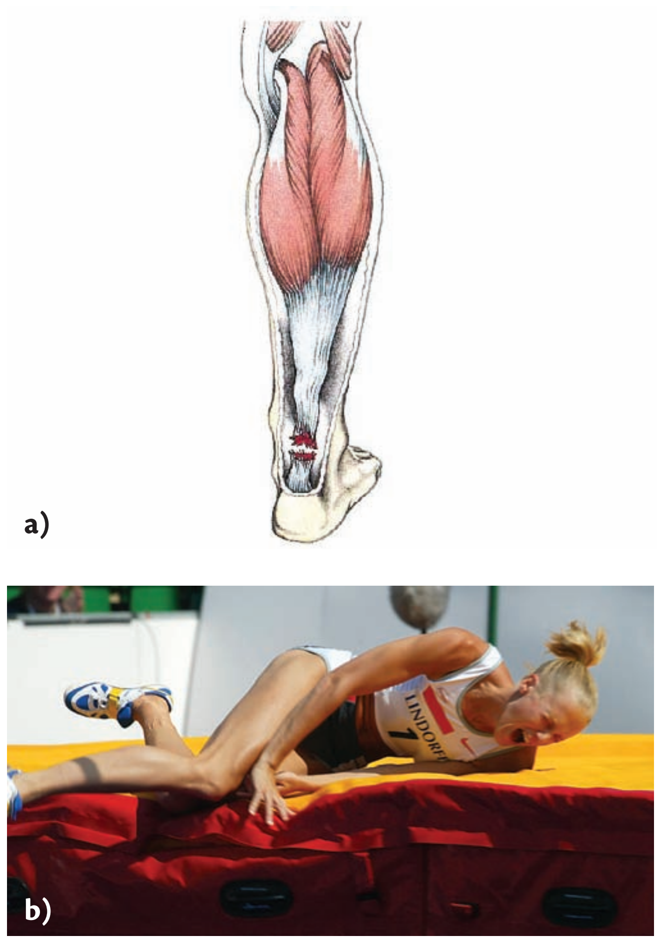


Figure 20.17 Complete rupture of the Achilles tendon. **a)** Illustration of a total rupture of the Achilles tendon; **b)** this injury can afflict top athletes such as high jumpers, due to fast transitions between acceleration and deceleration, and the jump itself. (With permission, by Bildbyrån, Sweden.)

Complete rupture of the Achilles tendon usually occurs in degenerated tendons that are subjected to increased load. Younger athletes are injured by a sudden, forceful overload such as push-off, jumps or quick starts, where deceleration and acceleration forces get in conflict.

Symptoms and diagnosis

- Intense pain is felt over the ruptured area of the Achilles tendon at the time of injury. The injured person will often state that 'something hit me from behind' at the moment the pain began. There is not much pain, however, after the acute phase, and the athlete experiences an improvement of the condition. Attention must be focused on the functional impairment.
- The injured athlete cannot walk normally on the foot or on tiptoe, and cannot 'push off' on that leg.
- Increasing swelling is caused by bleeding, which can gradually cause bruising over the lower part of the leg and the foot.
- Localized tenderness is felt over the ruptured area, which is often located about 2–8 cm (0.8–3.2 in.) above the calcaneus, while the athlete is lying prone.
- A gap can be seen or felt in the tendon (Fig. 20.18).
- The ability to bend the foot downwards (plantar flexion) is impaired.
- Thompson's test gives a positive result. For this test the injured athlete lies face down with the knee of the injured leg slightly bent. When the examiner compresses the calf muscle of the injured leg with one hand, the foot is bent downwards (plantar flexed) if the Achilles tendon is intact, but remains in its initial position if the tendon is torn (Fig. 20.18B).
- An MRI or ultrasound scan will verify the tear (Fig. 20.19), but is not needed if surgical treatment is planned. If conservative treatment is planned, it is sometimes necessary to exclude a 'mop tear' (see below), which can best be done by MRI or ultrasound. A mop tear may give poor results if treated conservatively.
- It should be pointed out that the diagnosis of a complete Achilles tendon rupture is usually straightforward, but the correct diagnosis is missed in 20% of cases by the first examining physician.

Treatment

The physician can treat the injury with a cast with the foot in physiologic plantar flexion to bring the torn ends in contact. The cast should then be worn for 8–10 weeks and gradually moved into the neutral position. There are indications that this can be done after 4 weeks, but the scientific support for this is not yet clear. Conservative treatment with a cast may be successful if the treatment starts within 48 hours of injury. One problem with conservative treatment is that there is an increased risk of a re-rupture compared with surgical treatment. This could be because the tendon tear can be of a type called 'mop tear' (Fig. 20.19C), in which the distal fragment of the tendon is folded down, making repositioning of the tendon ends impossible. Mop tears occur in 20%

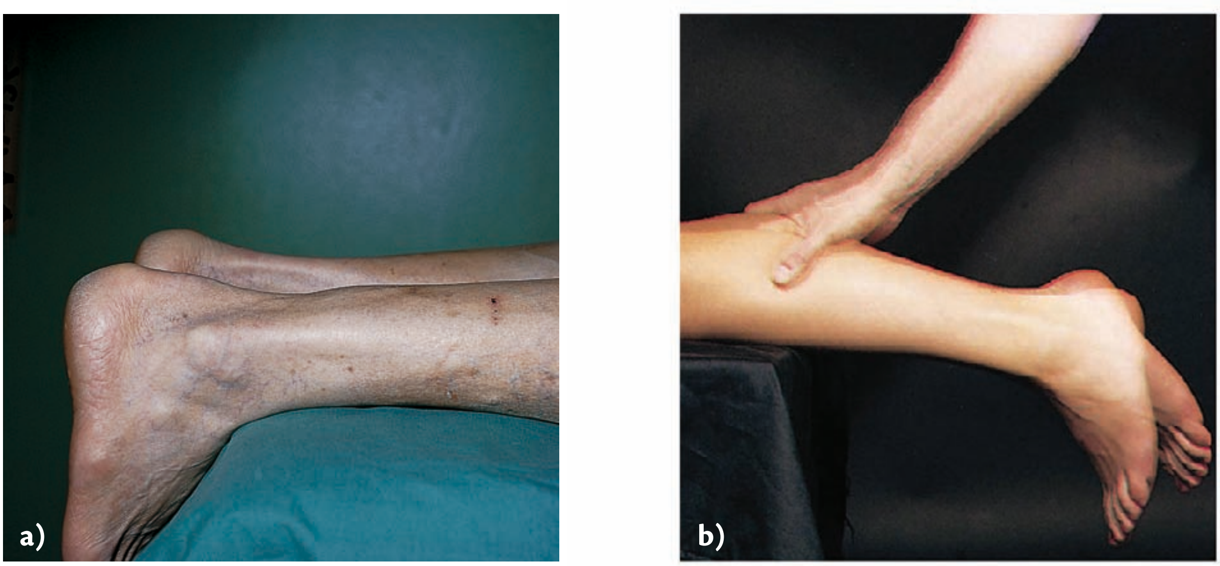


Figure 20.18 Complete rupture of the Achilles tendon. **a)** A gap in the tendon can be seen as a sign of a total rupture; **b)** Thompson test. With the patient lying in the prone position with the foot off the edge of the table, the examining physician presses the calf muscle of the injured leg together with one hand, to simulate a contraction of calf muscle; if the foot flexes (plantar flexion) toward the ceiling the Achilles tendon is intact but if it remains in the initial position the Achilles tendon is torn.

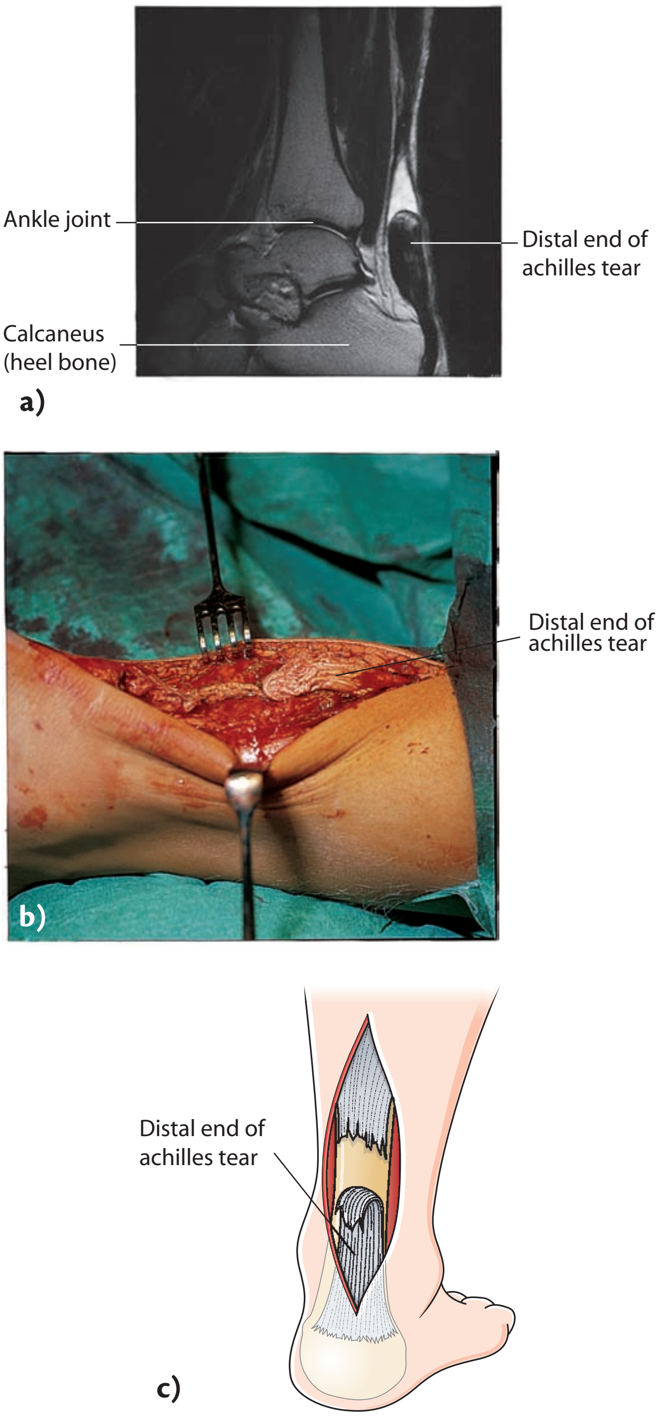


Figure 20.19 Complete rupture of the Achilles tendon. **a)** Magnetic resonance imaging of the Achilles tendon (arrow shows the rupture site); **b)** complete rupture as seen on the operating table; **c)** 'mop-end tear': the lower (distal) end of the tendon is turned inward and there is no guarantee that the ends meet and will heal naturally with conservative treatment, i.e. casting.

of cases. If the rupture gap is less than 2 mm (0.08 in.) on ultrasound scan, the patient may be treated conservatively with success.

Alternatively, the physician can operate by suturing the ends of the tendon together, whether in an open or closed operation, with or without mini-incisions. This allows for tension to be developed in the tendon, which encourages the return of proper orientation of its constituent collagen fibers, which is necessary to regain good tendon strength.

Surgery reduces the risk of re-rupture and allows an early return to sport. Furthermore, surgical treatment allows early motion, which is the key to rehabilitation and regaining strength.

Motion should start after the first week with plantar flexion of 0–20°. The patient wears a walking boot and can start weight bearing as tolerated, usually after 2 weeks. After 6 weeks the patient can start using jogging shoes, and return to sport is usually possible within 3–4 months (rehabilitation protocol on p. 490).

Healing and complications

There is an increased risk for re-rupture with conservative treatment (10–15%). The treatment should therefore be carefully monitored by a trainer or physical therapist. Return to sports such as running and jumping is usually not possible until after 9–12 months. Healing with elongation may cause decreased strength in plantar flexion.

Surgery with early functional mobilization and treatment allows an early return to sport. Return to sport at the same level as before a complete tear is 75% in top-level tennis players and 90% in recreational tennis players. These figures were much lower in a conservatively treated group. There are, however, occasionally mostly minor complications to surgery such as delayed healing of the skin wound and infection. The re-rupture rate in the operative group is less than 2%.

Partial rupture of the Achilles tendon

A partial rupture of the Achilles tendon can occur in runners, jumpers and throwers and also in participants in racquet sports, basketball, team handball, American football, rugby, volleyball and football/soccer (Fig. 20.20). This injury can lead to scar formation, which is liable to cause increased degenerative breakdown in the tendon and tendinosis/tendinopathy (p. 178). This often becomes chronic and can cause prolonged problems.

Symptoms and diagnosis

- Some young patients experience a sudden onset of pain at the time of injury, but others may not notice pain at the actual moment of rupture, the pain becoming more evident after the completion of the activity.

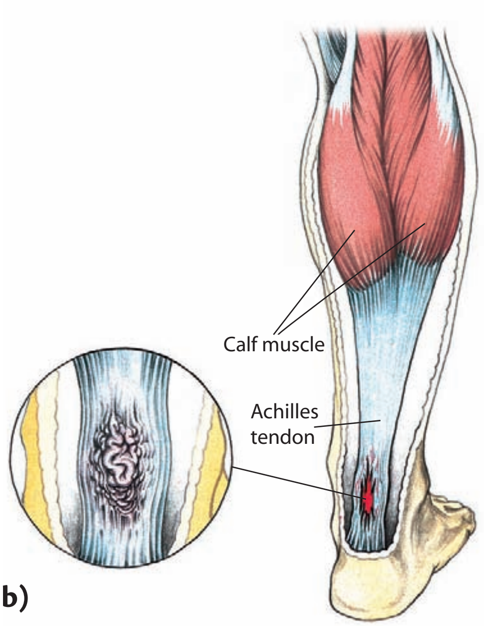


Figure 20.20 Partial rupture of the Achilles tendon. **a)** Even elite badminton player can get Achilles tendon injuries (with permission, by Bildbyrån, Sweden); **b)** enlargement of the local changes that occur in the tendon that are often found with this injury.

Figure 20.21 Partial rupture of the Achilles tendon. Often there is a slight local swelling at the site of the injury and a distinct tenderness can be felt when pressing against the area from the sides.

- When the injury is in its acute stage, a defect can be felt in the tendon (sometimes no larger than the top of the little finger) over which there is extreme tenderness (Fig. 20.21).
- When physical activity is resumed, the injured athlete feels an intense shooting, cutting or stabbing pain.
- During the following training period the symptoms may disappear for a while after warm-up, but they return with even greater intensity when the training is over. The result can be that the injured person enters a vicious circle of pain in which the condition becomes progressively more painful and progressively more difficult to treat.
- Stiffness occurs in the morning and also before and after exertion.
- When the healing process has started, local swelling is often found, over which a distinct tenderness is present when the area is pressed from the sides. The swelling is usually slight but can sometimes cause a change in the contour of the tendon.
- Swelling is usually very subtle, but it can sometimes be seen on the outer contour of the tendon.
- If the injured athlete is in severe pain, there is often tenderness when the swollen area is touched directly from behind.
- In cases of prolonged symptoms there is often a decrease in the strength and size (hypotrophy) of the calf muscle.
- An X-ray of the soft tissues is of value in showing local swelling of the ruptured area and swelling of the adjacent soft tissues.
- An MRI will provide a detailed assessment of the location of the tear, as well as the extent of the injury. Ultrasonography may support the diagnosis and permit evaluation of the size of the injury.

Treatment

The athlete should:

- Rest and treat the injury with ice in the acute phase.
- Use crutches if pain is severe.
- Use shoes with 1 cm (0.5 in.) heel wedges.
- Consult a sport medicine specialist.

The physician may:

- When the rupture is small and acute, apply a walking boot or a plaster cast for 4-6 weeks, holding the foot in slight plantar flexion; a walking boot can also be tried for 3–4 weeks in chronic cases.
- Prescribe an exercise program.

- In cases of prolonged chronic symptoms, operate to remove damaged tissue.

Pain persisting for more than 6 months in the distal part of the Achilles tendon is often resistant to conservative treatment. In such patients, surgery is often necessary, which includes excision of the scar and granulation tissue in the tendon. A careful progressive rehabilitation program with early motion within 1–2 weeks is necessary (Table 20.2) and should be carried out with supervision.

Healing and complications

After surgery the healing time is usually around 2 months. The rehabilitation period is then 3–4 months before the athlete can resume full training. The injured athlete should not count on resuming competition for at least 4–6 months. The average time is 6–8 months for serious chronic injury. Surgery gives excellent to good results in most patients, with 80% returning to former levels of activity.

Table 20.2 Rehabilitation protocol for Achilles tendon repair

Time elapsed since operation				
	0–4 weeks	**4–12 weeks**	**12 weeks–6 months**	**6–8 months**
Goal	Reduce/control pain, swelling Initiate ROM exercises	Begin to normalize ROM Increase function Initiate strength training	Normalize strength Reduce functional deficits	Prepare for return to activity
Weightbearing	Weight bearing as tolerable	Full weight bearing in ankle	Full weight bearing	Full weight bearing
status	walking boot or brace	stabilizer brace and jogging shoes		
ROM, flexibility	A/PROM PF 0–20° only Active toe flexion/ extension	Careful A/PROM DF/PF; IN/EV Avoid extreme DF At 8 weeks: • Achilles towel stretch • standing calf stretch	AROM, PROM exercises Achilles towel stretch Standing calf stretch	
Open kinetic chain strength training	None	At 6 weeks: • isometrics: all directions At 8 weeks: • rubber tubing exercises • DF/PF, IN/EV	Full lower extremity isotonic/isokinetic strengthening: all directions	Continue previous strength training
Closed kinetic chain strength training	None	At 8 weeks: • toe raises • heel raises	Straight-ahead lunges, skip Quick feet (forward, back)	Carioca, side-to-side hops, lunges Plyometric drills
Functional/ proprioceptive	Maintain fitness: stationary cycling	Double leg stance balance board Gait training Fitness activity: cycling, swimming – no flip turns or diving	Single leg stance balance board Slideboard, agility/balance Fitness activity: cycling swimming, stairclimbing Jogging on flat surface at 4 months	Single leg toe/heel raises Functional running patterns Jump rope Sport-specific drills
Restrictions or recommendations	No stretching or strength training Recommend scar mobilization as incision healing allows	No weight-bearing sports	May return to non-contact sports at 4 months	None

AROM: active range of motion; DF: dorsiflexion; EV: eversion; IN: inversion; PF: plantar flexion; PROM: passive range of motion.

The problem with the rehabilitation after this injury is that the patient often feels cured and starts to use the tendon too much after 2–4 months. The healing of a chronic tendon condition always takes a long time.

Exercise promotes healing, but too much activity, too soon return will result in pain, so it is necessary for the injured athlete to 'listen to the tendon'.

Achilles tendinopathy

These injuries are very common in sports. 10 years ago there were 2 per 100,000 individual Achilles injuries. These have since been increased to 12 per 100,000 in those 10 years.

By the age of 25 years, the Achilles tendon begins to show signs of degenerative changes (p. 178); these may be aggravated by changes in training, leading to tendinopathy (Fig. 20.22). Tendinopathy is a clinical term characterizing a condition that causes pain, swelling, stiffness and weakness in the Achilles tendon.

Symptoms and diagnosis

- Stiffness occurs in the morning and often before and/or after activity.
- A local swelling can often be palpated with distinct tenderness. This tenderness can be located on one side of the tendon (Fig. 20.23).

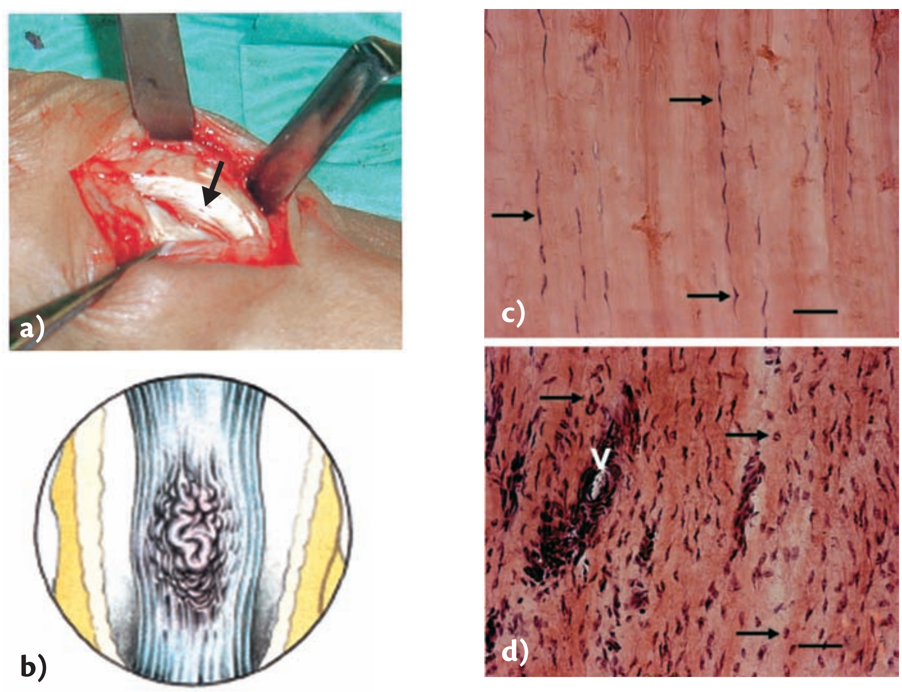


Figure 20.22 Degenerative changes in the Achilles tendon (Achilles tendinopathy). **a)** Degenerative changes seen in the Achilles tendon during an open operation with swelling; **b)** degenerative changes in the Achilles tendon, i.e. cell changes or micro-ruptures of collagen fibers, weakening of cross links with limited spontaneous healing in the tendon due to insufficient circulation in the tendon; **c)** a healthy tendon with parallel oriented collagen fibers along the length of the tendon, as seen under a microscope; **d)** partial tendon tear during healing with fibroblast invasion, abundance of small blood vessels (hyper vascularization - v), wavy structure and increased number of fibroblasts, as seen under a microscope.

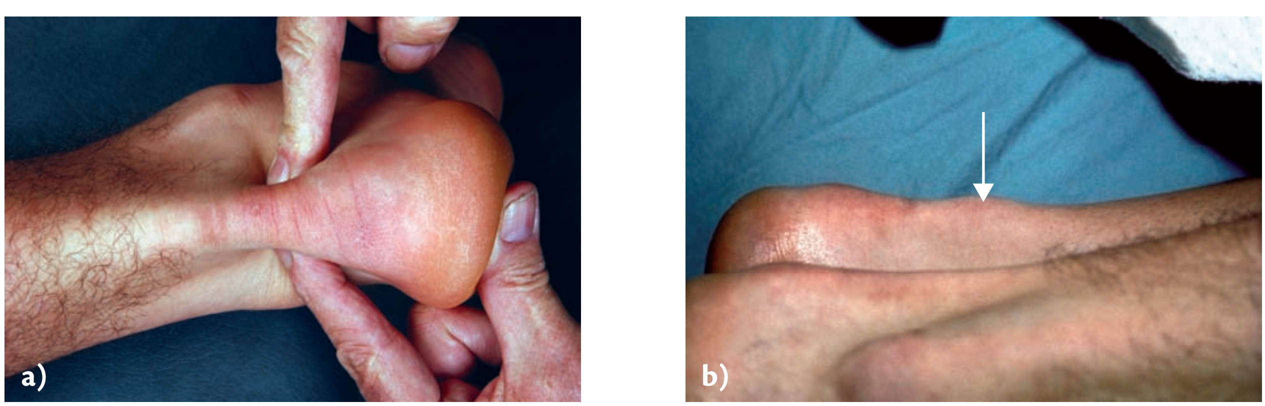


Figure 20.23 Clinical examination for tendinopathy. **a)** Tenderness when palpating especially if the examiner uses some palpation pressure; **b)** when there are degenerative changes the examiner can see or feel a swelling of the posterior contour of the tendon (arrow).

- An MRI or ultrasound scan will provide details of the tendinopathy and the extent of tendinosis (tendon damage at a cellular level) in the tendon (Fig. 20.24). An MRI scan can also provide a detailed evaluation of the tendon continuation, but it is expensive. Ultrasonography is less expensive and can therefore be used to follow the healing of the injury.

Treatment

The athlete should:

- Avoid situations causing pain and abuse of the tendon.
- Keep active with non-pounding activities such as cycling and jogging in water.
- Carry out stretching and eccentric strength exercises after instructions (Fig. 20.25).

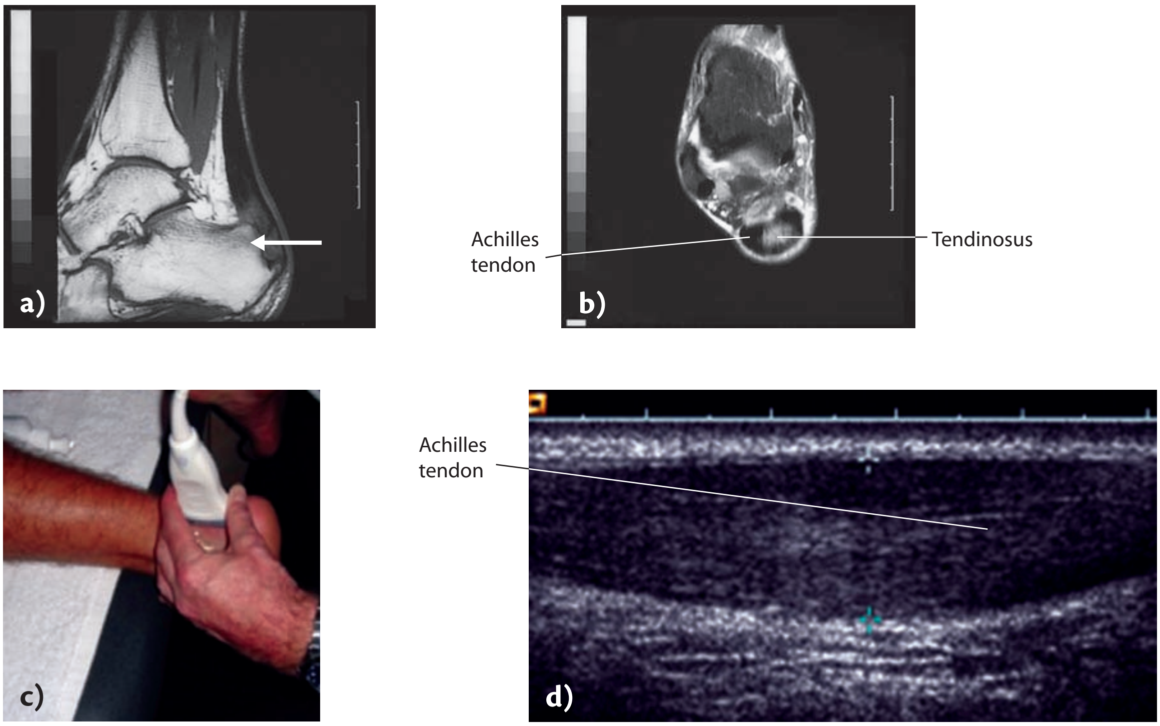


Figure 20.24 Magnetic resonance imaging (MRI) or ultrasound of Achilles tendinopathy (tendinosis). **a)** MRI show changes in the distal Achilles tendon. The arrow shows a bony enlargement on the top back of the heel bone (calcaneus) ('Haglund deformity'); **b)** MRI showing a cross-section of the Achilles tendon with clear degenerative changes shown by the arrow; **c)** ultrasound examination of the Achilles tendon; **d)** Achilles tendon during an ultrasound examination. The picture shows a normal Achilles tendon depicted by an arrow.

Figure 20.25 In the management of tendinopathy of the Achilles tendon, flexibility training is important. **a)** The left posterior located knee is stretched with the knee extended. In this position the gastrocnemius is mostly affected; **b)** the left posterior located knee is stretched with the knee flexed. In this position the soleus is mostly involved. (Photo, Linn Samuelson.)

- Follow the principles outlined on p. 200.
- Use an ankle orthosis, that limits the ability to plantar and dorsiflex.

The physician may:

- Prescribe an exercise program that includes stretching and strength training. If the tendinopathy is chronic, eccentric activities have been shown to give a good result; however, these should be carried out after instruction and initially under supervision. Close cooperation with a physical therapist or trainer is often important (Fig. 20.26).
- Instruct the injured athlete how to 'listen to the tendon' so that optimal training is achieved.

Tip

It is important to explain to the athlete that regular exercise stimulates faster healing. Tendons respond well to mechanical load, e.g. eccentric training.

- When the pain decreases increase the body load by using a barbell/weight plate/weighted back pack to strengthen the calf muscle. The exercise should be done using both a straight leg and flexed knee.
- Physical activity such as running or the like can continue during rehabilitation.

The concept of eccentric training was introduced by the Canadians Curwin and Stanish 1984. Why the good effect of eccentric training? One hypothesis is that eccentric exercises can stimulate increased production of collagen, that leads to healing of microscopic ruptures and reduction of pain.

Tip

Exercise is a cornerstone in the treatment of overuse injuries of tendons – tendinopathies. The rehabilitation should be supervised by an experienced physical therapist!

- Deep transverse friction massage performed by a specialist physical therapist can be tried, even if there is limited scientific support for any major effects (Fig. 20.27).
- Provide a sclerosing agent (Polidocan) as injections after examination by ultrasound with Doppler for the detection of newly formed small blood vessels with accompanying nerve endings. These can be repeated 2–3 times for 8 weeks. Rehabilitation includes cycling the second week, with gradually increasing load. The reason this is sometimes reported to work can be that the technique results in denervation (loss of nerve supply) of the tendon.

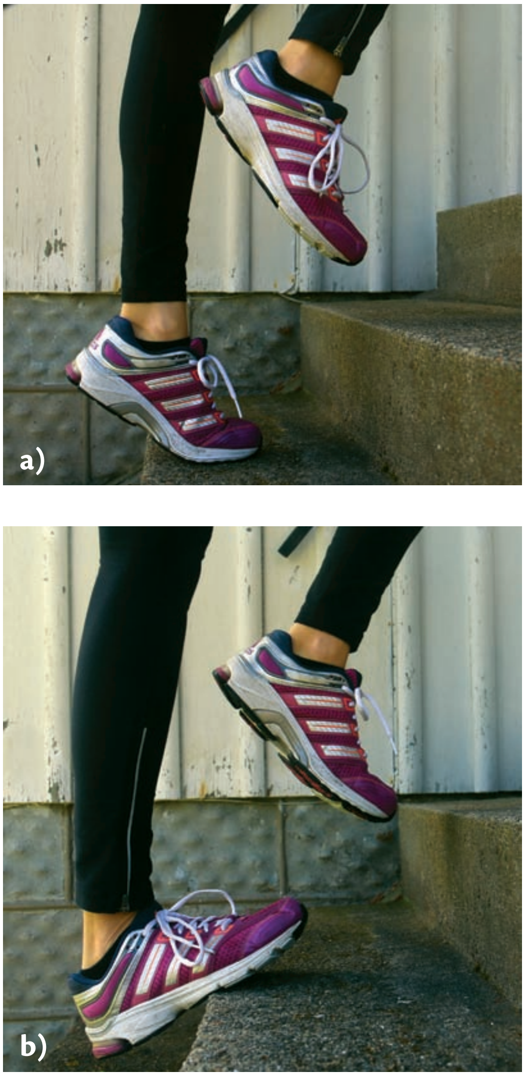


Figure 20.26 Eccentric calf muscle exercise should be included with Achilles tendon problems. Stand on a stair/step on the front part of the feet (forefeet). **a)** Lift up the body using both feet or one foot (here the left foot); this is a concentric action; **b)** slowly lower the body down by gradually resisting the dorsiflexion of the ankle of the injured leg on the step, allowing the muscle–tendon unit to stretch (lengthen) during simultaneous contraction of the muscles (here the right foot); this is eccentric action. (Photos, Linn Samuelson.)

- Recommend to be wary of cortisone treatment. Cortisone injections should not be given into the tendon! Cortisone has a good effect on inflammation, but a tendinopathy is not an inflammation, but a degeneration. Cortisone can weaken the tendon and making the tendon more prone to rupture.

Tip

A cortisone injection should not be given directly into a tendon!

Figure 20.27 a, b) Transverse friction treatment by a skilled physiotherapist.

- Shock wave-therapy. Long-term results suggest that this may be a treatment option if eccentric exercises and other treatments fail.
- Be aware that the recent research offers alternative treatments, including gene therapy, stem cell therapy, platelets, so-called platelet-rich plasma therapy (growth hormone treatment with platelets), etc. The scientific support for these treatments is still inadequate. However, there is no doubt that they will have an important role in the future management of tendon injury.
- Operate if all other treatment fails. Today, much of the surgery is performed with the aid of an arthroscope, an endoscopy. Surgery gives acceptable results in most patients, with 80% returning to former levels of activity. The postoperative treatment is early motion after the wound has healed, with some protection from an orthosis. The postoperative program should be carried out under supervision.

Healing and complications

The rehabilitation time varies from individual to individual. Often the athlete can quickly resume cycling and swimming. Running may begin after 3–6 months, depending on the seriousness of the injury. Surgery gives acceptable results in most patients, with 80% returning to former levels of activity.

Tip

Tendon overuse injuries constitute a real challenge and should be managed with great respect.

Achilles paritenonitis (tendon sheath inflammation)

There is rarely much inflammation present in the Achilles tendon. The surrounding tissues are more sensitive to an inflammatory reaction.

Acute inflammation

Acute inflammation of the Achilles tendon sheath (paritenonitis) often occurs in untrained individuals who start training too intensively, but may also occur in well trained athletes who change surface, type of shoe or technique, or who train in cold weather. Running on a very soft surface (sand) and running uphill can trigger pain.

Symptoms and diagnosis

- Pain is felt on using the Achilles tendon.
- Diffuse swelling occurs around the tendon.
- There is intense, diffuse tenderness and impaired function.
- In cases of severe inflammation, skin redness appears over the tendon.
- When the fingers are pressed on the tendon during ankle joint movement, a crepitus (creaking sensation) can be felt.

Prevention

Warm-up and stretching exercises are important. Well-designed training and competition shoes of good quality should be used. A heel wedge of 1 cm (0.5 in.) will relieve tension in the Achilles tendon.

Treatment

The athlete should:

- Rest; in the acute phase, crutches may be helpful.
- Cool the injury with ice to reduce pain and swelling.

- Use a 1 cm (0.5 in.) heel wedge.
- Apply local heat after the acute phase and use a heat retainer.
- Consult a physician if the complaint does not abate after a few days.

The physician may:

- Prescribe anti-inflammatory medication.
- Apply a plaster cast in severe cases.
- Prescribe a training program after the acute phase, which should include strength training and static stretching (p. 200). Eccentric exercises that put high load on the tendon should become part of the program when healing allows.

Healing

When treatment of acute inflammation of the Achilles tendon and its sheath has been started early, the prognosis is good and the injury heals in 1–2 weeks. The risk of recurrence is small if the athlete does not return to sporting activity too early. Acute inflammation of the Achilles peritenon (tissue sheath surrounding a tendon) can develop into a chronic condition, which is very difficult to treat. It is therefore of the utmost importance that athletes should rest when there are signs of Achilles peritenonitis.

Chronic inflammation

Chronic inflammation of the Achilles tendon sheath occurs in athletes (often elderly) who have been training intensively on a hard surface for a long time and who have ignored warning pains. These pains at first tend to disappear after the warm-up exercises before a training period so that the affected athlete can continue training. The symptoms return after training is over and gradually become more and more severe. Sooner or later continued running is impossible, and the athlete is trapped in the pain cycle.

Symptoms and diagnosis

- Pain, aching, and stiffness in the Achilles tendon occur before, during, and after exertion.
- There is diffuse swelling in the tendon.
- The tendon is diffusely tender on palpation.
- The athlete may suffer pain in the tendon when walking, especially uphill and upstairs.
- Athletes with this condition have in 50% of cases some kind of malalignment, such as increased pronation or forefoot varus.
- In cases of persistent Achilles tendon problems a combination injury with tendinopathy should be suspected and investigated by a physician.

Treatment

The athlete should:

- Avoid situations causing pain.
- Apply local heat and use a heat retainer.
- Use shoes with 1 cm (0.5 in.) heel wedge.

The physician may:

- Analyze the injured athlete's training, considering especially the design of the shoes and the type of training surface.
- Prescribe an exercise program with strength training and stretching (p. 200). The strength training should include eccentric exercises (p. 200).
- Prescribe anti-inflammatory medication for a short time.
- Prescribe ointments to stimulate blood flow and control the inflammation.
- Apply a walking boot or a plaster cast for 3–6 weeks if there is severe pain or malfunction.
- Operate in prolonged cases, releasing the tendon from the surrounding sheath scar tissue, which is then removed. Be aware that this injury can be combined with tendinopathy.
- Inflammation of the Achilles tendon sheath should be treated at an early stage.

Achilles bursitis

Bursitis over the calcaneus (heel bone) can occur in a superficial bursa located between the skin and the posterior surface of the Achilles tendon, which is vulnerable to pressure from shoes and often becomes inflamed. There is also a deeply located bursa (the retro-calcaneal bursa) between the Achilles tendon and the calcaneus, which can become inflamed if it is irritated either by external pressure or by a partial tendon rupture (Fig. 20.28). If prolonged pressure against the tendon attachment is the cause of the inflammation of the bursa, for example by repeated dorsiflexion, a bony prominence often appears on the posterior aspect of the calcaneus; this further increases the risk of the bursa being subjected to pressure or impingement between the bone and the tendon.

Symptoms and diagnosis

- Redness and thickening of the skin may occur over the calcaneus on the lateral side of the Achilles tendon attachment if the superficial bursa is involved.
- Pain can be experienced when running uphill or on soft surfaces.
- There are often symptoms such as tenderness and swelling, which make it difficult for the athlete to wear ordinary shoes.

- When the deep bursa is pressed from both sides anterior to the Achilles tendon, a spongy resistance and pain can be felt as well as discomfort.
- An MRI or ultrasound scan will confirm the diagnosis, but is seldom indicated.

Treatment

The athlete should:

- Relieve the calcaneus of pressure immediately symptoms begin, by wearing shoes without backs such as sandals or clogs.
- Relieve the area when the superficial bursa is inflamed with a foam rubber ring which is placed around the bony prominence if one has formed.
- Adjust the shoes, for example by raising the heel and softening the counter, in order to avoid pressure against the area.
- Apply local heat.

The physician may:

- Prescribe anti-inflammatory medication.
- Give ultrasound treatment.
- Give a local steroid injection and prescribe rest.
- Operate when the inflammation in the bursa has become chronic and a bony prominence (Fig. 20.29) has appeared. During the operation the bursa and the prominence are removed.
- Return to running is possible in 3–6 months depending on the type of surgery.

Sever's disease (apophysitis calcanei, insertionitis)

Sever's disease is an inflammation of the growth plate in the heel of growing individuals. Injury to the Achilles tendon apophysis insertion to the calcaneus may occur in both elderly and young athletes.

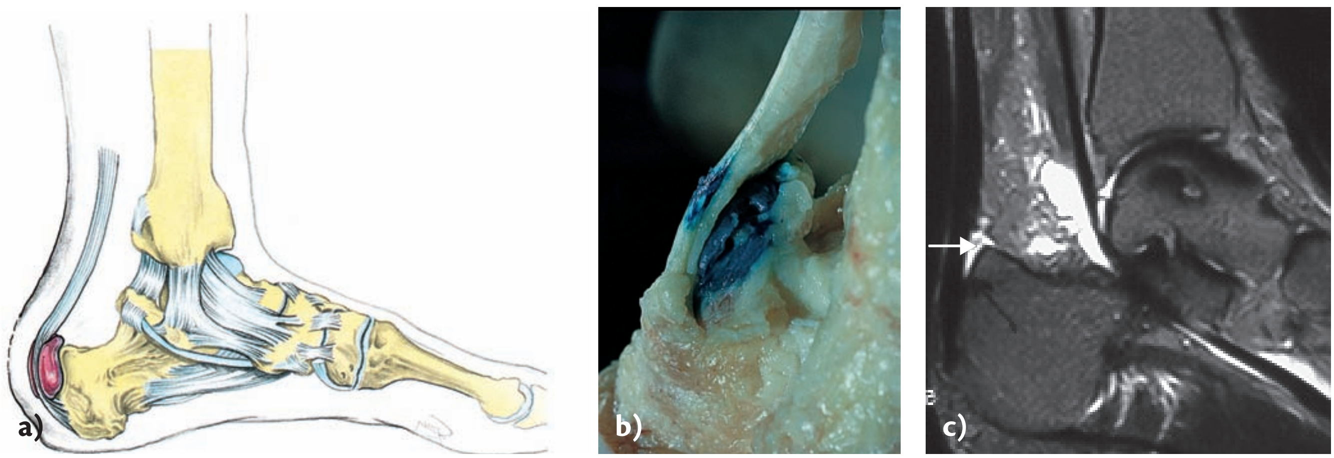


Figure 20.28 Calcaneal bursitis. **a)** Drawing of bursitis next to the calcaneus; **b)** bursa colored blue in a cadaver (courtesy of Dr. Christer Allenmark, Varberg Hospital, Sweden); **c)** magnetic resonance imaging of a bursitis behind the Achilles tendon (see arrow).

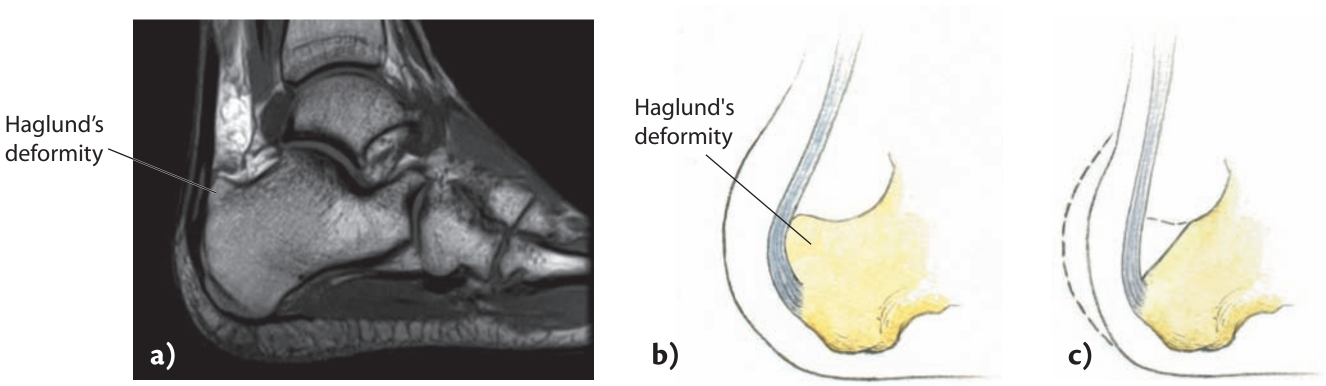


Figure 20.29 Haglund deformity. **a)** X-ray of the calcaneus. On top of the posterior corner of the calcaneus there is a bony growth (osteophyte); **b)** an osteophyte on the upper rear part of the heel bone (calcaneus), so-called 'Haglund deformity'; **c)** at surgery it is possible to remove the osteophyte and the bursa to reduce the pressure on the Achilles tendon. This can today be done through an endoscope (arthroscope).

Sever's disease in the elderly

The elderly often have degenerative changes in the tendon, which can form calcifications and cause tendinosis at the insertion site; these athletes have pain during running, and in chronic cases also after running. The distal tendon area is very stiff in the morning, and the athletes have difficulty starting activities. Treatment is conservative, but surgery may be needed if problems last for more than 9–12 months. The distal tendon may be the site of a partial tear of the tendon and associated with bursitis.

Sever's disease in the young growing individuals

In active individuals aged 8–15 years the Achilles tendon attachment (apophysis) to the calcaneus can become the site of fragmentation (Fig. 20.30), a condition, which is probably caused by overloading and can be seen on X-ray examination (compare Osgood–Schlatter's disease, p. 458).

Symptoms and diagnosis

- Pain in the calcaneus is usually aggravated by physical activity when running, jumping and walking. The complaint often remains after exertion, when stiffness sets in and causes a limp.
- Some swelling and tenderness occur over the Achilles tendon attachment to the calcaneus.
- An X-ray may support the diagnosis.

Treatment

The athlete should:

- Rest from painful activities until the pain has gone (the symptoms, however, often return).
- Use shoes with 1 cm (0.5 in.) heel wedge, which can alleviate the symptoms by relieving the Achilles tendon from tension.

The physician may:

- Occasionally apply a walking boot or a plaster cast for about 1–3 weeks, which can give permanent pain relief.
- Prescribe an orthotic device to unload the Achilles tendon and plantar fascia (in growing individuals).

Healing

The condition resolves spontaneously in the younger athlete on reaching the age of 16–18 years when ossification of the skeleton is complete. In the older athlete conservative treatment may be successful, but may take a long time. In chronic cases, if there is a distal partial rupture and bursitis, operative treatment may help.

Plantaris longus injury

The plantaris longus muscle has a long, thin tendon that inserts on the medial aspect of the calcaneus close to the Achilles tendon. It can be injured with partial and total ruptures on explosive activities with pronation involved. Only partial ruptures give remaining symptoms.

Symptoms and diagnosis

- Pain is felt on the medial aspect of the Achilles tendon when running and jumping.
- Local tenderness occurs medial to the Achilles tendon insertion. Sometimes there is swelling, and pain on plantar flexion.
- Ultrasonography or MRI may confirm the diagnosis.

Treatment

The athlete should:

- Rest until the pain and tenderness is gone.
- Use a heel wedge, and unload the tender area.

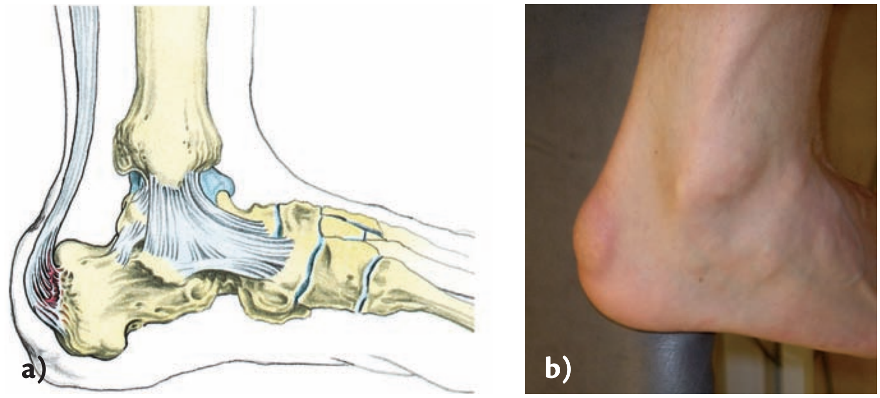


Figure 20.30 Sever's disease (calcaneal apophysitis). **a)** Achilles tendon attachment of the heel bone (calcaneus) can suffer from loosening and fragmentation; **b)** the result can be a bony growth (osteophyte – exostosis) on the back of the heel bone.

The physician may:

- Prescribe anti-inflammatory medication.
- Excise the damaged tendon in chronic cases.
- Allow use of a walking boot and early motion after surgery.
- Allow gradual return to sports activities 1–3 months after surgery.

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21

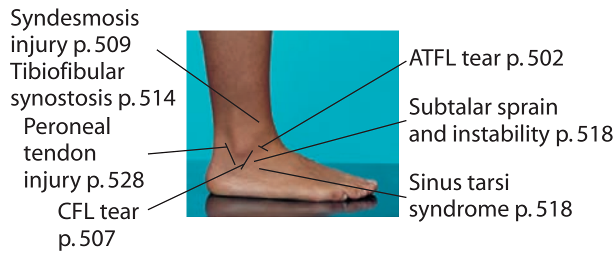
Ankle Injuries in Sport

It has been shown in several studies that injuries to the lateral ligaments of the ankle are the most common sports-related injuries that occur, constituting approximately 25% of all sports-related injuries. Other studies have estimated, that about 5,000 ankle injuries per day occur in the UK and 23,000 in the United States.

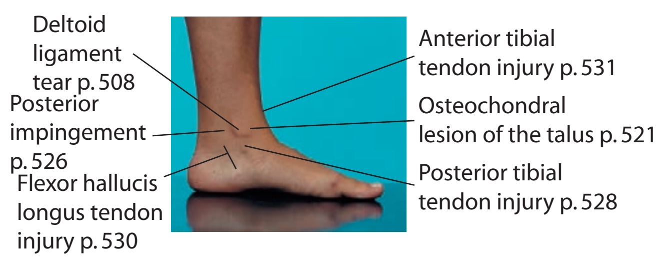
The ankle is the most injured body part in 24 of 70 investigated sports especially in volleyball and athletics.[1] A sprain, i.e. injury to the ankle ligaments, was the major ankle injury in 33 of 43 sports, especially in team handball, Australian football, field hockey, orienteering and squash. It was also common in sports such as rugby, football/soccer, volleyball and basketball.

The ankle joint is a remarkable example of the functional interplay between bones, joints, and ligamentous structures and muscle–tendons, with their protective action upon one another. The ankle joint is maintained by the wedge-shaped talus and its sculptured fit between the tibia and fibula. In the neutral position of the ankle, there are strong osseous (bony) constraints. With increasing plantar flexion, the osseous constraints decrease and the soft tissues and ligaments maintain the joint stability. It is in this position that the ligamentous tissues are most susceptible to injury. Added to this is the active stability exerted by the muscle–tendon during contraction.

Ankle injuries and ankle complaints can in practical terms be classified into ankle instability with acute and chronic ligament injuries, and ankle pain, with fractures, cartilage injuries, osteoarthritis, impingement, etc., although these may occur simultaneously (Figs 21.1–21.3).



21.1



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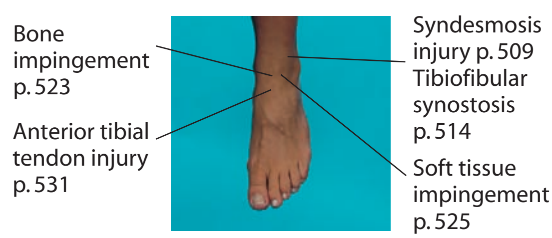


21.3

Figures 21.1–21.3 Injury location. ATFL: anterior talofibular ligament, CFL: calcaneofibular ligament.

Figure 21.4 Ligament injuries of the ankle are very common in sport. They are mostly managed early on the field, i.e. at the injury site as speedy management is considered important. **a)** Possible trauma for ankle injury; **b** and **c)** early cooling is often beneficial; **d)** taping often has good effect. (**a–c)** With permission by Bildbyrån, Sweden and by Bill Norris, ATC, Boca Raton, Florida, USA.)

Overview of ankle injuries

Ankle injuries are mostly related to ankle instability and/or pain. In order to understand this interplay Table 21.1 has been constructed.

Table 21.1 Different types of ankle instability and pain

Ankle instability	Ankle pain
Mechanical instability	Fracture
Functional instability	Cartilage (chondral) damage
Syndesmosis injury	Bone–cartilage injury
Subtalar instability	Impingement
Sinus tarsi syndrome	• Fibrous • Bone/osteophytes Tendinopathy – tendon rupture

Ankle instability

Acute ligament injury in the ankle

Ligament injuries of the ankle are among the most common sports injuries. They occur in most ball sports, jumping sports, and so on (Fig. 21.4). There is approximately one sprain per 10,000 persons each day. In a recent American study from a military academy, the incidence was 58 per 1000 persons/year. Women had a significant increase in injury severity compared with men. In this study men with a ligament injury in the ankle had higher average height, weight and body mass index (BMI) compared with non-injured men.[2]

Functional anatomy

The soft tissue structure of the ankle is maintained by three groups of ligaments functioning as static stabilizers: the lateral ligaments, the deltoid ligaments and the ligaments above the ankle joint (syndesmosis complex).

The lateral ligament complex of the ankle is composed of three ligaments: the anterior talofibular ligament (ATFL), the calcaneofibular ligament (CFL) and the posterior talofibular ligament (PTFL). The origin and insertion of these ligaments and their orientation at various ankle joint positions are important in determining their potential for injury (Fig. 21.5). The ATFL originates from the anterior inferior aspect of the lateral malleolus and courses anteriorly to insert laterally on the neck of the talus.

In the neutral position of the ankle this ligament is nearly parallel with the long axis of the foot. As the ankle moves into full plantar flexion, it becomes parallel with the long axis of the tibia to function as a primary ligament resisting ankle inversion. This ligament is the most often injured in inversion ankle sprains.

The CFL originates from the inferior aspect of the lateral malleolus and is directed slightly posteriorly and distally to insert on the lateral aspect of the calcaneus. It contributes to the subtalar stability. In the neutral position of the ankle the CFL is nearly parallel with the long axis of the tibia providing lateral stability to the ankle. As the ankle moves in plantar flexion, the CFL approaches a perpendicular position with the fibula and, therefore, has less mechanical advantage for providing ankle stability.

The PTFL originates from the posterior medial aspect of the lateral malleolus and runs posteromedially

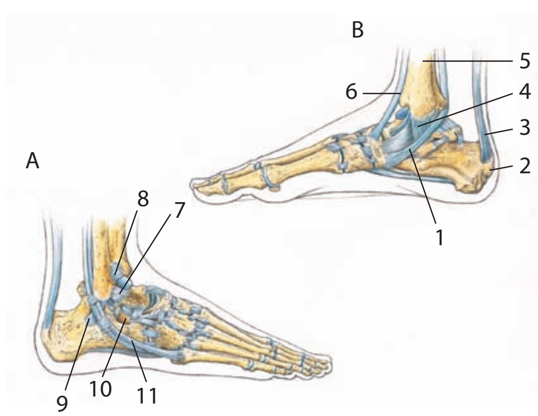


Figure 21.5 The ankle anatomy with joints, ligaments and tendons. **a)** The ligament complex on the lateral side includes three ligaments and the tendons; **b)** the ligaments in the medial ligament complex include collateral ligaments and posterior tibial tendon. 1. Posterior tibial tendon; 2. calcaneus; 3. Achilles tendon; 4. deltoid ligaments; 5. tibia; 6. anterior tibial tendon; 7. ATFL; 8. syndesmosis; 9. CFL; 10. sinus tarsi; 11. peroneal tendons.

to the posterior process of the talus. This ligament assists in preventing posterior displacement of the talus in relationship to the fibula. It is the least commonly injured ligament in a lateral ankle sprain.

The deltoid ligament is a broad, fan-shaped ligament on the medial aspect of the ankle expanding both the ankle and subtalar joints. It has a superficial and a central deep component, which stabilizes the talocrural joint; the superficial central part stabilizes the subtalar joint and the deep part stabilizes the tibiotalar joint. Functionally, both resist eversion of the talus in relationship to the tibia and to the calcaneus. The anterior superficial parts (the anterior tibiotalar and tibionavicular ligaments) resist anterior displacement of the talus and the posterior superficial part (tibiotalar) resists posterior displacement of the talus.

The ankle syndesmosis comprises the anterior-inferior tibiofibular ligament, interosseous membrane, and posterior-inferior tibiofibular ligaments and inferior transverse tibiofibular ligament. This ligament complex stabilizes the ankle mortise and may be injured in a lateral ankle sprain with the ankle in the dorsiflexed position. The ligament is commonly injured by an external rotation of the ankle when the foot is planted, i.e. an inward rotation of the body (see p. 510).

Ankle ligament biomechanics

The ATFL, the CFL and the PTFL function as a unit, and although one ligament may resist a specific motion, the primary stabilizing ligament is dependent upon foot position. Both the ATFL and CFL play a significant role in stabilizing the ankle, but in different positions.

The ATFL and CFL act synergistically, when the foot is unloaded. With and without physiologic loading of the ankle the articular surface becomes an important stabilizer, accounting for 30% of stability in rotation and 100% of stability in inversion. Without loading, the primary and secondary ligamentous constraints vary with testing modes and ankle position. Ligament loads remain low within the functional range of motion (10° of dorsiflexion to 20° of plantar flexion). This supports the concept that ankle ligaments act as kinematic guides rather than primary restraints during normal activity. With external loading, however, the ATFL functions as a primary stabilizer against inversion and internal rotation for all angles of plantar flexion. The CFL and PTFL function as primary stabilizers against inversion and external rotation for all angles of dorsiflexion. The ATFL is the weakest ligament, having the lowest yield force and ultimate load. The CFL is the second weakest ligament, and the PTFL is the strongest lateral-collateral ligament.

Mechanism of injury

A lateral ankle sprain frequently occurs when a plantar-flexed ankle is inverted, completely rupturing one or more of the lateral ligaments. An isolated ATFL tear is present in about two-thirds of the cases. The second most common injury is a combined rupture of the ATFL and CFL, which occurs in about 20–25% of the cases. The PTFL is rarely injured except in severe ankle trauma.

A medial ankle sprain may occur when the foot is turning inside-out (eversion – movement of the sole of the foot away) and externally rotated. Isolated ruptures of the medial deltoid ligament are rare, and usually occur in combination with fractures of the lateral malleolus and rupture of the syndesmosis, often associated with a fibular fracture in the midsection (shaft) of the bone (diaphysis).

The syndesmosis can also rupture and is called a high ankle sprain, which most commonly is a partial rupture. It is usually completely ruptured often in combination with fractures and deltoid ligament tears. A complete rupture occurs in isolation in only 3%.

The risk for future arthrosis (arthritis) development and ankle instability is great if a syndesmosis rupture is not recognized and treated correctly. It is, therefore, extremely important, that the physician is aware of the risk of this injury, and that it is diagnosed adequately through careful history taking, location of tenderness, stability assessment and radiology.

Tip

Be aware of the risk of syndesmosis injuries when there are long-term problems, which may become chronic.

Classification and grading

The classification of ankle sprains is based on the mechanism of injury. Excessive inversion motion of the tibiotalar joint in varying degrees of plantar or dorsiflexion results in an inversion or lateral ankle sprain. Excessive eversion motion of the ankle joint results in an injury to the medial aspect of the ankle and the deltoid ligament, and an eversion (movement of the sole of the foot away from the median plane) ankle sprain. An ankle sprain is further stratified into grade I, II or III based on the severity of the injury:

- Grade I: ligament stretch without microscopic tearing, minimal swelling or tenderness, minimal functional loss, no mechanical joint instability.
- Grade II: partial microscopic ligament tear with moderate pain, swelling and tenderness over the involved structures. There is some loss of joint motion and mild to moderate joint instability.
- Grade III: complete ligament rupture with marked swelling, hematoma and tenderness. There is a loss of function and severe joint instability. These patients have difficulties with full weight bearing.

Every sprain in which the range of movement of the ankle joint has been exceeded causes damage to the stabilizing tissues with bleeding, swelling, and tenderness, and should be considered as a ligament injury. In cases of sprains and dislocations it is mainly the lateral and medial ligaments of the ankle joint that tear. Sometimes a small portion of bone is torn away at the point of ligament attachment, while the ligament itself remains intact. This type of avulsion injury is found in young, growing athletes with strong ligaments, and also in elderly individuals with brittle bones.

Ligament injuries in the ankle joint should never be neglected, as correct treatment often ensures complete recovery. A return to sporting activity should be deferred until there is no pain, and normal mobility and strength have been restored to the ankle joint. The injured athlete therefore should allow 2–12 weeks' break from training, depending on the degree of severity of the injury. When starting to strengthen the ankle joint by training, the joint should be supported by tape or bandage (see p. 57). Gradually, proprioceptive training should be started.

When instability is present in the ankle joint after treatment has finished or after repeated trauma to the joint, surgery may be necessary.

Tear of the ATFL

The ligament in the ankle joint most frequently injured – the ATFL – runs between the fibula and the talus. Its main function is to prevent the foot from slipping forwards in relation to the tibia. In about 65–70% of ligament injuries of the ankle, this ligament alone is injured. In about 20% of cases there is a combination injury, with tears of the ATFL and the CFL. The mechanism of injury is usually a supination (turning the sole of the foot inwards) (Figs 21.6, 21.7).

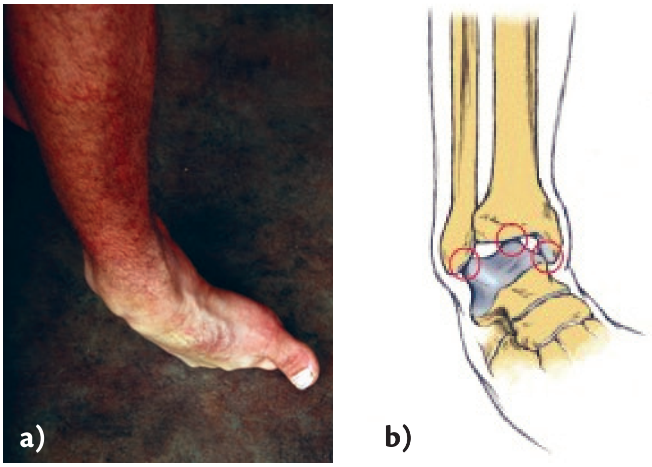


Figure 21.6 The ankle may be injured by a supination/inversion trauma. **a)** An ankle distorsion can be sustained, when the foot is plantar flexed and the forefoot is internally rotated and then one or several of the lateral ankle ligaments can tear; **b)** typical areas for damage during these traumas.

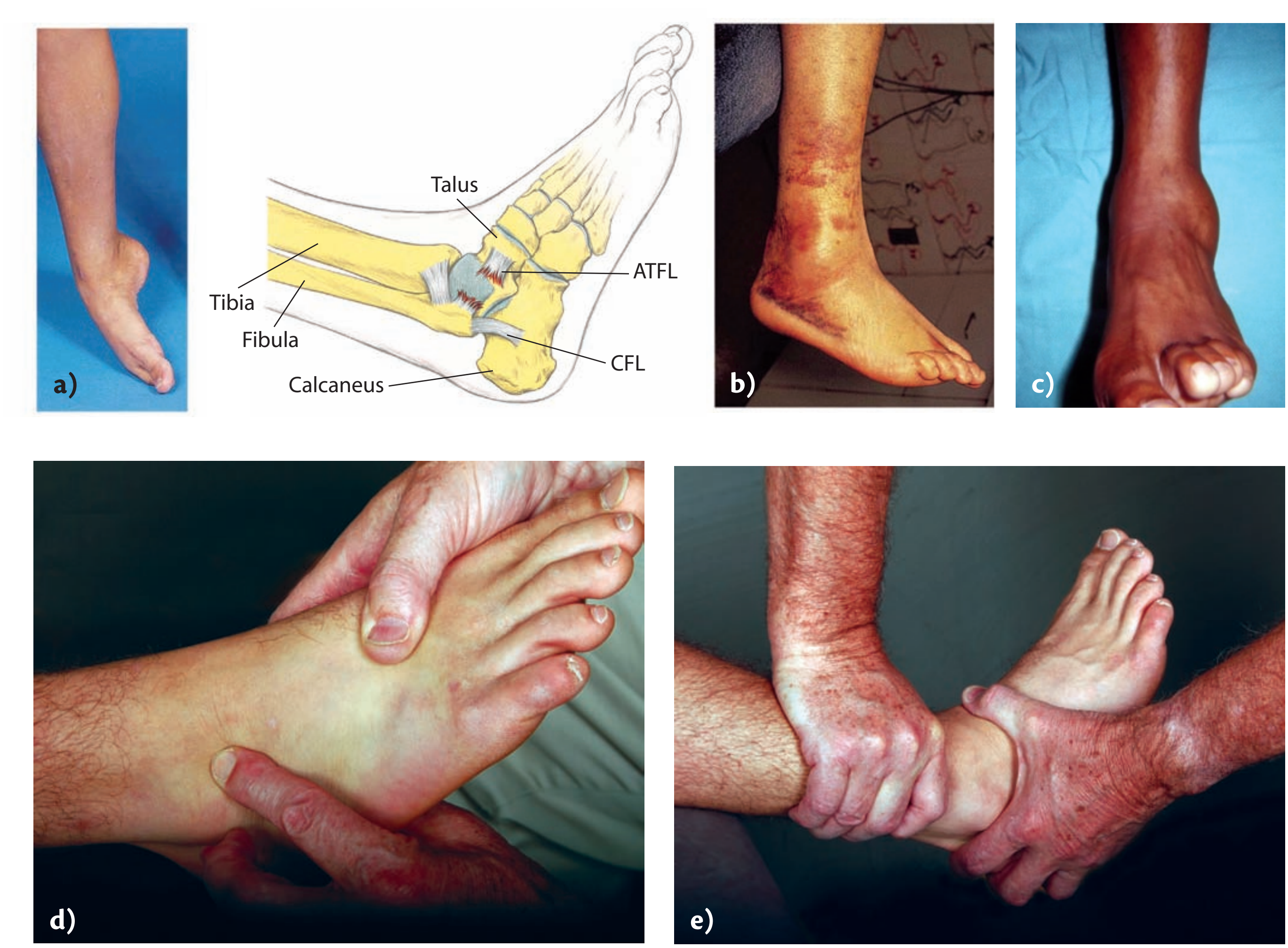


Figure 21.7 A tear of the ligaments between the fibula and the talus (anterior talofibular ligament – ATFL). **a)** At a supination trauma an isolated injury of the ATFL may occur. **b)** a hematoma with swelling may occur 2 days after the trauma; **c)** there may be swelling around the lateral malleolus (bony bump on the outer side of the ankle); **d)** tenderness may be felt during palpation of the ligament; **e)** stability test with anterior drawer test.

Symptoms and diagnosis

- Pain is felt on weight bearing and ankle motion.
- Swelling and tenderness occur anterior to the lateral malleolus.
- Effusion of blood later results in a hematoma, with bruising and skin discoloration around and distal to the injury.
- Instability in cases of a total ligament tear can be tested by pulling the foot forwards in relation to the tibia (anterior drawer test) (Fig. 21.7E). This test evaluates the integrity of the ATFL. The maximum amount of anterior displacement is produced when the ankle is in 10° of plantar flexion; normal displacement is less than 3–4 mm (0.12–0.16 in.). A comparison with the other side should be made.
- The inversion stress test (formerly talar tilt test, p. 508 Fig. 21.13) evaluates the integrity of the CFL. With the ankle in neutral and the distal tibia stabilized, an eversion stress is placed on the heel and the tilt deformity of the hindfoot relative to the distal tibia is assessed. The normal range is 0–30°. Comparison with the contralateral uninjured ankle is recommended.
- An evaluation of an acute ankle sprain is optimally carried out 4–7 days after injury. It is then possible to detect the most tender areas by palpation, indicating where the ligament injuries are. Stability tests will also be more reliable. Hematoma formation and spreading can be evaluated.

Tip

The optimal time to perform a clinical examination of an acute ankle injury is 4–7 days after the injury, as the swelling and pain have become static.

- X-ray examinations are performed in most ankle distortions to exclude fractures. However, many unnecessary X-ray examinations may be performed. Therefore, the 'Ottawa rules' for ankle X-ray examination were established, which most experts follow today (Fig. 21.8).

Ottowa rules

An X-ray examination is only required, when there is pain around the ankles, the bony prominences on the sides (malleoli) or one of the following locations:

- Bony tenderness along the distal 6 cm of the posterior portion of the tibia or the tip of the medial malleolus or
- Bony tenderness along the distal 6 cm of the posterior portion of the fibula or the tip of the lateral malleolus or
- Inability to put weight on the foot immediately or take four steps in the examination in the emergency department.

These Ottawa rules have a sensitivity of almost 100%, i.e. they are sensitive and have a moderate specificity. They have a very low rate of false-negative findings. Their usefulness in growing individuals has not yet been fully evaluated.

Tip

If the Ottawa rules are used properly, they can reduce the need for unnecessary radiographs by 30–40%.

- Stress X-rays during provocative testing of the anterior drawer and inversion stress test (former talar tilt) may aid in assessing ligament disruption.
- Magnetic resonance imaging (MRI) gives a good evaluation of the ankle ligaments (Fig. 21.9), but is rarely needed in the acute setting.
- Ultrasonography by an experienced radiologist gives equivalent good results.
- Arthrography and bone scan are rarely justified.

Treatment

The treatment depends on the grade of the injury, but also on the functional capacity and whether there are recurrent 'giving way' problems.

The athlete should:

- In cases of suspected ligament injury, rest from all potentially damaging physical activity.
- Treat the injury acutely with ice and compression (Fig. 21.10).

The physician may:

- Initiate early functional treatment with range of motion (ROM) and strength training, with the joint protected by supporting bandages. Several randomized studies have shown that functional treatment:[1,3]
- Allows fastest retrieval of full mobility.
- Allows fastest return to sport and physical activity.
- Has no appreciable effect on the mechanical stability of the joint.

Tip

Early functional treatment should be used in the treatment of acute ligament injuries of the ankle.

Figure 21.8 X-ray examination of the ankle using the Ottawa rules. **a)** X-ray picture of the ankle; Ottawa rules state an X-ray should be taken if there is: **b)** tenderness over the medial or lateral sides of the ankles (malleolus); **c)** tenderness over the medial posterior edge of the tibia; **d)** tenderness over the distal lateral posterior edge of the tibia and fibula.

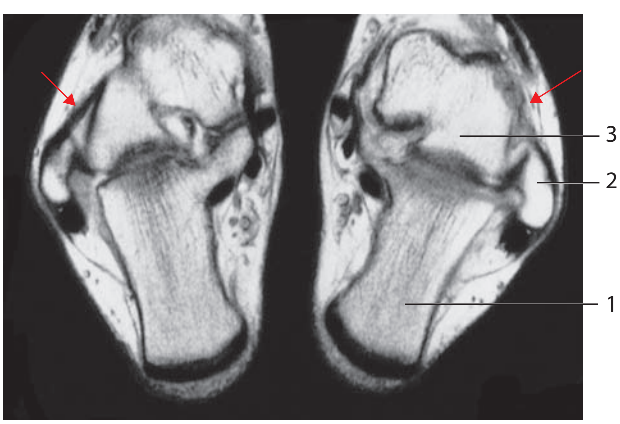


Figure 21.9 Magnetic resonance imaging is seldom needed in the acute phase, but will give a good evaluation of both the anatomy and the extent of the injury. On the picture to the left the arrow indicates a normal ATFL ligament, and on the picture to the right the arrow indicates a torn ATFL ligament. 1: Calcaneus (heel bone); 2: fibula; 3: talus.

- Scientific evidence demonstrates that functional treatment will result in better outcome than immobilization and indicates that ankle brace treatment resulted in socioeconomic savings.[3,4]

Tip

The use of braces after acute ankle sprains should be considered.

- Rehabilitation should include ROM exercises, strength training and functional activities according to the program on pp. 533–4, p. 535 Table 21.2 after a clinical examination and stability testing.
- Early weight bearing is usually accompanied by early return to sports.

Figure 21.10 Adequate acute treatment of an ankle injury is important. **a)** Icing or cooling is combined with a compression bandage, a commonly used first treatment of an ankle injury; **b)** new cooling systems are constantly developed (courtesy of Jan Häggström, Hässelby, Sweden); **c)** many athletes use the cooling spray in the acute phase in spite of the fact that it has a very limited effect; **d)** use of tape may be effective to stabilize the ankle (with permission, by Bildbyrån, Sweden).

Tip

If the injured person cannot weight bear on the foot and ankle, a more serious injury should be suspected.

X-ray the joint in a grade III sprain or if an ankle gives persistent pain, in order to determine whether there is a fracture or an avulsion injury.

An X-ray is especially indicated if there is distinct tenderness over the tips of the malleoli and the posterior aspect of the fibula (see the Ottawa rules p. 504).

Start proprioceptive training with a tilt-board. These exercises can usually begin within 2 weeks for grade I and grade II injuries, to improve balance and neuromuscular control, and should be continued for at least 10 weeks for maximum effect.

- Neuromuscular training on a tilt-board is a very efficient training for ankle injuries. The risk of recurrent injury is markedly reduced (Fig. 21.11).
- Despite the fact that acute surgery, in general, gives slightly better results in the long term, surgery is rarely necessary for acute ligament injuries of the ankle as:
  - ✓ static instability is less important compared with the dynamic stability, strength and proprioception;
  - ✓ early movement is important;
  - ✓ a late surgical reconstruction with modern technology gives good results.

Figure 21.11 Balance (proprioceptive, neuromuscular) training. **a)** Balance training on a tilt-board. The good effects are evidence-based and good results are shown within 10 weeks of training; **b)** neuromuscular training on a soft surface with simultaneous movement of the load (photo by Heijne/Frohm).

Tip

The reasons mentioned above are why acute ankle instability today is usually treated with early functional treatment, without surgery.

- If instability persists a surgical anatomical reconstruction, a so-called modified 'Broström' reconstruction, is performed (see Fig. 21.25). After surgery the ankle is immobilized in a walking boot or a cast for 6 weeks, but motion outside the boot is allowed. Return to sport is possible within 10–12 weeks. If a large avulsion injury is present, surgery may be indicated.

Healing and complications

The healing of a ligament injury in the ankle joint can take 1 week for a grade I injury, 2–3 weeks for a grade II injury and 8 weeks or longer for a grade III injury, depending on the severity of the impact and the extent of the injury. However, problems can remain for 8–10 months after the incident. When the injured athlete has no pain on moving the ankle joint and has good mobility athletic training, often with an ankle support, can start (pp. 533–4).

Proprioceptive training is extremely important, otherwise the ligament is liable to be injured again. Strengthening of the anterior tibial and peroneus longus and brevis muscles should also be carried out. During the training period, which can extend over 6–8 weeks, the ankle should be protected from further overstretching with the help of an ankle brace, adhesive strapping, an elastic bandage or tape. An untreated ligament injury can result in stretching of the ligament that can lead to permanent instability with recurrent sprains.

If a ligament injury still causes problems with recurrent instability after 6 months, the ligament can be surgically reconstructed (see p. 517).

Tear of the CFL

On supination and dorsiflexion of the foot an isolated injury can occur to the CFL (Fig. 21.12). This is rare, however, and it is more likely to be injured in combination with the ATFL. This ligament originates on the medial aspect of the fibula, passing under the peroneus tendons and attaches to the lateral tubercle on the calcaneus. This ligament is stretched during dorsiflexion. It passes over the subtalar joint and contributes to the stability of this joint.

Tip

The CFL is almost always injured in combination with an injury of the ATFL.

Symptoms and diagnosis

- Swelling and tenderness occur over the injured ligament, distal to the lateral malleolus.
- Pain is felt during weight bearing and when moving the ankle joint.
- Effusion of blood causes hematoma and bruising behind and below the lateral malleolus.

The inversion stress test (former talar tilt test) shows increased supination compared with the undamaged ankle joint (Fig. 21.13).

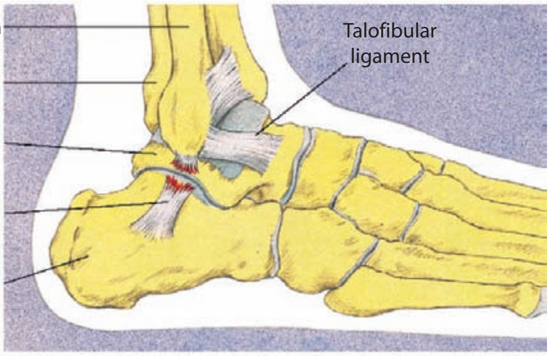
- A stress X-ray with inversion stress test provocation is occasionally used to confirm the diagnosis.

Treatment

The treatment is the same as for an ATFL tear, but in addition the athlete should consult a physician if there is persistent pain or recurrent instability.

The physician may recommend supporting the ankle joint with an ankle brace, adhesive strapping, an elastic bandage or a plaster cast for about 2–3 weeks if the injury is serious. Surgery may be needed in a combination injury with the ATFL.

a)



b)

c)

Figure 21.12 Rupture of the calcanofibular ligament (CFL). **a)** Supination, i.e. internal rotation of the foot can cause injury to the CFL; **b)**drawing showing the tear of the ligament; **c)** localized palpation can give tenderness over the area below the lateral malleolus.

a)

b)

Figure 21.13 Techniques for supination provocation (inversion stress test) of the ankle joint, when there is a suspicion of injury of the CFL. **a)** Test seen from anterior/front; **b)** test seen from posterior/back.

Tear of the deltoid ligament (medial collateral ligament of the ankle)

This ligament consists of a deep anterior portion (tibiotalar fibers), a deep anterior portion (tibiofibular fibers), superficial anterior portion (tibionavicular) fibers), deep central portion (tibiotalar fibers), superficial central portion (tibiocalcaneal fibers), and a superficial posterior portion (tibiotalar fibers) (Figs. 21.14, 21.5).

In about 10% of all cases of ligament injuries in the ankle joint, the deltoid ligament is damaged. Usually the tear is partial and injury occurs during pronation (eversion), when the sole of the foot is turned outward. Tears of the deltoid ligament are most often located in the anterior aspect of the deltoid ligament (Fig. 21.14, 21.15).

Symptoms and diagnosis

- Pain is felt on weight bearing and on moving the ankle joint.
- Swelling and tenderness occur over the course of the ligament, usually in the anterior part of the medial malleolus.
- When the tear is complete, there is increased pronation/eversion in comparison with the range of movement of the undamaged joint.

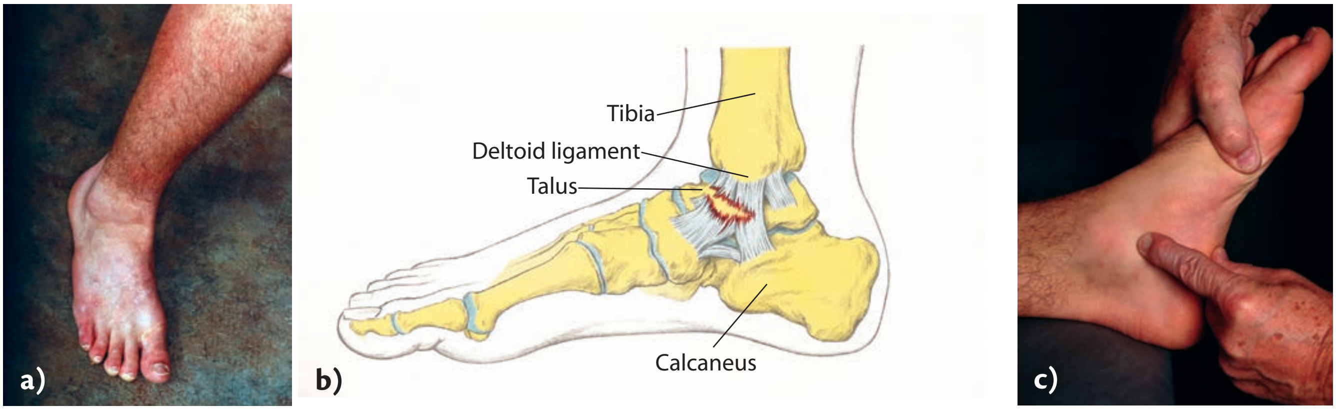


Figure 21.14 Tear of the medial ligament of the ankle (deltoid ligament). **a)** Injury can occur when the sole of the foot is turned outwards, i.e. pronation of the ankle and external rotation of the foot; **b)** drawing of a partial injury of the deltoid ligament; **c)** palpation of the injured area will elicit tenderness.

Figure 21.15 A tackle from the outside (lateral side) of the ankle can cause serious ligament injuries as well as fractures. These injuries should not occur if the existing rules are followed! (With permission, by Bildbyrån, Sweden.)

- An external rotation stress test evaluates the syndesmosis, but also the deep deltoid ligament as a pronation/eversion stress test.

Treatment

The athlete may:

- Apply compression, elevation and cold treatment (see Chapter 7).
- Start early functional treatment.
- Consult a physician.

The physician may:

- In cases of partial tear and maintained stability support the ankle joint with a brace, adhesive strapping or an elastic bandage for 3–4 weeks.
- When it is difficult to decide if instability is present, examine the joint with the patient under anesthesia.

This ligament can take time to heal and when it finally heals it heals with a lengthening, which is characteristic of a chronic deltoid injury. When the joint is unstable, surgery may be needed, followed by immobilization in a walking boot or a plaster cast for 4–6 weeks.

A potential major problem is the shift that can occur laterally of the talus, i.e. a talar shift, which may be the result of a not completely healed or malaligned fracture of the lateral malleolus or an injury to the syndemosis and deltoid ligaments. This can result in a broadening of the ankle joint space, i.e. the ankle mortise, and a chronic ankle instability with osteoarthritis and severe discomfort as the final result.

Injury to the syndesmosis (high ankle sprain)

Syndesmosis injuries are not common in sport, although a marked increase has occurred in recent years due to increased awareness of these puzzling and often severe injuries. The incidence has been reported to range from 1% to 11% of all ankle injuries. Absence from the sport due to a syndesmosis injury is between 2 and 7 weeks, although the literature indicates that it would be between 0 and 137 days with an average in the range of 10–14 days up to 52 days. A recently published study of very active American cadets found an incidence rate of syndesmosis injuries of 4.8 per 1000 persons/year. There was no gender difference in terms of the incidence of syndesmosis injuries.[2]

The syndesmosis comprises the anterior and posterior tibiofibular ligaments and the interosseous membrane (Fig. 21.16). Diastasis (widening) of the syndesmosis occurs with partial or complete rupture of the syndesmosis ligament complex, including the tibiofibular ligaments and the interosseous membrane.

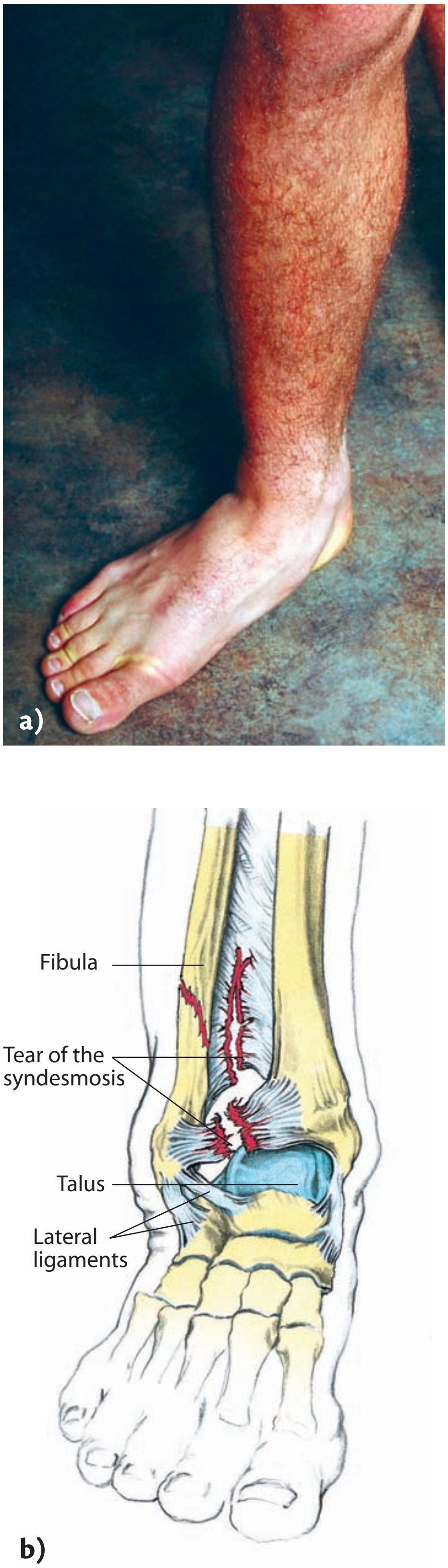


Figure 21.16 Injury to the syndesmosis, i.e. the tibiofibular ligaments and the interosseous membrane. **a)** The injury is sustained during pronation of the foot with concurrent external rotation of the forefoot; **b)** anatomic picture of a rupture of the syndesmosis.

Tip

Broström showed already in the 1960s, that around 10% of all ligament injuries in the ankle are partial ruptures in the anterior part of the syndesmosis.

Mechanism of injury

The importance of an accurate history to ascertain the mechanism of injury and a careful clinical examination of the patient with acute ankle trauma cannot be stressed enough. External rotation is usually involved in the mechanism of this injury. A common injury mechanism is a combination of external rotation and dorsal flexion of an axially loaded ankle.

The most common injury mechanism in ice hockey is an external rotation of the ankle, which can happen in several ways, e.g. the player slides into the boards with the feet first and the big toe side gets caught. The ice hockey player can receive a tackle against the lateral aspect of the knee joint with the skate stuck in the ice and externally rotated, etc. A violent external rotation with the ankle in plantar flexion can sometimes cause a partial rupture in the lower part of the anterior tibiofibular ligament. American football players as well as basketball, football/soccer and ice hockey players are more commonly afflicted. These injuries also occur in skiing, motocross, ice skating and other ball sports (Fig. 21.17).

In American football and downhill skiing the external rotation of the ankle also plays a central role. In American football, where these injuries are most common, an external force against the lateral aspect of the thigh or lower leg with the athlete's foot planted is the cause.

Isolated complete rupture of the syndesmosis without concomitant fracture is rare. The reported incidence of isolated syndesmosis injuries in acute ankle sprains ranges between 1% and 16%. When ankle disability lasts for more than 2 months after an ankle sprain, the incidence increases to 23.6%.[5]

A rupture of the syndesmosis often occurs in combination with a rupture of the deltoid ligament or with a fracture of the medial malleolus. The ruptures are usually partial and include most of the time the anterior portion. In more severe instability the central deep and superficial portions of the deltoid are ruptured. Often there is a concomitant fracture of the middle or upper part of the fibula.

Symptoms and diagnosis

- Athletes with this injury often complain of pain on the anterior and lateral aspect of the lower leg above the ankle. The pain becomes worse when the ankle is rotated.

- Tenderness and swelling occur at the anterior aspect of the syndesmosis between the tibia and the fibula. Less sharp pain is felt at the posterior region of the syndesmosis (Fig. 21.18).

Figure 21.17 a–c) High sprains, i.e. syndesmotic injuries are not unusual in sports with lots of contact such as tackles. (With permission, by Bildbyrån, Sweden.)

Tip

If there is tenderness directly over the syndesmosis and possibly up across the membrane between the tibia and fibula, there are good reasons to suspect a syndesmosis injury.

- Tenderness over the medial malleolus and deltoid ligament is an important sign of a more serious injury to those structures and may also indicate a fracture of the middle or upper part of the fibula.
- Swelling over the syndesmosis. The large egg-shaped swelling that is present in a common lateral ankle sprain is not common in a syndesmosis injury.

Tip

The swelling is often quite limited at a syndesmosis injury. This may lead to an underestimation of the injury.

- The athlete is unable to bear weight on the injured leg.
- Active external rotation of the foot is painful.

Clinical tests for a syndesmosis injury

- The external rotation test for suspected partial rupture of the syndesmosis is performed in standing with full load. The injured person's body is rotated internally with the foot fixated. The injured person can then feel the pain over the syndesmosis. The injured person recognizes the instability problems especially after the acute stage (Fig. 21.19A).
- The external rotation test for suspected complete rupture of the syndesmosis is carried out with the leg hanging and the knee in 90° of flexion; the foot is externally rotated while the tibia is fixed with the other hand (Fig. 21.19B). Pain around the syndesmosis during this test is a strong indication of syndesmosis injury. This test needs to be evaluated more.
- The squeeze test is considered positive if a compression of the tibia and the fibula above the syndesmosis, often in combination with an external rotation of the lower leg, produces pain in the membranes between the two bones or its supporting structures (Fig. 21.19C).
- The Cotton test is carried out with one hand holding the calcaneus and talus while the foot is tested for motion in a medial-lateral direction with the tibia fixed (Fig. 21.19C). It assesses the medial-lateral motion of the talus in the ankle. A feeling of side-to-side play when the foot is in neutral position is considered an indication of possible diastasis.

Figure 21.18 Injury to the syndesmosis. **a)** A hematoma is often localized at or behind the lateral malleolus; **b, c)** palpation over the injured area can elicit tenderness.

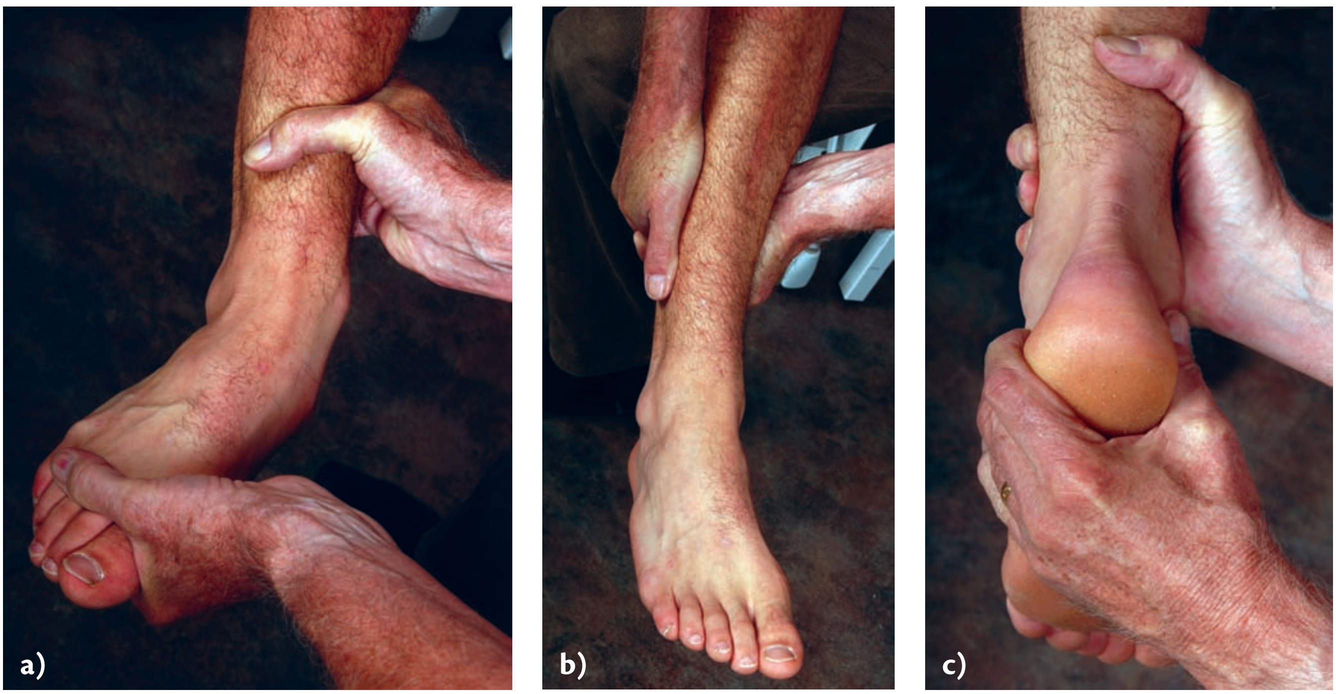


Figure 21.19 Functional tests for evaluating injury to the syndesmosis. **a)** External rotation test; one hand is holding tibia in place and the other rotates the foot externally; **b)** compression test (squeeze test); the tibia and fibula are squeezed together above the injury; **c)** Cotton test: the heel bone (calcaneus) is grabbed with the opposite hand and the heel is moved from side-to-side.

- The ankle stability and above all the deltoid ligament should be examined with the pronation test and otherwise examined by asking the injured person to perform a number of functional tests, such as standing on tiptoe, walking and jumping.
- Radiographs with an antero-posterior lateral and mortise view are needed to exclude fractures and avulsions. Stress radiographs in external rotation in both dorsiflexion and plantar flexion can display the diastasis between the tibia and the fibula. A widening of the ankle mortise is a sign of syndesmosis tear (Fig. 21.20). A widening between the medial malleolus and the medial talus joint surfaces suggests simultaneous deltoid rupture.
- It should be noted that X-ray examination without provocation is not completely reliable since it can be difficult to correctly position the ankle for an examination.
- Syndesmosis injuries with a widening of the ankle mortise, i.e. between the tibia and fibula as a sign of a syndesmosis rupture, are easy to diagnose and thereby initiate adequate treatment.

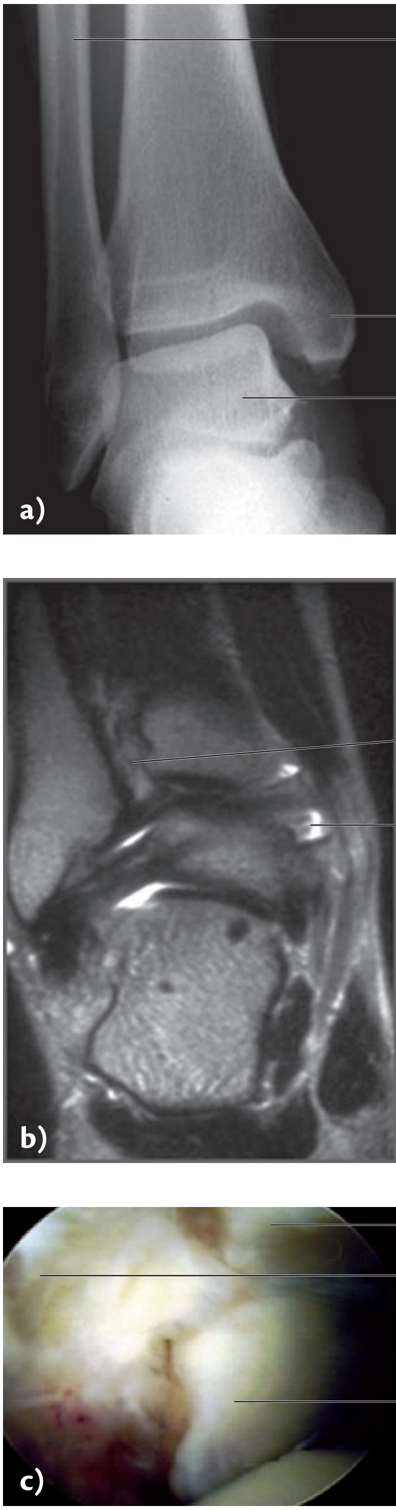


Figure 21.20 Examinations for a syndesmosis injury. **a)** X-ray of the ankle will show a widening of the gap between the talus and the medial malleolus; this is a sign of a rupture of the syndesmosis and should raise suspicion that there may be a tear also of the deltoid ligament on the medial side; **b)** magnetic resonance imaging of a syndesmosis rupture; **c)** arthroscopy of an ankle shows indications of syndesmotic injuries. (Courtesy of Ned Amendola, University of Iowa, USA.)

- However, normal findings can be viewed between ligaments and bones on X-ray, which makes it much more difficult to evaluate the severity. A renewed X-ray with provocation should be performed.

Tip

This type of injury represents both a diagnostic and treatment dilemma for the physician.

- MRI is sometimes needed to estimate the extent of the injury and is today more and more included as an early choice of diagnostic examinations. Several studies show a greater accuracy, sensitivity and specificity with an MRI examination if these findings have been confirmed by an ankle joint arthroscopy.
- Arthroscopy of the ankle may give indications that the syndesmosis is damaged (Fig. 21.20C).
- A computed tomography (CT) scan is more accurate than customary plain radiography but is less accurate when it comes to minor injuries. CT has another important function, which is to detect other injuries associated with syndesmosis injuries, e.g. avulsion fractures. They can occur on either the anterior or posterior aspect of the tibia and occur in up to 50% of syndesmosis injuries.

Treatment

The athlete should:

- Apply compression, elevation and cold treatment (see Chapter 7).
- Consult a physician as soon as possible.

Tip

Return to full ankle movement and weight bearing are major challenges after this injury.

The physician may:

- In cases of partial isolated syndesmosis tears, treat the injury conservatively with an ankle brace and early functional treatment.
- Tape to limit the forces that have caused the damage. Sometimes extra tape loops can be put over the lower tibiofibular joint to limit its mobility. It can be quite difficult to treat a syndesmosis injury with tape and supportive orthotics (Fig. 21.21B).
- In cases with complete tears of the syndesmosis, decide on surgery. If the syndesmosis is completely ruptured, the fibula can shorten and rotate externally

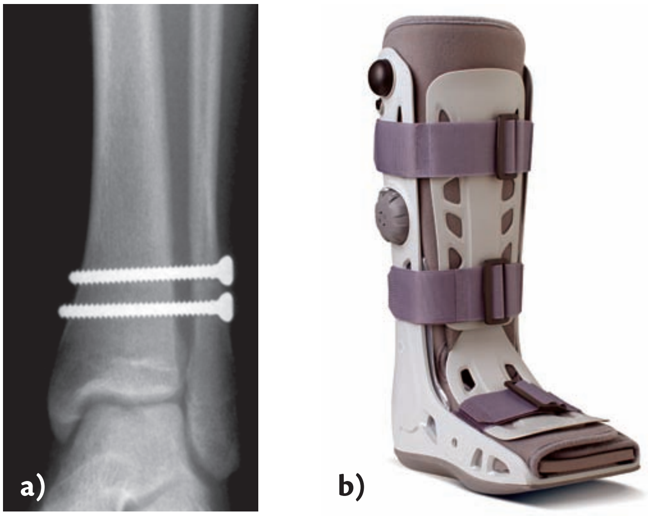


Figure 21.21 Injury to the syndesmosis, i.e. the tibiofibular ligaments and the interosseous membrane (high ankle sprain). When there is a complete tear the ligament ends can be sutured together and a temporary fixation of the tibia and the fibula can be made with screws. **a)** Fixation with screws seen from anterior on X-ray; **b)** a lower leg orthosis/walking boot to be used after surgery for this injury (with permission, from DJO, LLC. All rights reserved).

leading to ankle joint incongruency and post-traumatic osteoarthritis. A complete tear is managed by suturing the ligament and temporary fixation of the tibia and fibula with a screw, staple, or cerclage (steel wire) (Fig. 21.21A).

- If a deltoid injury is present it also should be sutured. An ankle brace/orthosis or a cast is used and worn for 6–8 weeks. Early movement is encouraged. Screw fixations are commonly removed 8–12 weeks after treatment.
- Late complications include instability, incongruency of the ankle joint, late arthrosis/arthritis and ossification of the interosseous membrane.

Tip

- Management of a syndesmosis injury is still controversial in most sports, as there is no consensus on how to optimally fix the syndesmosis.
- The injury mechanism causes great stresses and strains on many of the structures that are central to the biomechanics of the ankle's various joints, with the result that normal, pain-free function is difficult to achieve.
- Return to sports can be slow and often leads to frustration for everyone involved – it is therefore important to provide early diagnosis and treatment of this injury.

Tibiofibular synostosis

Tibiofibular synostosis (ossification of the syndesmosis) can occur after an ankle sprain associated with a syndesmosis rupture involving the interosseous membrane. The rupture produces periosteal damage and a hematoma, which later ossifies, leading to partial or complete ossification of the syndesmosis. This injury may be an underlying cause of tibial pain with activity or ankle pain of uncertain origin.

The typical patient is an athlete with a 3–12-month-old history of an acute or recurrent ankle sprain in whom a syndesmosis rupture was not considered. The patient experiences pain during the stance phase and the initiation of the push-off phase of running and side cutting (rapid change of direction). The pain occurs because the synostosis impairs the normal tibiofibular motion by preventing the fibula to move distally on weight bearing, and by restricting the normal increase in width of the ankle mortise that occurs on dorsiflexion of the talus. Clinical examination usually reveals restricted dorsiflexion of the ankle. Radiographs show development of the synostosis.

- Conservative treatment is recommended initially aimed at restoring normal fibular motion. If the athlete has continuous pain, surgical excision of the synostosis is indicated.

Inadequate rehabilitation syndrome

Many athletes return to sports before they are fully rehabilitated and may often incur a re-injury or an additional injury. Examination demonstrates loss of ROM, such as limited dorsiflexion or a plantar flexion contracture. Hypotrophy of the lower leg muscles is common. Ankle motion may be painful and stiffness is common, although the X-rays are normal.

To prevent this problem, adequate acute treatment of ankle ligament injuries is important. Functional treatment should be the method of choice for complete rupture of the lateral ankle ligaments. Initial treatment should include a short period of ankle protection by brace, bandage or tape, and early mobilization and weight bearing. Rehabilitation exercises are the most important step in the treatment process, with the goal of re-establishing ankle ROM, muscle strength and neuromuscular control. Emphasis should be placed on strength training of the peroneal muscles, the anterior and posterior muscles and the intrinsic muscles of the foot. Proprioceptive training on an ankle tilt-board should be combined with increasing agility and sports skills training. If functional treatment of an acute injury fails, surgery may be necessary.

- Immobilization with a lower-leg cast for 2–3 weeks is still common treatment; however, immobilization will result in weakening of all tissues, as well as hypotrophy of the muscles and limitation of motion, although may give a better stability in the end.

Inadequate rehabilitation syndrome can be prevented by scrupulously continuing rehabilitation until the patient has achieved full ROM, strength and the ability to walk and run. Full rehabilitation often requires careful supervision and monitoring by an experienced physical therapist. Compliance by the patient is essential for success.

If the syndrome does occur, treatment is reinstitution of the rehabilitation program. This treatment is usually successful.

Chronic instability of the ankle

Chronic ligament injury in the ankle

Large studies have shown that 20% of those who have had repeated ankle sprains developed chronic instability. It is common with recurrent ankle sprains of mild, temporary character: 50–75% of patients have recurrent sprains, and 25% report frequent sprains.

Certain sports create particular risks. Football/soccer players with previous injuries are 2–3 times more likely to sustain another ankle injury than those without any history of injury. Recurrent multiple sprains are reported by 80% of high-school basketball players with a previous sprain. Chronic ankle instability can be characterized as mechanical or functional (Fig. 21.22).

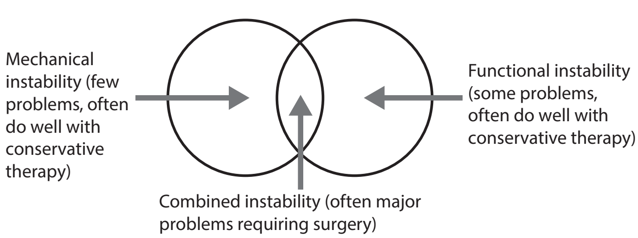


Figure 21.22 Chronic instability of the ankle is characterized as either mechanical or functional. In some cases there is both mechanical and functional instability.

Mechanical instability

Mechanical instability is characterized by ankle mobility beyond the physiologic ROM, which is identified on the basis of a positive anterior drawer and/or inversion stress test (talar tilt test). However, the criteria for mechanical instability are variable. Most agree that mechanical instability is present when there is more than 10 mm (0.4 in.) of anterior translation on one side or the side-to-side difference is over 3 mm (0.12 in.), and/or if inversion is more than 9° on one side or the side-to-side difference is over 3° at provocation with the talar tilt. These measurements can be carried out objectively with a technique using a telos stress device during X-ray, which allows the user to determine exactly the amount of stress applied to the joint, i.e. standardized and quantitative stress examinations of the ankle including the talar tilt provocation test.

Today the talar tilt provocation test is only in limited use for scientific studies not the least because it requires an experienced and interested radiologist. Furthermore, pure mechanical instability of the ankle is rarely the reason for the development of late symptoms.

Tip

Moderate mechanical ankle instability has limited clinical significance, but in pronounced instability in combination with functional instability it may need to be fixed!

Functional instability

Functional instability is signaled by a subjective feeling of the ankle 'giving way' during physical activity or during simple everyday routines after a sprain. Frequent ankle sprains are associated with recurrent pain and swelling. Functional instability can be described as mobility beyond voluntary control; however, the physiologic range of motion is not necessarily exceeded. The diagnosis of functional instability is made primarily on the basis of a history of frequent and recurrent giving way, which is often associated with difficulty in walking on uneven ground.

The physical examination may show evidence of mechanical instability, but this finding is not necessary to make the diagnosis. Functional instability is frequently associated with muscle weakness and hypotrophy, but this is often subtle. The incidence of functional instability after ankle sprains has been reported to range from 15% to 60% and seems to be independent of the degree of severity of the initial injury.

The etiology of functional instability is complex, with important roles for several types of factors such as neural (proprioception, reflexes and muscular reaction time), muscular (strength, power and endurance), and mechanical (lateral ligamentous laxity). Other possible factors have also been considered, such as adhesion (scar) formation leading to decreased mobility of the ankle, especially in dorsiflexion; peroneal muscle weakness; and tibiofibular sprain and articular cartilage damage.

An ankle sprain may be followed by complications, including mechanical instability, muscle hypotrophy and functional instability. The magnitude of disability correlates best with how many of these sequelae are present. The association between functional and mechanical instability remains unclear. Repeated sprains caused by functional instability may later result in mechanical instability. Mechanical and functional instability may be sequential, but the two do not always occur together.

Tip

Functional instability is prevalent in 80% of patients with mechanical instability, and in 40% of patients with mechanical stability.

With continuing recurrent pain, the two instabilities tend to become coexistent. Chronic lateral ankle instability syndrome is most commonly a combination of mechanical and functional instability, regardless of the clinical manifestation.

Chronic ankle instability is often characterized by repeated episodes of 'giving way' with asymptomatic periods between episodes. In contrast, athletes with other causes of chronic ankle pain usually experience a constant aching discomfort in the ankle, although symptoms may vary. This difference in history can often be an important key to the correct diagnosis (Fig. 21.23).

Tip

Functional instability is a clinical problem. If functional instability persists after adequate conservative treatment and mechanical instability also exists, the mechanical instability should be addressed.

Treatment

The athlete should:

- Carry out functional rehabilitation including proprioceptive and muscle exercises (p. 507 Fig. 21.11) such as tilt-board training.
- Use an ankle brace (see p. 57) or tape to provide external stabilization (Fig. 21.24).
- The physician may operate if there are recurrent 'giving way' episodes (see below).

Surgical treatment of ankle instability

Isolated mechanical instability without symptoms such as pain and 'giving way' is not in itself an indication for surgery. Rather, it is the combination of mechanical and functional instability, that is the most commonly reported indication for surgery (Fig. 21.25).

Figure 21.23 Different techniques to evaluate functional instability. **a)** The athlete holds one leg in a flexed position, extends the leg and is thereafter asked to return the leg to the original position (called joint position sense, JPS); **b)** the athlete stands on a tilt-board; the board is tilted and the time for the ankle reflexes to be activated when the foot is suddenly tilted is measured with electromyography; **c)** an evaluation of neuromuscular control by using a balance test on a force-plate (measurement of the postural sway).

Figure 21.24 Different methods to support an unstable ankle joint. **a)** Tape at the sports arena (with permission, by Tommy Eriksson, Swedish Athletic Association); **b)** a Push Aequi brace works very well as treatment and prevention of ankle sprain in most sports when there is chronic ankle instability (with permisssion, by NEA International); **c)** Aircast brace is used extensively in sport for stabilizing the ankle (with permission, by DJO, LLC. All rights reserved); **d)** Air-Stirrup II Aircast brace in shoes can be an effective combination (with permission, by DJO, LLC. All rights reserved).

It should be emphasized that repeated episodes of giving way do not seem to predispose to degenerative arthritis (loss of joint cartilage) in the ankle, but this may develop over a long period. The main reason for surgery is that the patient is not willing to accept the discomfort and functional loss that follows the recurrent 'giving way' episodes. The decision to operate is based on the history and clinical examination findings. Stress radiographs can sometimes be of value.

Surgical procedures can be divided into:

- Non-anatomic reconstructions, in which another structure (such as the peroneal tendon) is used to replace the injured ligament. With the non-anatomic techniques, the normal biomechanics cannot be restored. This technique is seldom used today.
- Anatomic reconstructions, in which the injured ligament is repaired secondarily with or without augmentation (reinforcement). With the anatomic techniques, usually both the ATFL and the CFL are reconstructed.

In the 1960s Lennart Broström described a technique of dissection of the original rupture ends and then re-suture of them in his research about the ankle ligaments. His technique is still the basis of the surgical management of ankle sprains. The above described technique is the anatomic reconstruction modified by Lars Peterson.

After an anatomic reconstruction, a brace or walking boot should be used. The ankle can be taken out of the boot to allow movement of the foot in 0–20° of plantar flexion. The healing time is 6 weeks, and return to full activity is possible after 10–14 weeks (rehabilitation protocol on p. xx).

The results of anatomic reconstruction are reported to be good or excellent in around 90%. Four factors may predict poor outcome:

- A history of 10 years or more of instability prior to surgery.
- Associated ankle osteoarthritis.
- Generalized joint hypermobility.
- Previous tendon reconstruction (tenodesis).

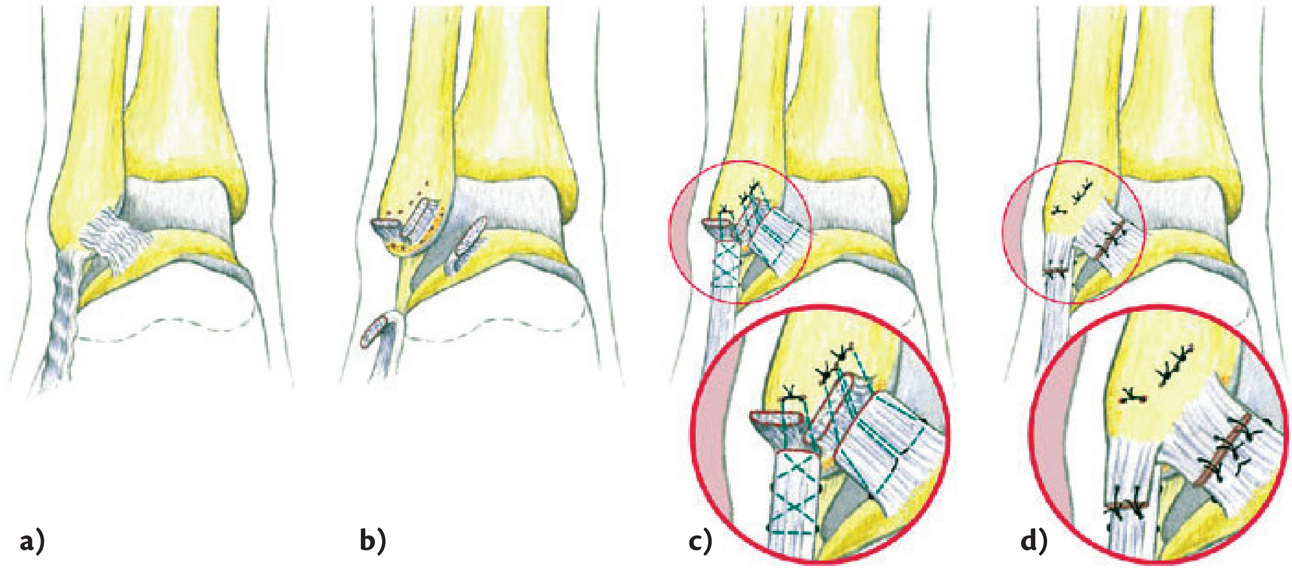


Figure 21.25 Surgery of chronic instability of the ankle with an anatomic re-suturing designed by Lennart Broström, Sweden in the 1960s and later modified by Lars Peterson. **a)** Elongation of the ligaments between fibula and talus (ATFL) and between fibula and calcaneus (CFL) after insufficient healing, which has caused functional and mechanical instability; **b)** the elongated ligaments are divided 3–5 mm from the insertion in the fibula; thereafter drill holes are made through the lateral malleolus until raw bone is seen under the insertions of the ligaments; **c)** sutures are taken through the drill holes and the distal ends of the ligament are tensioned and tied over the bony bridges at the lateral malleolus. The ankle is held in pronation when this is done; **d)** the proximal ligament ends are sewn with extra sutures as reinforcement.

Tip

The anatomic technique is considered simple and allows early return to function.

It should be the primary choice when surgery is indicated.

Subtalar sprain and instability

The subtalar joints consist of the talocalcaneal and talonavicular joints. The subtalar sprain has remained a mysterious and little-known clinical entity. The incidence is unknown, but it is widely accepted that most subtalar ligamentous injuries occur in combination with injuries of the lateral ligament of the ankle. Subtalar instability is estimated to be present in about 10% of patients with lateral instability of the ankle. A severe subtalar instability includes damage to the interosseous ligament. Medial subtalar instability due to rupture of the deep and superficial central parts of the deltoid ligament is a very rare type of subtalar instability and may be suspected when pain presents around the medial malleolus with instability. It should be investigated with stress radiography and sometimes requires surgery.

An athlete with chronic subtalar instability usually describes 'giving way' episodes during activity and has a history of recurrent sprains and/or pain, swelling and stiffness. There is a feeling of instability, especially when walking on uneven ground. Because the symptoms in subtalar and ankle instability are similar, athletes with a clinically serious recurrent ankle sprain should be carefully evaluated for subtalar instability. Localized tenderness on palpation over the subtalar joint is suggestive of involvement of the subtalar ligaments, but clinical evaluation of subtalar instability is difficult and unreliable.If a major sprain of a subtalar joint is suspected clinically, the diagnosis can be verified with subtalar arthrography, a subtalar stress view or stress tomography. Although scientific studies proving the value of CT and MRI are not yet available, one or the other may ultimately be established as the best diagnostic modality. Arthroscopy of joints is under development, but currently not routine.

The treatment is functional with exercises (as for ankle sprain, p. 533–4, p. 535 Table 21.2) and the use of an ankle brace. Surgery is occasionally indicated: anatomic reconstruction can be used.

Sinus tarsi syndrome

The sinus tarsi is located on the lateral aspect of the hindfoot (Fig. 21.26). Sinus tarsi syndrome (pain at the lateral junction of the talus and calcaneus) is characterized by pain and tenderness over the lateral opening of the sinus tarsi, accompanied by a feeling of instability and giving way of the ankle.

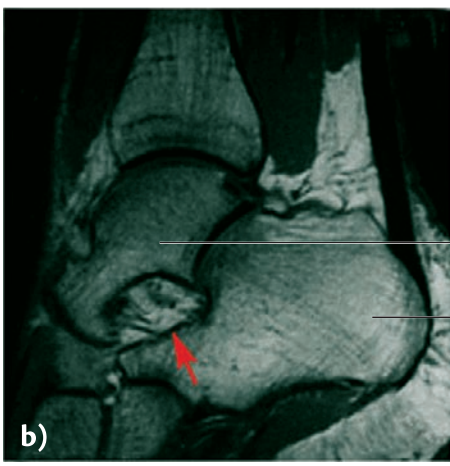


Figure 21.26 Sinus tarsi syndrome. **a)** Tenderness over sinus tarsi; magnetic resonance imaging shows the normal sinus tarsi; **b)** and with an increased amount of liquid (synovitis) in the sinus tarsi after injury.

This is an uncommon injury: about 70% of affected athletes will have sustained trauma, usually a severe inversion sprain of the ankle. If the CFL is torn, the interosseous talocalcaneal ligament, which occupies the sinus, can be sprained as well. In most cases the ligaments heal quickly with little residual disability. However, because of the abundance of synovial tissue in the sinus tarsi area, synovitis may ensue.

Symptoms and diagnosis

- Pain and tenderness at the sinus tarsi are often combined with a feeling of instability (Fig. 21.26).
- Pain on the lateral side of the foot is increased by firm pressure of the lateral opening of the sinus tarsi; this is a characteristic clinical sign.
- Pain is most severe when the patient is standing or walking on uneven ground.
- An MRI scan may demonstrate a rupture of the talocalcaneal interosseous ligament and signs of synovitis (Fig. 21.26). The role of MRI in this case is, however, not fully evaluated.

Treatment

The physician may:

- Give an injection of local anesthetic solution and corticosteroids into the sinus tarsi; this usually relieves the pain. Approximately two-thirds of patients respond to injections at weekly intervals (2–4 times). The number of injections should be limited because of the small amount of subcutaneous tissue in the area.
- Carry out surgery with excision of the tissue filling the lateral half of the sinus tarsi. In refractory cases subtalar arthrodesis (stiffening of the joint) may be indicated.

Ankle pain

Fractures

The ankle joint is one of the areas that is subject to many injuries in sport, including fractures. As the bones and surrounding ligaments cooperate to maintain stability in the ankle joint, combination injuries are common.

Mechanism of injury

The most common mechanism of injury is an inward turning movement of the sole of the foot (inversion) and the front of the foot moving towards the center line of the body (adduction). A combination of inversion, plantar flexion and adduction is called supination. Depending on the force and degree of supination, different injuries can occur:

- Tearing of the ligament between the talus and the fibula (the anterior talofibular ligament).
- Fracture of the fibula on a level with the joint line.
- Fracture of the medial and lateral malleolus.
- Dislocation of the talus.

Another common injury is an outward turning movement of the sole of the foot (eversion) and the front of the foot away from the center line of the body (abduction). A combination of eversion, dorsiflexion and abduction is called pronation. Again, different injuries occur depending on the force of pronation:

- Tearing of the deltoid ligament or a fracture of the medial malleolus.
- Tearing of the syndesmosis.
- Fracture of the fibula above the level of the ankle joint.
- Dislocation of the talus.

Other mechanisms of injury are also possible.

Symptoms and diagnosis

- Intense aching and pain are felt when the foot is under load.
- Tenderness and considerable swelling occur.
- Sometimes there is visible displacement.
- An X-ray shows a skeletal injury.

Treatment

The athlete should:

- Immediately cool the injury, apply a compression bandage and elevate the foot (see Chapter 7).
- Consult a physician.

The physician may:

- Apply an ankle brace, a walking boot or a plaster cast for 4–8 weeks, if there is no major displacement and the ankle joint is assessed as stable.
- Operate in cases of a fracture with displacement or where there is instability of the ankle joint.

The recovery time is about as long as the immobilization period, i.e. 4–8 weeks. The injured athlete can start to train the ankle and the muscles of the lower leg after the cast has been removed (see pp. 533–4 for ROM, strength and proprioception training). An ankle joint fracture needs at least 2–3 months to heal to full stability, and the injured athlete should allow a break from competition of at least 4 months. When training is resumed a brace should be used.

After surgery during which the injured bone has been realigned to its exact position, the prognosis is good. Slight displacement in the fracture during healing, however, can result in wearing of the cartilage and impaired future functioning due to progress to osteoarthritis.

Persistent ankle pain

Persistent ankle pain after an ankle sprain may be caused by incomplete rehabilitation, intra-articular injuries that include osteochondral or chondral lesions of the talus or tibia, loose bodies, arthrosis and impingement problems, as well as chronic tendon disorders involving the peroneal tendons and posterior tibial tendons. Undetected fractures and nerve injuries may be present.

Important tools for persistent ankle pain – ankle arthroscopy

Ankle arthroscopy is an increasingly useful technique for dealing with a wide range of ankle problems. It is used not only for diagnosis but also as a valuable therapeutic tool (Fig. 21.27). Indications include loose bodies, removal of osteophytes, debridement of osteochondral defects of the talus, removal of chronic hypertrophic synovial tissue, lysis of adhesions and repairs of the joint surface.

Arthroscopy is carried out with the patient supine and often with spinal anesthesia. This allows the patient to watch the television monitor, and the surgeon can

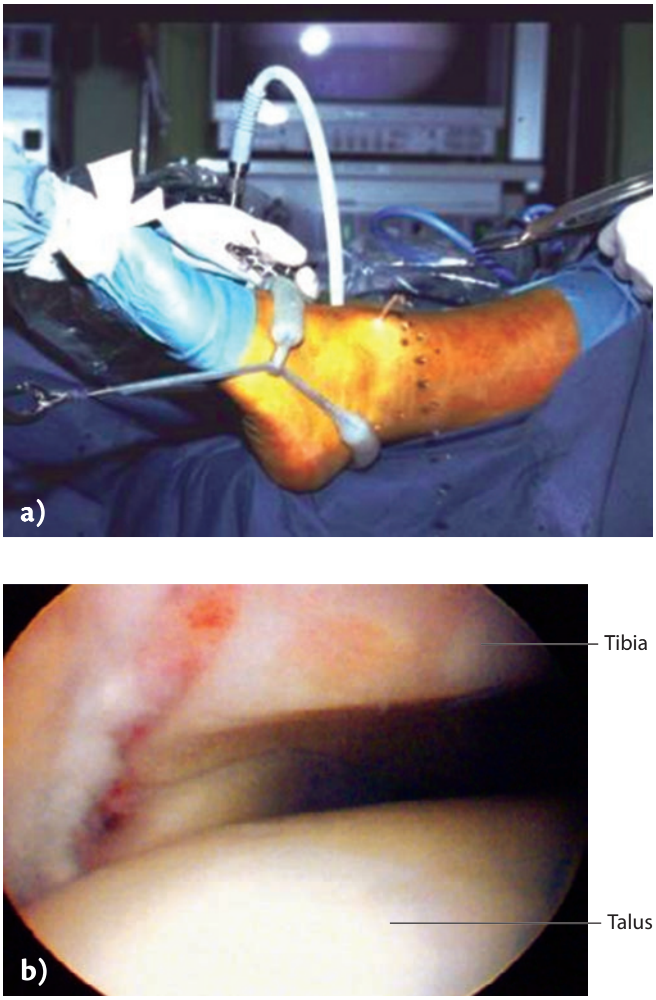


Figure 21.27 Arthroscopy of the ankle. **a)** Positioning for ankle arthroscopy; **b)** arthroscopic picture of the lateral part of an ankle with the end of the tibia upwards and the top of the talus downwards.

explain the findings. A 4 mm, 30° arthroscope is used. If the joint is narrow, a smaller arthroscope is used.

The anteromedial and anterolateral portals are routinely used. The anteromedial portal is first established just above the tibiotalar joint. The skin incision is made just medial to the anterior tibial tendon at the level of the tibiotalar joint. The wound is opened bluntly down to the capsule. The saphenous vein and accompanying nerve should be avoided. The anteromedial portal is more easily identified using transillumination. Before the skin incision is made, the intermediate dorsal cutaneous branch of the superficial peroneal nerve is identified and the course of the nerve is marked with a pen. It is easier to palpate the nerve when the ankle is plantar flexed and in some inversion. Posterior portals such as the posteromedial and posterolateral portals are not routinely used, but they can be suitable for the treatment of posterior medial osteochondral lesions. The anterior central portal has been described, but is seldom used. The authors prefer to work with the arthroscope in the anterolateral portal and use the instruments in the anteromedial portal, but this may be dependent on the location of the lesion.

Occasionally there is a need for an ankle joint distractor. It is not routinely used because most lesions can be reached through the anterior portals without distraction.

The portals are closed with tape or sutures, and a simple compressive dressing is used. The athlete can bear weight and carry out active ROM exercises as tolerated. The patient can return to full activity 2–8 weeks following surgery except in the case of osteochondral lesions. The indications for return to sports are pain-free ROM and jogging without pain.

Patients with symptoms consistent with the above indications for arthroscopy are appropriate for referral if their symptoms have not improved or resolved after a reasonable course of conservative therapy. Unfortunately, many problems of the ankle can be difficult to diagnose, and it is frequently difficult to decide when operative intervention is indicated. Loose bodies and osteochondritis dissecans are clear indications for arthroscopic intervention. Athletes with anterior impingement due to osteophytes are also relatively simple to diagnose. A great many patients, however, present with symptoms of pain after an ankle sprain, and it can be difficult to distinguish whether their symptoms are due to relative muscle weakness or imbalance, subtle instability, impingement or possibly an injury to the syndesmosis, such as a pronation (external rotation) injury, that may take more than 3 months to heal. These problems should be identified by detailed physical examination, strength testing, etc., but in practice it can be very difficult to establish a specific diagnosis, even for physicians who deal with these problems regularly. Residual problems 3 months after an ankle sprain are often due to incomplete rehabilitation, but undetected trauma or intra-articular injuries may be present. Therefore, if there has been no response to conservative therapy after approximately 3 months, referral for arthroscopy should be considered even if the specific indications listed have not been clearly identified.

Osteochondral (bone–cartilage) lesions of the talus

Osteochondral lesions, which involve injury to both the bone (osteo) and the overlying articular cartilage (chondral) tissues, can be sustained during an ankle sprain. Osteochondral injury of the talus has been reported to occur in 6.5% of patients who have had an ankle sprain, and some form of chondral injury may occur in more than 50%.

Osteochondral lesions are potentially serious injuries in the ankle. They can either heal and remain asymptomatic or worsen as a deep pain in the ankle during load stress and cause progressive damage (sclerosis, formation of cysts) in the bone under the cartilage (subchondral bone).

There are 4 stages of osteochondral lesions (Fig. 21.28).

Symptoms and diagnosis

- There is often a history of ankle sprains with 'popping' sensations. A ligament tear may mask the pain from an osteochondral lesion.
- Pain is felt during and after exercise.
- Swelling of the ankle occurs.
- Tenderness may be present on the lateral side, occasionally on the medial side. The lesions are most commonly located in the anterolateral or posteromedial parts of the talus.
- A locking sensation of the joint is experienced. Severe locking or catching symptoms, giving problems of the ankle to bend, may indicate a large osteochondral lesion or a loose piece of cartilage or free bone within the joint.
- Ankle movement is limited.
- An X-ray will often confirm the diagnosis. Examination is made with anteroposterior, lateral and mortise views in ankle flexion and extension. Mortise views in plantar flexion may disclose a posteromedial lesion, and corresponding views in dorsiflexion may disclose an anterolateral lesion.

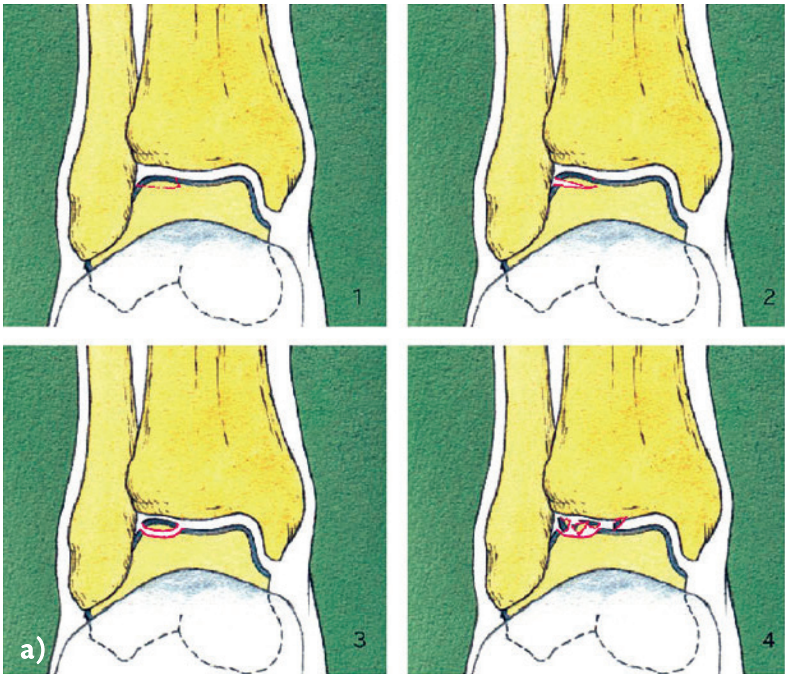


Figure 21.28 Injuries to bone and cartilage tissue in joints can be divided into 4 different stages. **a)** Stage 1: a compression injury has caused microscopic injury to the bone tissue under the articular cartilage; X-ray looks normal; stage 2: an avulsed fragment is seen on X-ray; stage 3: a bone–cartilage fragment has completely avulsed but is located in its anatomical position; stage 4: avulsed fragments have come loose in the joint; **b)** arthroscopic picture of an osteochondral injury.

- Bone scan is indicated in patients with persistent pain if routine X-rays are negative (Fig. 21.29).
- Plain tomography, MRI or a CT scan (Fig. 21.29) can determine the exact location and extent of the lesion. A CT scan can be a help for the preoperative plan.

Treatment

The athlete should:

- Avoid pain-causing situations.
- Keep up conditioning with cycling and other non-impact activities.

The physician may:

- Treat stage 1 and stage 2 lesions conservatively, which usually involves immobilization and restricted weight bearing. They often heal well and have a good prognosis.
- Give an intra-articular injection of 10 ml of local anesthetic solution to help differentiate the pain caused by these lesions from that of other causes. If there is relief of pain, surgery can be considered.
- Carry out early surgery on stage 3 and 4 lesions; delayed surgical treatment of these lesions often fails. These injuries are treated by arthroscopic debridement. Drilling of the lesion bed may encourage repair with fibrocartilage. Open treatment is occasionally necessary, with bone grafting in large bony defects. Postoperative weight bearing is delayed for at least 2–6 weeks.
- Operate with the body's own cartilage–bone cylinders to the injured area or the body's own cells to the injured area (see p. 162).

Healing and return to sport

The degree of success depends in part on the time between the occurrence of the injury and surgical treatment. Good results are reported in 40–80% of cases if treatment is early. Advanced lesions for which treatment has been delayed for more than 1 year generally have a poor outcome. Return to sport depends on the healing. When the body's own cell or tissue transplantation has been done a success rate of 80–90% can be achieved.

Tip

Have great respect for these injuries! A well-planned treatment schedule should be initiated early by a skilled orthopedic specialist.

Loose bodies in the ankle

Loose bodies originating from a stage 4 transchondral fracture of the talus should be suspected in patients with intermittent pain, swelling and clicking. A few loose bodies may also originate from osteophytes (bony deposits) on the anterior distal rim of the tibia or the dorsal neck of the talus. Pure chondral loose bodies may cause the same problems; in these cases plain X-rays will appear normal and loose bodies can be detected with arthrography, CT or MRI. Arthroscopy will secure the diagnosis of osteochondral lesions.

The treatment is arthroscopic removal of the loose bodies, sometimes with debridement and drilling of the lesion bed or with the body's own cell and tissue transplantation (see p. 162).

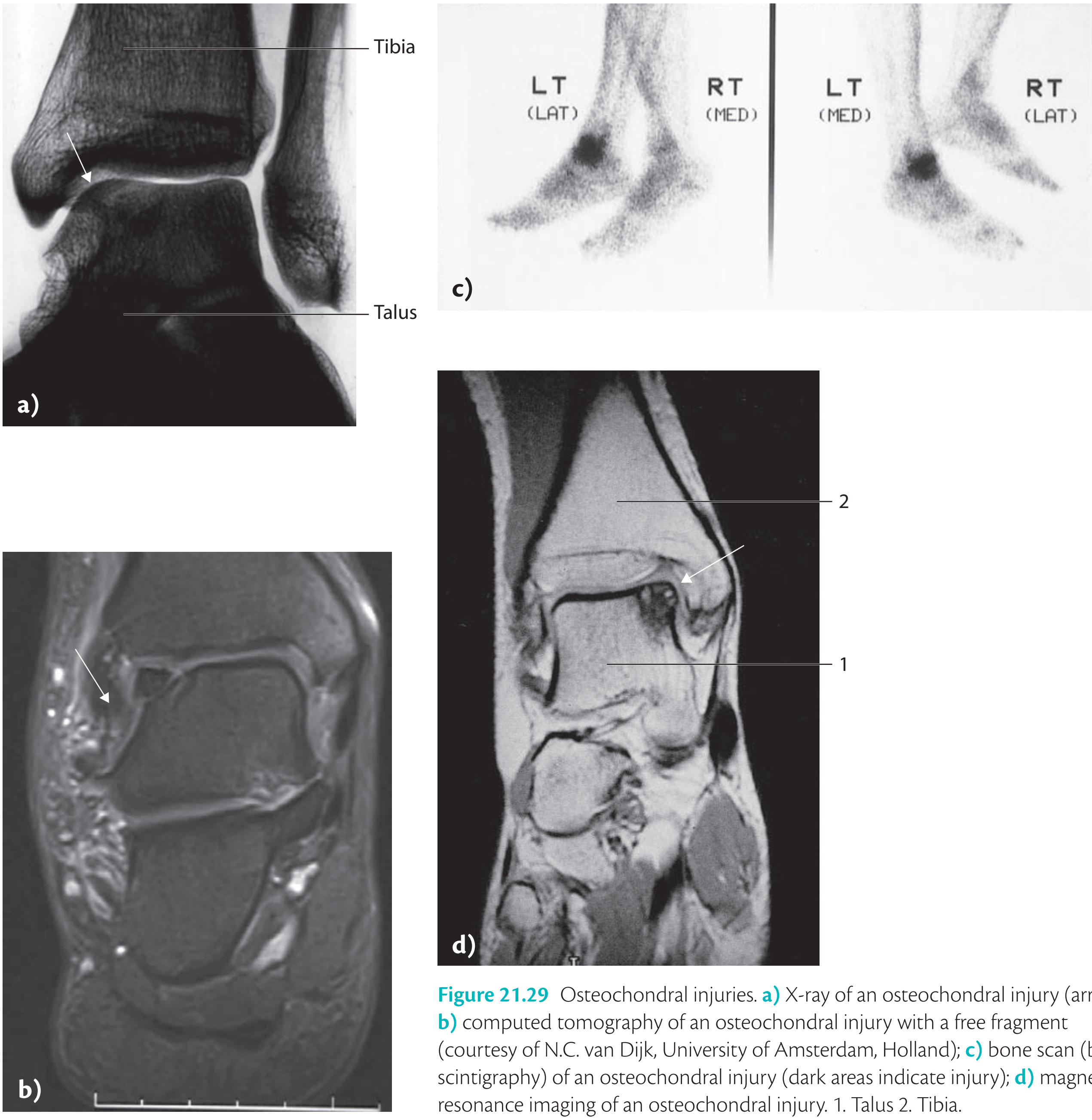


Figure 21.29 Osteochondral injuries. **a)** X-ray of an osteochondral injury (arrow); **b)** computed tomography of an osteochondral injury with a free fragment (courtesy of N.C. van Dijk, University of Amsterdam, Holland); **c)** bone scan (bone scintigraphy) of an osteochondral injury (dark areas indicate injury); **d)** magnetic resonance imaging of an osteochondral injury. 1. Talus 2. Tibia.

Impingement problems

Bone impingement (footballer's ankle)

In cases of untreated acute or chronic overstretching of the ankle joint, changes can occur in the form of osteophytes anteriorly, where the joint capsule is attached. The condition is not uncommon and mainly affects athletes who have been participating in football/soccer, cross-country running, orienteering, and so on, for many years.

The cause may be repeated shooting exercises. Well-made biomechanical studies from Amsterdam have shown that the contact between the ball and the foot in shooting a football is on the anterior medial aspect. Few reach full plantar flexion when making a shot. The study's conclusion was that the occurrence of osteophytes on the anterior tibial rim causing impingement is related to recurrent ball contact, i.e. recurrent micro-trauma to the

Figure 21.30 A football player who is using his/her ankle when shooting the ball can sustain impingement problems. (**a)** with permission, by Tommy Holl, GAIS, Göteborg, Sweden; **b)** with permission, by Bildbyrån, Sweden.)

ankle anterior rim, where these osteophytes are formed (Fig. 21.30).[6]

Hyperextension or hyperflexion of the ankle joint causes traction in the attachment of the joint capsule or minor fractures due to acute or repeated impact between the bone surfaces of distal tibia and the neck of the talus (Fig. 21.31). The bony damage can react with osteophyte formations and may cause inflammation in the joint capsule and tendon sheaths.

Symptoms and diagnosis

- Tenderness is felt when pressing with the fingers over the front of the ankle joint. Sometimes the osteophytes can be felt (Fig. 21.32).
- Pain occurs as a band across the ankle joint, e.g. when kicking in football/soccer.
- Pain occurs when the foot is bent up or down.
- Mobility in the ankle joint is often slightly impaired, especially in dorsiflexion. This symptom should always raise a suspicion of impingement.

Tip

Difference in dorsal flexion between the ankles should raise the suspicion of an impingement syndrome.

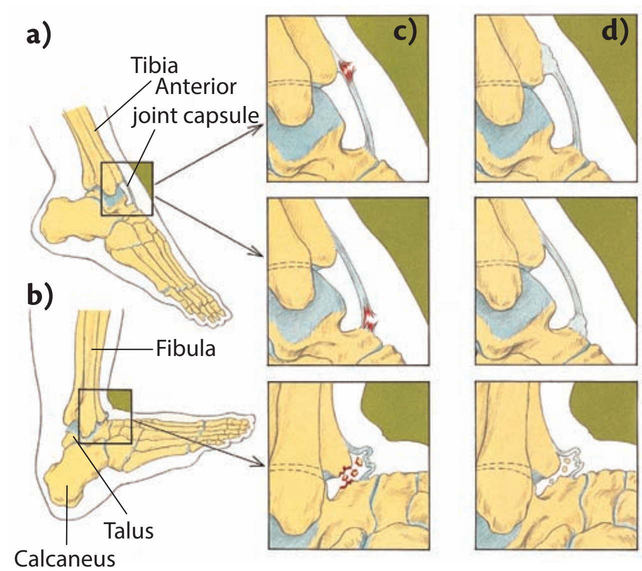


Figure 21.31 'Footballer's ankle'. Some possible explanations for the development of bony changes in the ankle. **a)** Passive hyperextension when flexing the ankle downwards, i.e. plantar flexion; **b)** passive hyperextension when extending the ankle upwards, i.e. dorsiflexion; **c)** alternative injuries in the acute phase; **d)** residual injuries.

Figure 21.32 The injured athlete may experience tenderness if there is pressure over the anterior and/or lateral aspect of the ankle.

- Osteophytes show up on X-ray (Fig. 21.33B).
- Arthroscopy ensures the diagnosis.

Treatment

The athlete should:

- Carry out strength and mobility training and also static stretching exercises.
- Try a heel lift (a build-up under the heel).
- Use a heat retainer.
- Apply brace or tape.

The physician may:

- Administer a steroid injection into the tender spot and prescribe rest.
- Operate in cases of pronounced problems, with arthroscopic removal of the osteophytes.
- Postoperative recommendations include early motion and return to physical activity, in most cases after 1–2 months.

Tip

Return to sport can often take longer than expected or planned.

Soft tissue impingement

An inversion sprain may result in posttraumatic synovitis (inflammation of the joint lining) with synovial thickening and an effusion. The term 'meniscoid lesion' has been used to describe entrapment of a mass of hyalinized tissue between the talus and the fibula during ankle motion. This injury was described by Wolin in 1949. A ligamentous origin has been recognized. After an inversion sprain of the ankle, ligament and capsule may impinge on the anterolateral aspect of the talus. Meniscoid lesions may also be tears of the ATFL in which the torn fragment becomes interposed between the lateral malleolus and the lateral aspect of the talus – the lateral gutter syndrome.

Symptoms and diagnosis

- The key to correct diagnosis is awareness of this lesion.
- A long history of repeated ankle sprains is characteristic.
- Occasional locking and catching sensations occur.
- A snapping phenomenon can be elicited when the foot is tested for inversion stability.
- Pain is experienced at push-off.
- Pain and discomfort occur at the anterior aspects of the ankle.
- Tenderness is felt just anterior to the lateral malleolus and discomfort in dorsiflexion, which often is limited.
- There is no evidence of mechanical instability, and X-rays are normal.
- Often there is limitation of dorsiflexion of 5–10° compared with the other side. This is a diagnostic finding (Fig. 21.33A).
- Restriction in dorsiflexion compared with the other ankle is a diagnostic finding.
- Relief of symptoms after injection of 10 ml of anesthetic solution at the point of tenderness supports the diagnosis.
- An MRI scan can help to establish the diagnosis but the sensitivity and specificity vary. Techniques of using contrast, a so-called arthrography, may be of value.

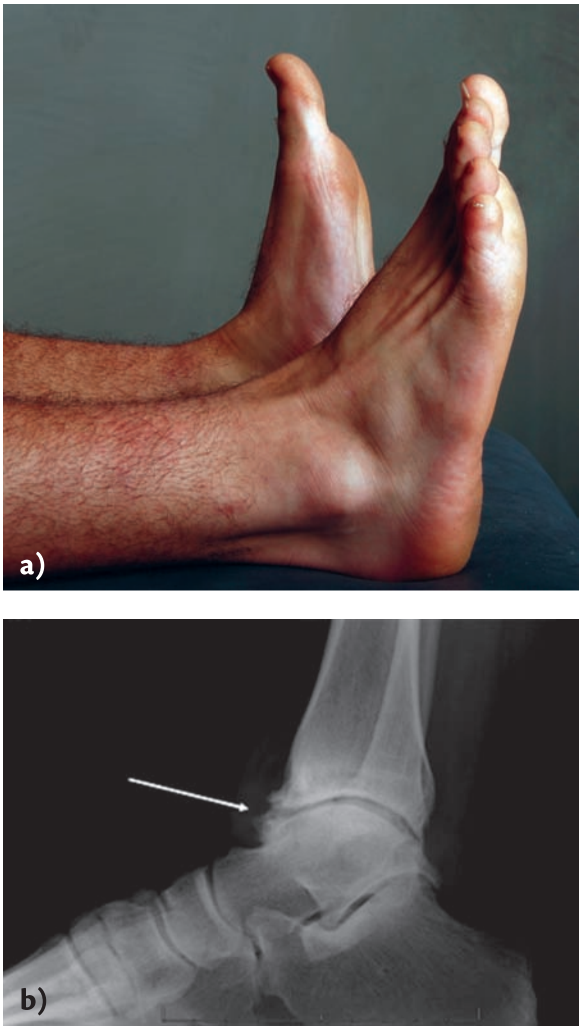


Figure 21.33 Impingement in the ankle. **a)** Impingement of the ankle is characterized by decreased mobility in the ankle especially during dorsiflexion (the foot is bent upwards); **b)** X-ray of the ankle showing bony osteophytes on the anterior aspect of both the tibia and the talus (arrow).

Treatment

The athlete should:

- Carry out dorsiflexion stretching.
- Use a heel wedge.
- Use an ankle brace.

The physician may:

- Carry out arthroscopic examination to confirm the diagnosis and remove the lesion (Fig. 21.34).
- Return to full activity is possible in 2 weeks to 2 months.

Posterior talar impingement (os trigonum)

Posterior impingement syndrome is most common in ballet dancers. It occurs with weight bearing with the foot in plantar flexion. It is usually, but not always, associated with an os trigonum, a small accessory (extra) bone found just posterior; however, an os trigonum can be present without causing pain. The bone can exist in 3–14% of normal feet. Impingement may also be caused by a fracture of the posterior process of the talus.

This injury is caused either by micro-trauma of repeated hyperplantar flexions, as with dancers, or of an episode of acute powerful hyperplantar flexion, as in soccer players. The dancers' repetitive activities in pointe and semipointe causes enormous stress to this area (Fig.21.35).

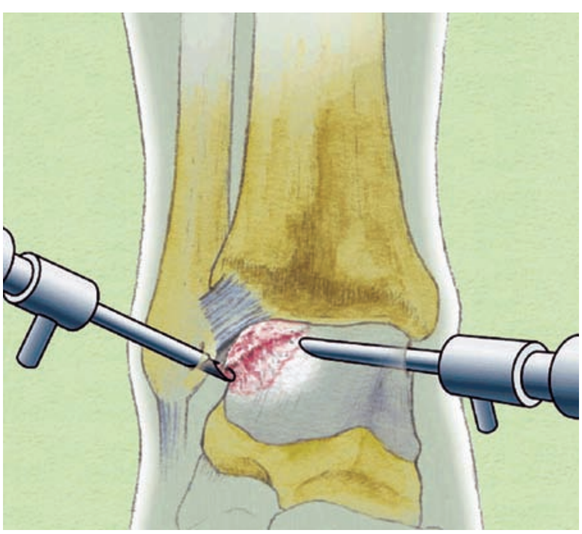


Figure 21.34 Arthroscopic examination allows confirmation of the diagnosis and can be part of the treatment, as it allows the use of a so-called shaver to remove the bony osteophytes and/or scar tissue.

Figure 21.35 Posterior impingement can be caused by os trigonum. In extreme hyperplantar flexion the posterior bony prominence of the talus may come in conflict with the accessory bone fragment (os trigonum) located just posterior of the talus. This may occur in sports such as gymnastics **a)** and ballet **b)**; **c)** computed tomography scan of the talus with os trigonum. 1. Os trigonum 2. talus 3. joint space 4. tibia.

Symptoms and diagnosis

- Tenderness is felt behind the lateral malleolus of the ankle.
- Pain is felt behind the lateral malleolus of the ankle when the toes are pointing downwards, especially with weight bearing.
- An X-ray will usually show an accessory bone fragment (os trigonum) just posterior of the talus (Fig. 21.35). Because the majority of these bone fragments are asymptomatic, its presence does not mean that it is the cause of the problem.
- Diagnosis is confirmed if injecting local anesthetics into the area temporarily relieves pain.

Treatment

The athlete should:

- Modify activities to avoid plantar flexion.
- Begin physical therapy to strengthen ankle muscles for better support.

The physician may:

- Prescribe anti-inflammatory medication.
- In refractory cases, inject corticosteroid medication into the area to reduce inflammation.
- In cases that do not respond to the above, operate to remove the bone fragment and soft tissue. This disorder only rarely needs surgery. This can be performed with an endoscopic technique using an arthroscope. Return to sport is possible after 6–8 weeks.

Osteoarthritis: arthrosis of the ankle ('worn-out' joint)

The incidence of ankle arthrosis is low compared with that of arthrosis of the hip and knee joints. It is most commonly present after fractures about the ankle, especially when a fracture heals in a non-anatomic position (Fig. 21.36). Other predisposing factors include stage 3 and stage 4 osteochondral lesions of the tibia or the talar dome. Long-standing ligament instability with chondral damage over a long time may cause osteoarthritis (see Chapter 7).

Treatment is symptomatic and includes unloading of the joint surfaces and reducing the reactive inflammation with nonsteroidal anti-inflammatory drugs. When 'catching' and 'locking' sensations are present, arthroscopic debridement and removal of loose bodies or osteophytes may be necessary. Ankle arthrodesis is an option if conservative measures fail. The functional disability after an ankle arthrodesis can frequently be well compensated for, especially in a young patient. Today, ankle replacement has been developed and could be an option in older patients.

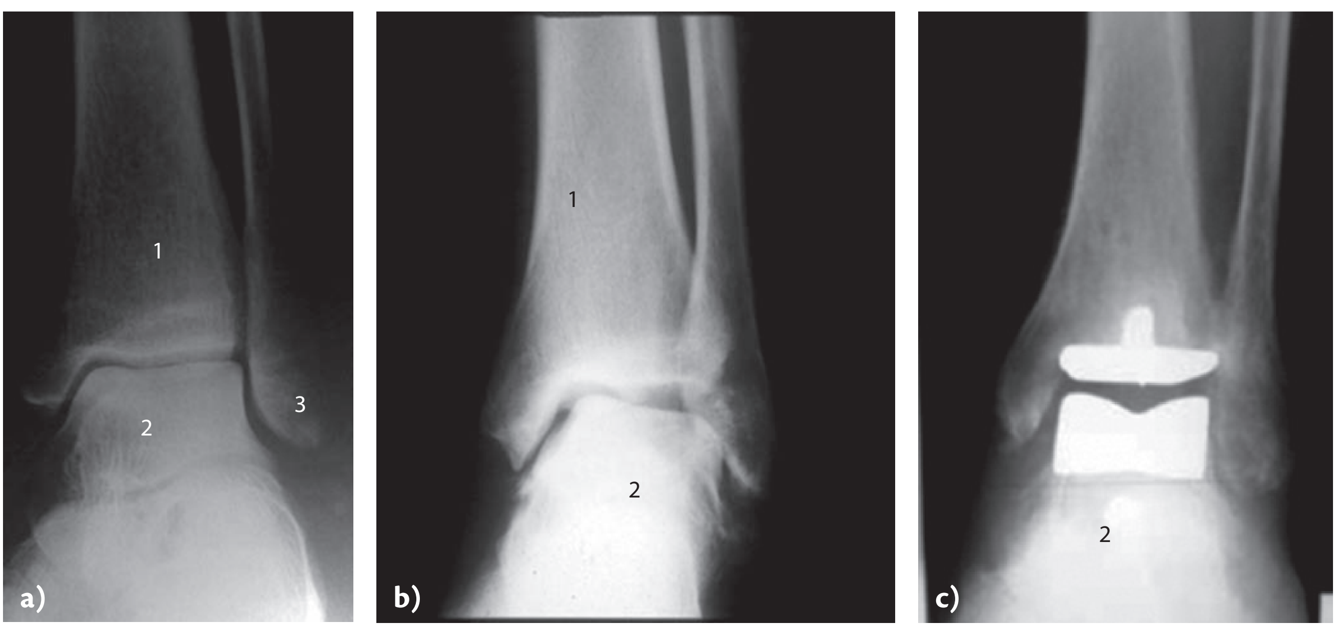


Figure 21.36 X-rays of osteoarthritis ('worn out' joint) in the ankle. **a)** Healthy ankle; **b)** ankle with reduced height of the cartilage, i.e. starting osteoarthritis; **c)** ankle prosthesis. On average 90% of the prosthesis are still in place and functioning at 8–10 years, after which time new surgery may be needed. 1; Tibia, 2; Talus, 3; Fibula.

Chronic ankle tendon injuries

Peroneal tendon injuries

The peroneal tendons run behind the lateral aspect of the ankle and midfoot to their insertions on the plantar side of the foot. The tendons pass behind the lateral malleolus in the groove of the fibula and beneath the retinaculum, by which the tendons are held in position. Peroneus brevis is the strongest abductor of the foot and functions as a secondary flexor of the ankle and everter (the sole of the foot moves away from the median plane of the foot). The tendon functions to stabilize the foot during gait, particularly in the final portion of the stance phase. Lateral instability loads the tendons and especially the short peroneal tendon inserting on the head of the fifth metatarsal may sustain a longitudinal rupture.

In downhill skiing, the athlete can have a trauma of internal rotation in combination with inversion. The retinaculum that holds the tendons in their compartment can then tear or avulse from the fibula. This allows the tendons to slip forward across the lateral malleolus (Fig. 21.37).

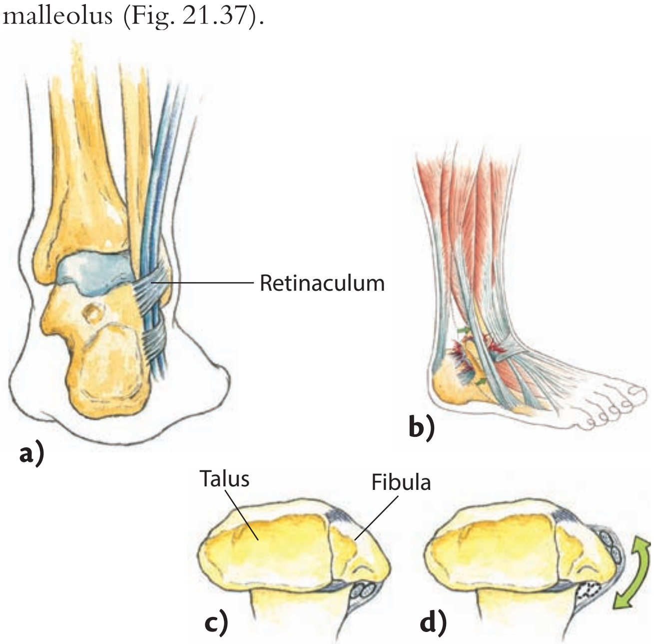


Figure 21.37 Injuries to the peroneal tendons (tendons to the long and short peroneal muscles). **a)** Ankle seen from behind. The peroneal tendons are seen behind the lateral malleolus; **b)** rupture of the retinaculum (a string of connective tissue holding the tendons in place); the peroneal tendons will luxate forward; **c)** cross-section through the ankle showing the normal position of the tendons through the lateral malleolus; **d)** cross-section showing the tendons after they have glided out of their position (dislocated) anterior to the lateral malleolus.

A subluxation or dislocation of the tendons can occur, as well as a tear. Recurrent dislocation of the tendon results in an inflammatory reaction, as well as degenerative changes causing a secondary tear, which may cause chronic problems. This injury can occur in athletes who have recurrent ankle sprains and unstable joints, as well as in downhill skiers, and in athletes who engage in jumping sports including football and basketball.

Symptoms and diagnosis

- Localized tenderness may be felt behind the lateral malleolus (Fig. 21.38).
- Pain is felt on active pronation of the ankle.
- The athlete can often reproduce a subluxation of the tendon by plantar flexing or dorsiflexing the ankle. This results in an often visible and palpable dislocation of the tendon anterior to lateral malleolus. This maneuver can cause pain. The tendon can also be dislocated by pressing from behind with the thumb against the lateral malleolus, which shows a defect behind the lateral malleolus (Fig. 21.38).
- Swelling around the tendon is common.
- Occasionally a rim avulsion fracture of the lateral malleolus may occur (15–50%). These fractures are best seen on an ankle mortise view X-ray.

Treatment

The physician may:

- Apply a cast or a walking boot for 3–4 weeks in an acute injury.
- Operate in order to deepen the groove and suture the retinaculum back to bone. A walking boot or a cast is applied for 4–6 weeks and return to sport is possible after 2–3 months.
- Repair tendon tear (often longitudinal) if it is present.

Posterior tibial tendon injuries

The posterior tibial muscle arises from the back of the tibia and fibula and merges into a tendon enclosed in a sheath that runs behind the tibia and the medial malleolus and is attached to the boat-shaped navicular bone on the inside of the foot. The main function of the tendon is to hold up the arch and support the foot when walking.

Increased pronation of the foot results in increased load and tension on the tendon of the posterior tibial muscle, leading to partial tears of the tendon and/or to inflammation of the tendon sheath. The tendon is subject to mechanical pressure behind the medial malleolus where it runs in a narrow groove. Inflammation around the tendon is common, causing problems primarily in running but also in skating and skiing.

If inflammation around the tendon is not treated properly, complete rupture of the tendon can occur. Complete rupture is not very common in athletes, occurring mostly in middle-aged women; it can be debilitating and treatment is difficult, with variable results. The key is to recognize the symptoms and institute aggressive treatment prior to complete rupture.

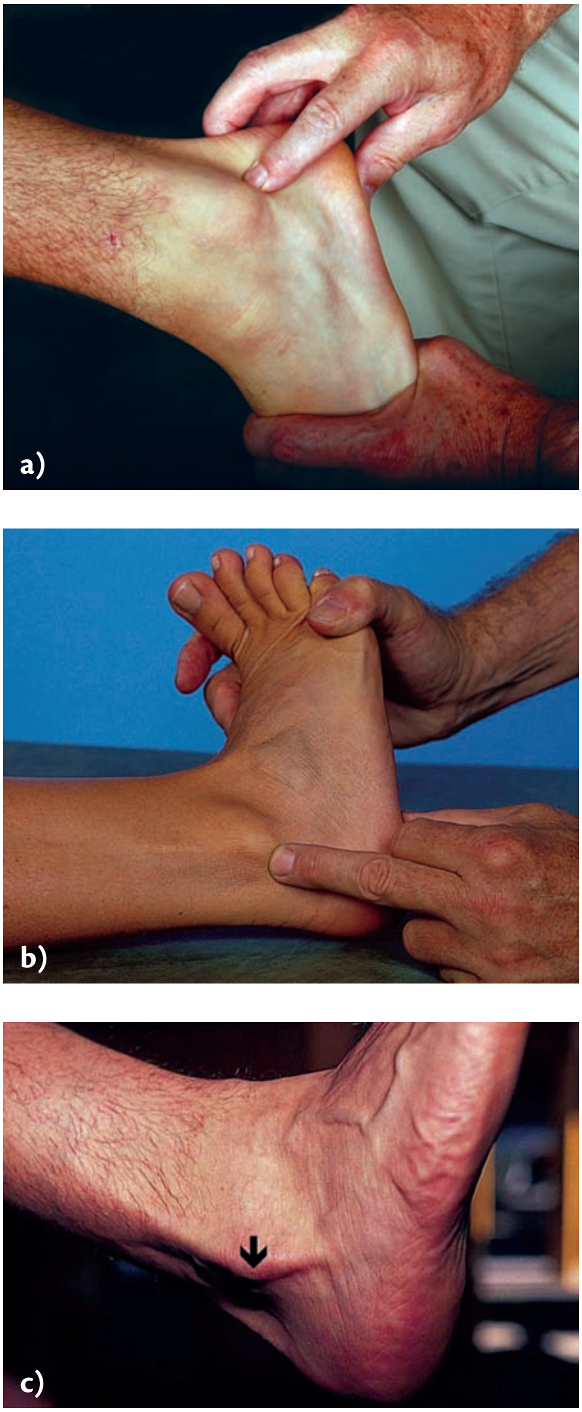


Figure 21.38 Dislocation (luxation) of peroneal tendons behind the lateral malleolus. **a, b)** Local tenderness behind the lateral malleolus; **c)** the tendon is seen easily with muscle contraction.

Symptoms and diagnosis

- Pain is felt when the tendon slides in the sheath during movements.
- Pain is felt when the tendon is subjected to passive loading and active exercises.
- Tenderness can occur, as a rule, over the attachment of the tendon to the navicular bone, but also over the course of the tendon behind the medial malleolus (Fig. 21.39).
- Swelling sometimes occurs.
- Crepitations can be felt over the tendon when the injury is in its acute stage.
- Increased pronation of the foot is often present.
- In complete rupture a flat foot will develop, when the longitudinal medial arch is collapsing towards the inside of the foot and the toes pushing to the outside of the foot.
- In complete rupture the athlete will not restore the arch when standing on the toes, and toe-standing may not be possible.
- An MRI scan will confirm the diagnosis.

Figure 21.39 Tibial posterior syndrome. Tenderness may be present over the tendon insertion of the navicular bone and over the tendon when it is going behind the medial malleolus.

Treatment

The athlete should:

- Stop active sport and rest the foot for 1–2 weeks.
- Apply cold treatment when the injury is in its acute stage and after that apply local heat, for example by using a heat retainer.
- Apply tape or an ankle brace to the injured area.
- Use a semi-rigid shoe orthotic (insert), preferably custom-made, which supports the longitudinal arch and reduces the pronation of the foot.

The physician may:

- Prescribe anti-inflammatory medication.
- Give a corticosteroid injection into the tendon sheath (never into the tendon) and prescribe rest.
- Apply a walking boot or a plaster cast for 3–4 weeks.
- Operate if the tendon sheath has become constricted so that the tendon can no longer glide normally in it. The surgical exploration deals with whatever pathologic condition is present, whether it is a chronic tendon sheath inflammation, tendinosis or a tear along the tendon.
- Prescribe shoe inserts for cases of chronic rupture.
- Operate in cases of acute complete rupture to repair the tendon.
- Operate in cases of painful chronic rupture. Surgery cannot restore the arch, but can reduce the pain. Return to activities after complete rupture is unpredictable.

Flexor hallucis longus tendon injuries

The flexor hallucis longus runs in a groove in the posterior talar process. At the level of the ankle joint the flexor hallucis longus passes, together with the posterior tibial and flexor digitorum longus tendons, under the flexor retinaculum. The flexor hallucis longus muscle and tendon unit is primarily responsible for bending the big toe.

Injuries and overuse problems to the flexor hallucis longus tendon are not uncommon in activities such as ballet dancing and gymnastics, owing to frequent and forceful plantar flexion activities of the ankle and big toe. Repetitive push-off maneuvers transmit substantial forces across the tendon and sheath with possible irritation, swelling and malformation. Injury can also occur in other movements such as push-off and rotation in the tennis serve (Fig. 21.40). Tendinopathy of the flexor hallucis longus tendon is much more common than complete disruption.

The flexor hallucis longus tendon can contribute to posterior ankle impingement due to os trigonum, an extra bone present in 3–14% of the population.

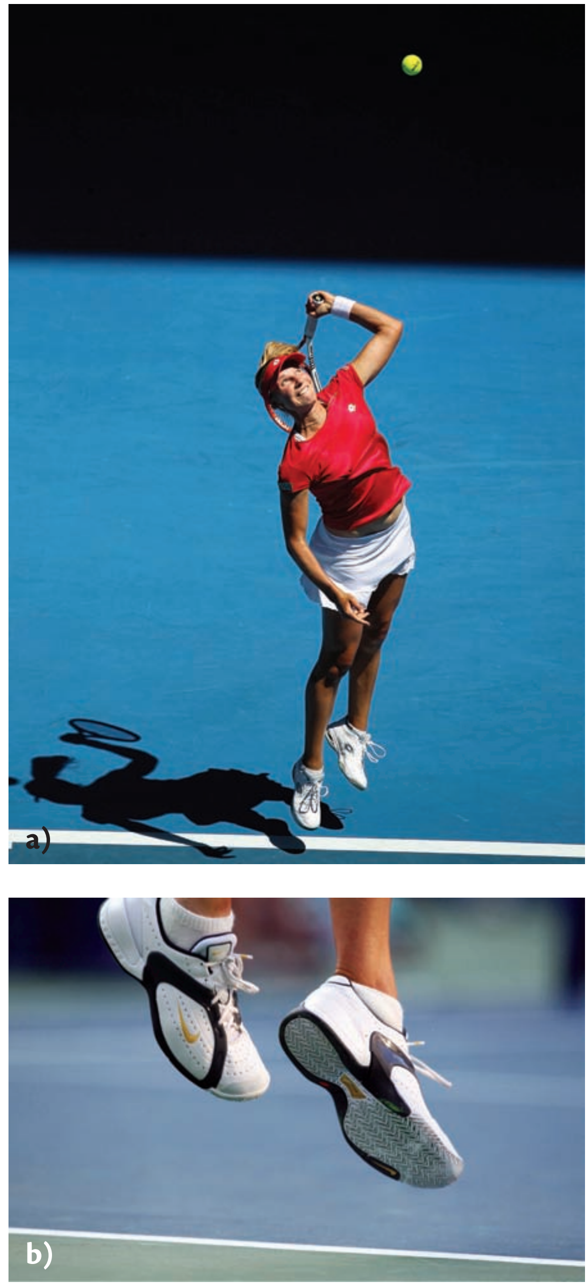


Figure 21.40 Overload of the flexor hallucis longus can occur in sports in association with push off, rotation and landing. **a)** Injury can occur when landing after a tennis serve; **b)** during the serve a tennis player is above the ground and will load the tendon when landing. (With permission, by Bildbyrån, Sweden.)

Symptoms and diagnosis

- Pain is reproduced with forceful ankle plantar and big toe flexion.
- Insidious pain can be located at the posterior medial aspect of the ankles behind the malleolus.
- Sometimes there is 'catching' or 'locking' of the tendon, caused by swelling of the tendon at an anatomically tight location behind the medial malleolus.

- Localized tenderness is felt over the tendon usually posterior or distal of the medial malleolus (Fig. 21.41).
- At forceful active contraction of the flexor hallucis longus, there is a snap or pop, and crepitation over the posterior medial region of the ankle.
- MRI can show fluid in the tendon sheath and sometimes tendinosis (Figure 21.42).

Treatment

The athlete should:

- Rest the area, with the help of crutches.
- Apply cold treatment.
- Apply tendon treatment principles (p. 493).
- Dancers can continue working out, but should avoid dancing en pointe.

The physician may:

- Prescribe anti-inflammatory medication.
- Immobilize the joint with a walking boot for a short period.

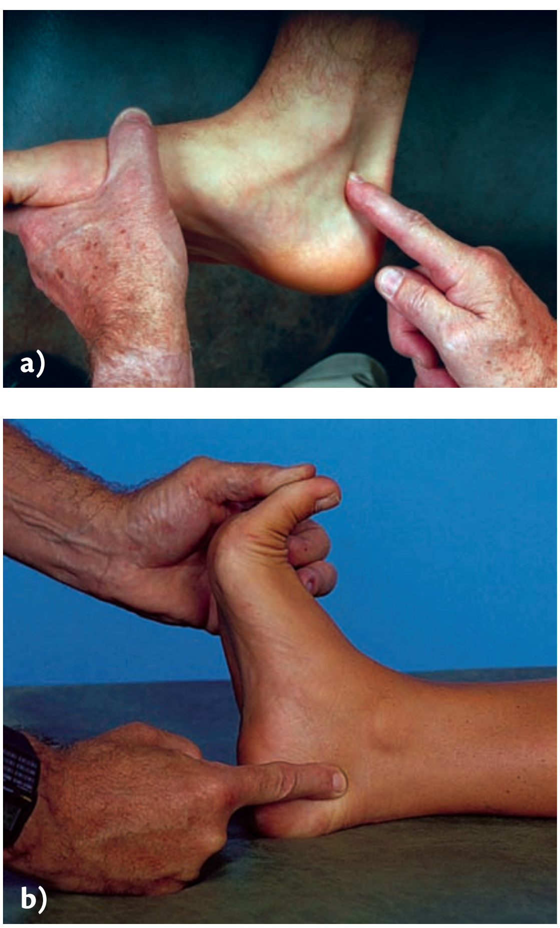


Figure 21.41 Injury to the flexor hallucis longus tendon. **a)** Local tenderness can be felt behind the tendon or below the medial malleolus; **b)** pain is elicited by forceful dorsiflexion of the big toe (the big toe is bent upwards).

- Operate to release the tendon sheath, a procedure that can be done arthroscopically. The scar tissue from surgery can sometimes be as incapacitating as the tendinopathy was present prior to surgery. Dancers require at least 3 months of slow, progressive rehabilitation before they will be able to return to dancing en pointe.

Anterior tibial tendon injuries

The tendon of the tibialis anterior muscle runs down the front of the lower leg and across the ankle joint, bending the ankle joint upwards. This tendon and its sheath can become inflamed in any part of its course. The inflammation can occur as a result of overloading or external pressure, often because of shoes or skating boots that are laced too tightly. There can also be a rupture resulting in swelling, tenderness and weakness in dorsiflexion of the foot. The injury may occur in ice hockey, team handball and basketball players, and also in runners and racquet players.

Symptoms and diagnosis

- Pain is triggered, when the foot is dorsiflexed at the ankle joint.
- There is a significant reduction of strength in dorsiflexion.

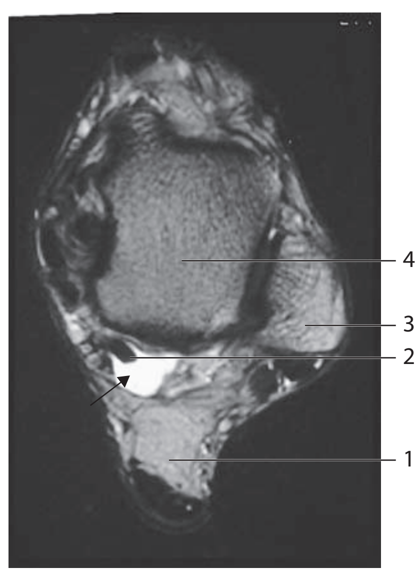


Figure 21.42 Magnetic resonance imaging of the flexor hallucis longus tendon. 1. Calcaneus 2. Flexor halluces longus tendon 3. Fibula 4. Talus.

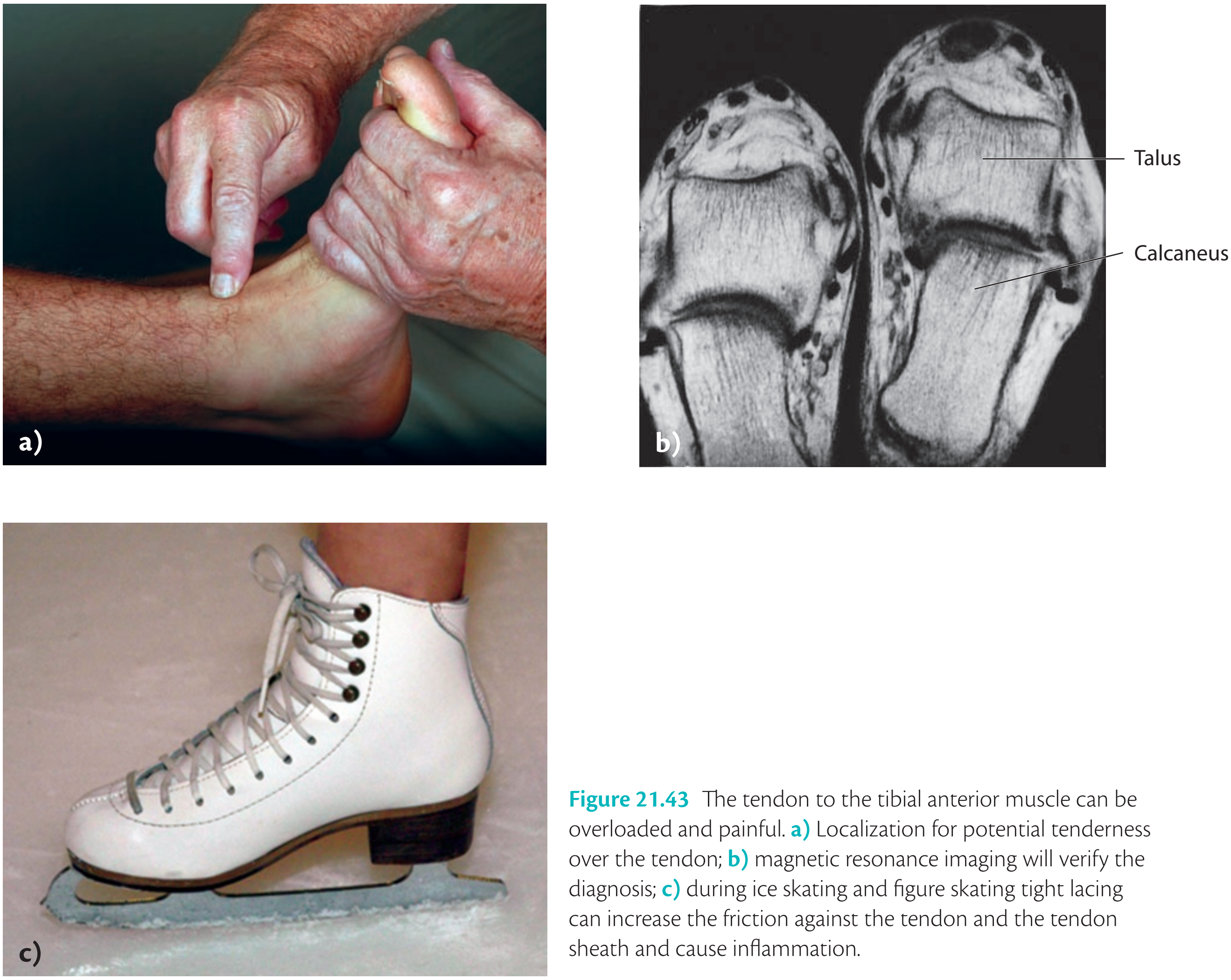


Figure 21.43 The tendon to the tibial anterior muscle can be overloaded and painful. **a)** Localization for potential tenderness over the tendon; **b)** magnetic resonance imaging will verify the diagnosis; **c)** during ice skating and figure skating tight lacing can increase the friction against the tendon and the tendon sheath and cause inflammation.

- Tenderness, swelling, and sometimes redness occur over the tendon in the acute phase and function is impaired.
- Crepitus (creaking) can be felt if the foot is bent up and down when the injury is in its acute phase.
- MRI will support the diagnosis (Fig. 21.43).

Treatment

The athlete should:

- Rest from painful activities, especially dorsiflexion of the ankle.
- Apply ice massage in the acute phase (alternately with heat treatment).
- Apply local heat and use a heat retainer after the acute phase.
- Relieve pressure on the tendon by distributing the pressure of the shoe or skating boot over the surrounding parts of the foot, e.g. by putting foam rubber between the lacing and the tendon.

The physician may:

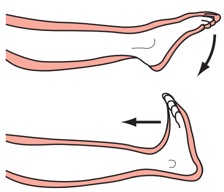
- Prescribe anti-inflammatory medication and ointments.
- Prescribe an exercise program after the acute phase.
- Apply a plaster cast or walking boot in severe cases when the injury is in its acute phase.
- Operate in cases of complete rupture.

Specific ankle rehabilitation

The biomechanics of the ankle and foot are important for the normal function of the lower extremity. The foot is the terminal joint in the lower kinetic chain.

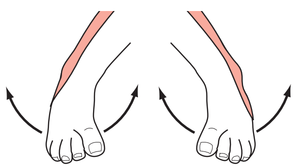
ROM exercises

Ankle dorsiflexion and plantar flexion



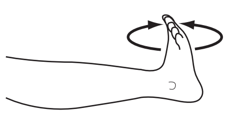
- Sitting with your legs out straight, pull your whole foot and ankle up towards you as far as possible, keeping your knee straight.
- Hold for 5 seconds, then push your foot and ankle away from you as far as possible. Hold for 5 seconds.
- Use a belt around the foot to help the dorsiflexion. Repeat.

Ankle inversion and eversion



- Sitting on a chair with the foot on the floor and a towel under the foot move the lower leg from side to side.
- Be sure to keep the sole of the foot to the floor so that the movement occurs in the foot, not in the leg. Hold for 5 seconds, then turn the sole of the foot outward as far as it goes. Hold for 5 seconds. Repeat.

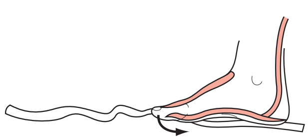
Ankle circles



- Sitting with your legs out straight, turn your involved foot in small circles clockwise.
- Repeat counterclockwise. Start with small circles, then gradually increase the size of the circle.
- Repeat 10 times each way.

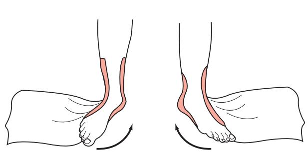
Ankle strengthening

Towel curls (toe and foot flexors, extensors)



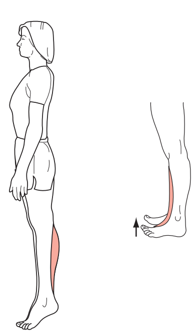
- In a seated position, spread a towel out on the floor in front of you.
- Place the heel of the involved foot on the towel. Try to curl the towel up using your toes, keeping the rest of your foot still.
- Progress by placing a small weight or book on the end of the towel for more resistance. Repeat 5–10 times.

Towel inversion/eversion (ankle and foot inverters/everters)

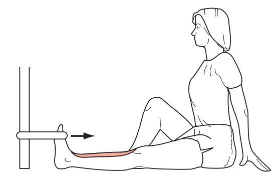


- From a seated position, spread a towel out to the side of the involved foot.
- Place the heel of the foot on the end of the towel and rotate your foot inwards, pulling the towel with your toes and foot.
- Repeat until you reach the end of the towel. Spread it back out and repeat 5–10 times.
- Repeat the above exercise with the towel spread to the inside of the involved ankle, and rotate the foot outwards, pulling on the towel. Repeat 5–10 times.

Heel raise (gastrocnemius, soleus)

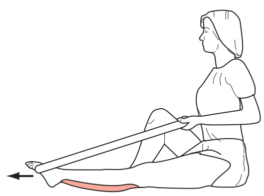


- Stand with equal weight on both feet.
- Slowly rise up on your toes as far as possible, then lower. Repeat 10–15 times.
- Progress to standing on your involved leg only and repeat the exercise. This may also be done with the heels hanging off the edge of a step for additional ROM.



Toe raise (ankle dorsiflexors)

- Stand with equal weight on both feet.
- Lift your toes and the front of your foot off the floor, keeping your heels in contact with the floor. Slowly lower. Repeat 10–15 times.



Exercises using rubber tubing

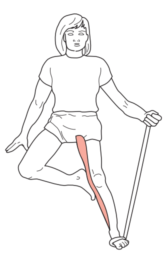
Secure a length of rubber tubing to a stable object low to the ground. Perform 2 or 3 sets of 10–15 repetitions.

Resisted dorsiflexion

- Sitting on the floor with your legs out straight in front, loop the tubing around the top of your foot just below your toes.
- Slide back to place some tension on the tubing.
- Slowly pull your ankle towards you as far as possible against the tubing.
- Slowly lower. Repeat.

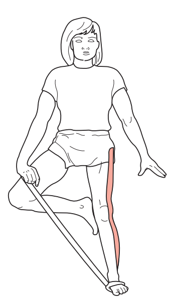
Resisted plantar flexion

- This exercise can be done instead of standing heel raises if the patient is not ready for that level of loading.
- Sitting on the floor with your legs out straight in front, loop the tubing around the ball of your foot, and hold the other end in your hand.
- Slowly point your foot downwards against the tubing, then slowly return to the starting position. Repeat.



Resisted inversion

- Sitting on the floor with your legs out straight in front, loop the tubing around the top of your foot just below the toes. The tubing should be to the outside of your involved leg.
- Slide your body to the side to place some tension on the tubing.
- Slowly turn the sole of your foot inwards, pulling against the tubing. Ensure the motion is coming from your foot and that your whole leg is not rotating.
- Slowly return to the starting position. Repeat.



Resisted eversion

- Sitting on the floor with your legs out straight in front, loop the tubing around the top of your foot just below your toes. The tubing should be to the inside of your involved leg.
- Slide your body to the side to place some tension on the tubing. Slowly turn the sole of your foot outwards, pulling against the tubing.
- Ensure the motion is coming from your foot and that your whole leg is not rotating.
- Slowly return to the starting position. Repeat.

Table 21.2 Rehabilitation protocol for acute ankle sprain (see p. 502)

	Early phase	Intermediate phase	Late phase	Return to activity
Goals	Reduce/control pain, swelling Protect joint Maintain ROM	Increase A/PROM Protect joint Increase function Initiate strength training	Resolve strength deficits Functional progression of activities	Prepare for return to activity
Weight-bearing status	To tolerance with ankle stabilizing brace of choice	Full weight bearing with ankle support brace of choice	Full weight bearing	Full weight bearing
ROM, flexibility	Active PF/DF, toe extension	AROM IN/EV, PROM exercises: PF/DF, IN/EV Achilles towel stretch Standing calf stretch	Standing calf stretch	Continue previous program
Open kinetic chain strength training	Isometric PF/DF; IN/EV Towel curls	Rubber tubing exercises: PF/DF, IN/EV Towel curls Towel IN/EV	Continue previous program Add: rubber tubing exercises – multiaxial ankle exerciser	Continue previous strength training Lower extremity strength training
Closed kinetic chain strength training	One-foot balance as tolerated	Heel raises Toe raises	Lunges, hops, bounds Quick feet (forward, back) Backward/forward running	Carioca, side-to-side hops, bounds Plyometric drills
Functional/ proprioceptive	Maintain fitness: stationary cycling, swimming	Double leg stance balance board Balance drills, stork stands Maintain fitness: cycling, swimming, stair climbing, pool running	Single leg stance balance board Slide board, agility/ balance drills Run, cycle, swim, stair climbing	Functional running patterns Jump rope Box agility drills

AROM: active range of motion; DF: dorsiflexion; EV: eversion; IN: inversion; PF: plantar flexion; PROM: passive range of motion.

Table 21.3 Rehabilitation protocol for lateral ankle reconstruction (anatomic) (see p. 517)

	Time elapsed since operation			
	0–3 weeks	**3–6 weeks**	**6–12 weeks**	**12 weeks to 4–6 months**
Goal	Reduce control/pain, swelling Initiate ROM exercises	Normalize ROM Initiate strength training Increase function	Normalize strength Reduce functional deficits	Prepare for return to activity
Weight-bearing status	Weight bearing to tolerance in ankle brace or walking boot	Full weight bearing in ankle stabilizer brace of choice	Full weight bearing Ankle stabilizer brace for activity	Full weight bearing

contd...

Table 21.3 Rehabilitation protocol for lateral ankle reconstruction (anatomic) (see p. 517) (*contd...*)

	Time elapsed since operation			
	0–3 weeks	**3–6 weeks**	**6–12 weeks**	**12 weeks to 4–6 months**
ROM, flexibility	PROM DF/PF Limited AROM toe flexion/extension	AROM DF/PF Avoid extreme IN/EV At 8 weeks: Achilles towel stretch	AROM, PROM exercises Achilles tendon towel stretch	Continue ROM, stretching
Open kinetic chain strength training	None	At 8 weeks: – isometrics: DF/PF, IN/EV – rubber tubing exercises: DF/PF	Full isotonic/isokinetic strengthening: all planes Rubber tubing exercises: four planes	Continue previous strength training
Closed kinetic chain strength training	None	Heel raises Toe raises	Straight-ahead lunges, hops, skip Quick feet (forward, back)	Carioca, side-to-side hop, lunge, skip drills Plyometric drills
Functional/ proprioceptive	Maintain fitness: stationary cycling with walking boot on	Double leg stance balance board Gait training Fitness activity: cycling, swimming, deep water running	Single leg stance balance board Slide board Fitness activity: cycling, swimming, stair climbing	Functional running patterns Jump rope Sport-specific drills Agility/balance drills Jogging on flat surface at 4 months
Restrictions	No stretching or strength training	No weight-bearing sports	None	None

AROM: active range of motion; DF: dorsiflexion; EV: eversion; IN: inversion; PF: plantar flexion; PROM: passive range of motion.

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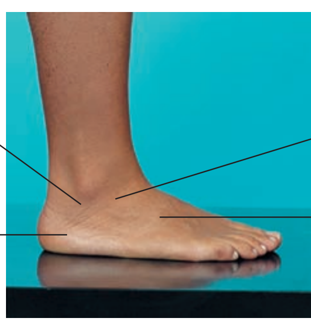
22

Foot Injuries in Sport

The foot is a strong and complex mechanical structure, which receives and distributes the body load when walking, jumping and running. Most sports contain elements of running or jumping, during which the strains on the lower extremities of the body increase sharply (see Chapter 6).

Anatomy and function

The lower extremities should be seen as functional units in which different parts cooperate. Deviations from the normal anatomy of the foot can cause problems in the knee and hip joints, and vice versa (Figs 22.1–22.4).



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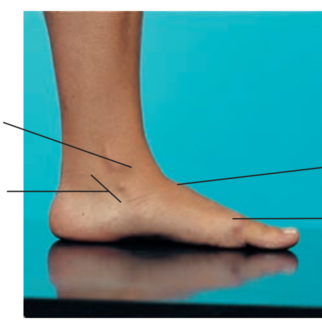

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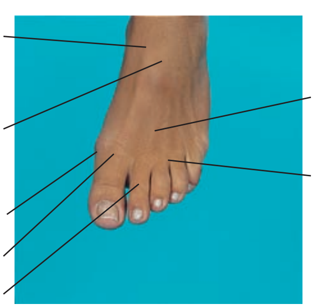

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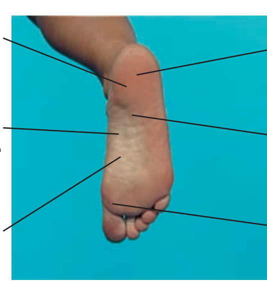


22.4

Figure 22.1–22.4 Localization of various sports injuries to the foot.

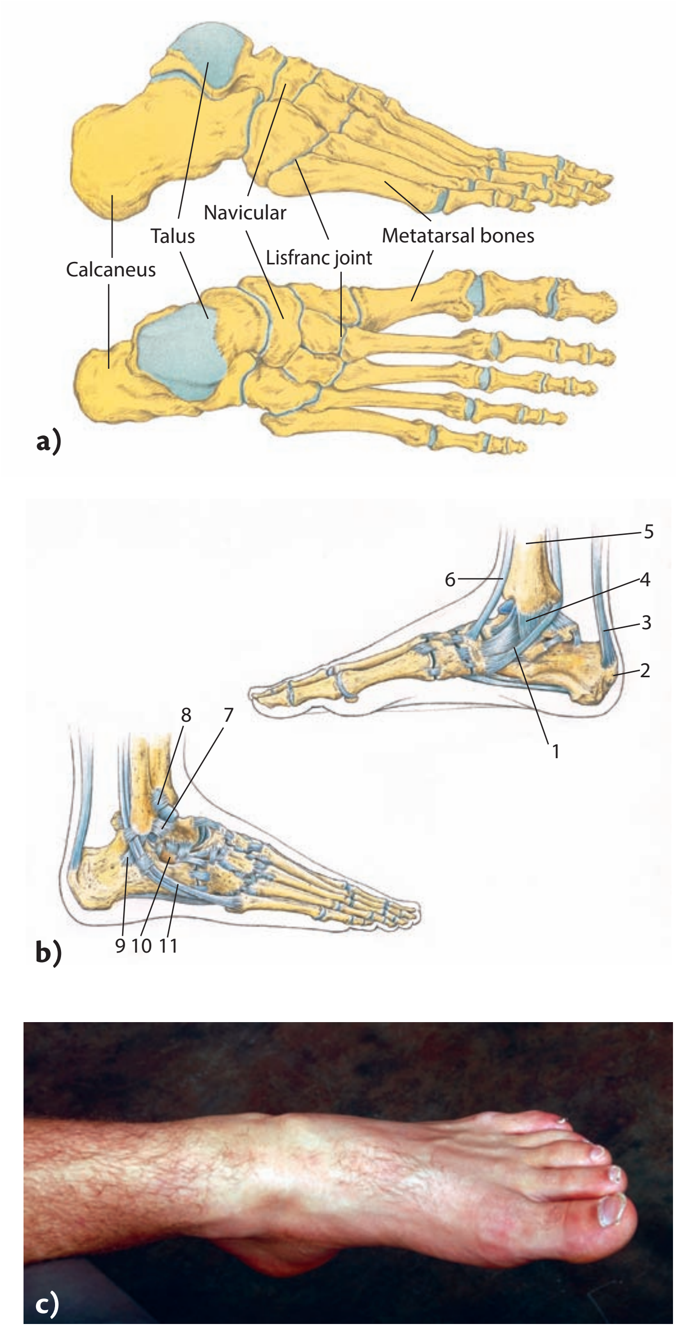


Figure 22.5 Foot anatomy. **a)** The foot bones and joints viewed from the outside (lateral) and above (anterior); **b)** the foot architecture viewed from the outside (lateral) and the inside (medial) 1. Posterior tibial tendon 2. calcaneus 3. Achilles tendon 4. deltoid ligaments 5. tibia 6. anterior tibial tendon 7. ATFL 8. syndesmosis 9. CFL 10. sinus tarsi 11. peroneal tendons **c)** the foot as seen from above; **d, e)** the foot is exposed to various movements and loads, shown here in gymnastics.

The foot comprises 26 different bones, which are interconnected at 33 joints and held together by numerous ligaments and joint capsules (Fig. 22.5). Some 30 tendons, including those of the muscles of the lower leg and those from the muscles of the foot itself, are involved when the foot moves. The foot can be divided into three parts:

- The hindfoot consists of the talus (ankle bone) and the calcaneus (heel bone).
- The midfoot consists of the navicular bone, four other bones (the cuboid and three cuneiform bones).
- The forefoot consists of the five toes and the five proximal long bones forming the metatarsal bones. The big toe, like the thumb, consists of only two phalanges, while the other toes consist of three. The length and shape of the toes can vary considerably. When the toes are loaded, the big toe is pressed against the surface while the other toes make a grasping movement. Under the head of the first metatarsal bone there are two sesamoid bones.

There are two arch systems in the foot: a transverse anterior arch, and a longitudinal medial arch, which follows the inside of the foot from the calcaneus to the metatarsophalangeal joint of the big toe. The transverse anterior (front) arch runs obliquely across the tarso-metatarsal joints and is held together by the fibrous joint capsules and ligaments, including the plantar aponeurosis (the arch ligament), which runs along the arch from the calcaneus to the toes. In an unloaded state the ligaments maintain the shape of the arch; in a loaded state they are stretched as the arch is pressed against the surface. The more the arch is loaded, the tighter the ligaments become.

Many movements of the foot and toes are controlled by muscles that have their origins in the lower leg and whose tendons are attached to the foot. Movements of more precision are controlled by muscles that have both their origins and insertions in the foot itself.

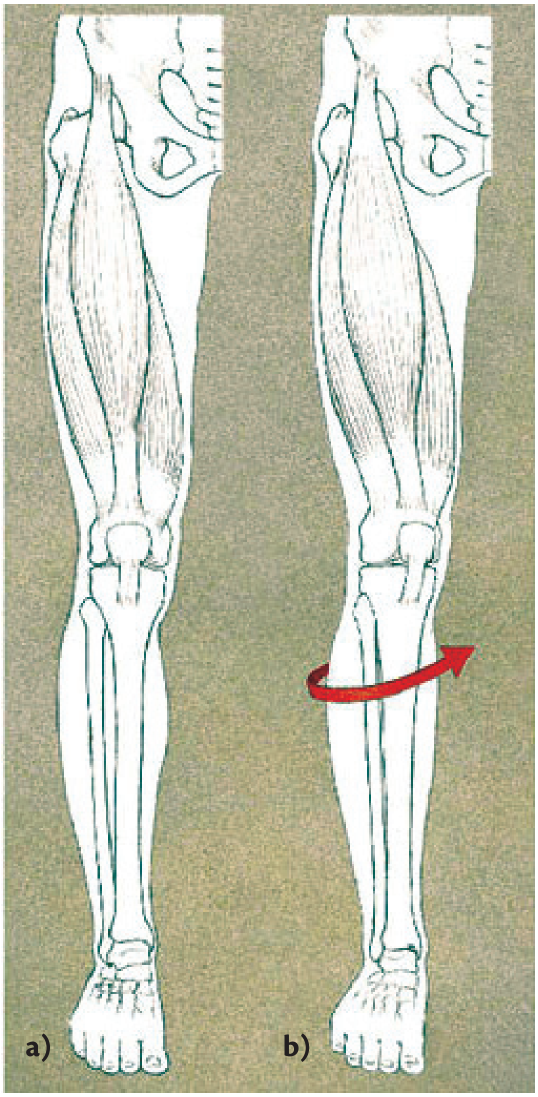


Figure 22.6 Foot pronation, i.e. foot sole is turned outward. The leg in the normal position **a)** and with pronated foot **b)**. When the foot is in excessive pronation, the result is often a compensatory inward rotation of the lower leg.

Foot movements

The foot has two axes around which movements can be made. One runs horizontally through the talus and is the axis for vertical movements at the ankle joint. The other axis runs diagonally, starting from behind in the lower part of the calcaneus and extending forward and upward through the head of the talus. The movements the foot makes around this diagonal axis are known as pronation and supination.

In pronation the sole of the foot is turned outward and the main part of the inside of the foot has contact with the ground, as in the position of a flat foot (Fig. 22.6).

In supination the sole of the foot is turned inward, so that the medial border of the foot is higher than the outer border.

Running and walking

During running and walking, the foot is slightly supinated just before it is planted. The foot is usually placed on the ground with the outside of the heel touching first. During the supporting phase the arch is loaded and flattened and pronation begins which, together with contraction of the calf muscles, causes the forces generated to spread through the whole foot and leg. The flattening of the longitudinal arch continues until the arch ligament (plantar aponeurosis) is tightened. By this time the forces generated by the body weight have passed through the foot, and preparations for push-off have started. The foot is in pronation for about 40–70% of the supporting phase and then gradually changes into supination, which stabilizes the front of the foot so that a better lever is available for push-off.

The angle of the foot

The angle of the foot in relation to the lower leg is important. The angle can be checked against skin markings, which are made along the anterior tibia. The vertical axis through the talus and the calcaneus should be parallel to the tibial skin markings; it should also be at right angles to a line through the anterior transverse arch.

Causes of foot overuse injuries

The causes of foot injuries in running are multifactorial. Factors that influence the distribution of load include: anatomical features, body weight, shoe type, running surface, technique and training program.

Anatomical factors

Significant deviations from the normal anatomical structure of the foot (e.g. excessive pronation and pes cavus) can cause injuries, but even minor variations and/or malalignments can be sufficient to do so if subjected to prolonged or repeated loading.

Pronated foot

Pronation occurs when weight is transferred from the heel to the forefoot and the foot rolls inwards/the sole turns outwards upwards and sideways. A certain degree of pronation is normal in a foot that is loaded, but excessive pronation is a compensatory movement caused by an incorrect relationship between the heel and the foot or between the leg and the foot (Fig. 22.7). It is common for the relationship between leg and foot to be slightly imperfect, and the result can easily be inadequate balance. During weight bearing, the soles of the feet can be forced against the ground by excessive pronation.

During running, overuse injuries can recur because excessive pronation, or pronation maintained for too long in the supporting phase, causes increased stress on the supporting structures of the foot and also causes increased work for the muscles. Excessive pronation may also be a mechanism by which the body compensates for other slight anatomical defects and deviations.

Excessive pronation can be confirmed by the 'wet foot' test (Fig. 22.8). The foot is dipped in water and footprints are made by walking on a smooth, dry surface. The footprints then show the load distribution across the foot. When the foot is normal the longitudinal arch does not leave a print, but if excessive pronation is present, a print of the whole foot appears.

Excessive pronation during walking or running may cause increased load on the whole of the lower extremity, since it results in an increased internal (medial) rotation of the lower leg, knee and thigh. This hyperpronation (overpronation) internally can lead to a change of the biomechanical work pattern of the thigh musculature so that the lower leg, the knee and the hip are subjected to increased load. This can be the cause of overuse injuries or other painful conditions in these areas. Injuries associated with excessive pronation include chondromalacia

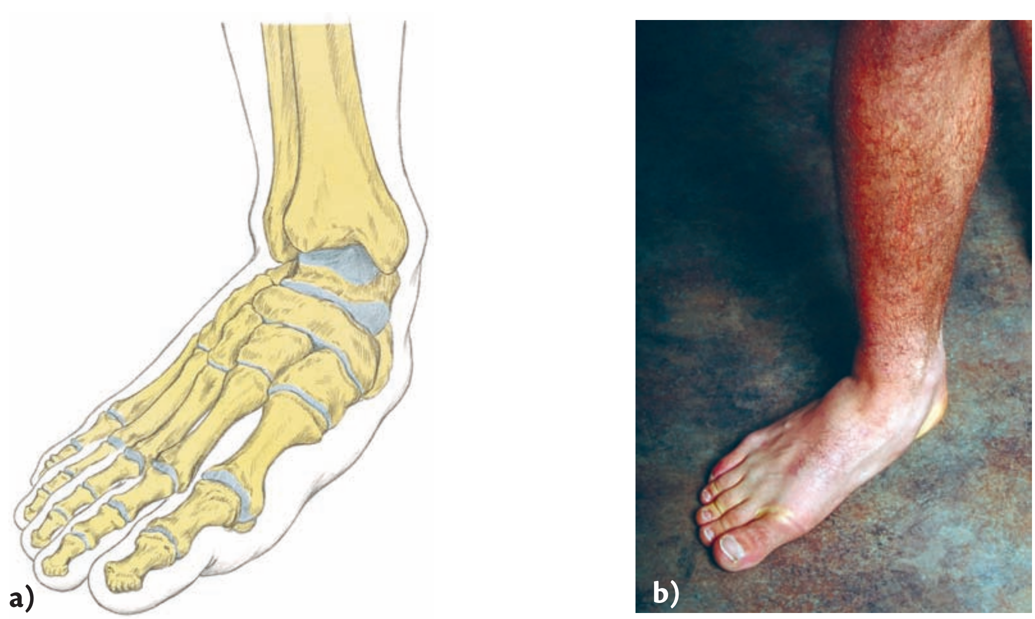


Figure 22.7 a, b) Pronation is normal in a loaded foot. Over-pronation (excessive pronation, hyperpronation) is an excessive compensatory movement, which causes an erroneous functional anatomy.

Figure 22.8 The foot arch configuration can be observed by the wet footprint step test. **a)** Foot with high arch (cavus foot); **b)** normal foot; **c)** foot with flattened arches, due to increased pronation (flatfoot), among other conditions.

Figure 22.9 Cavus foot, i.e. a high foot longitudinal arch.

patellae, tibialis posterior syndrome, plantar fasciitis and trochanteric bursitis. It is, however, important to stress that the anatomical changes – malalignments – bear no direct relationship to a specific diagnosis. The diagnosis can well be made by a podiatrist, physiotherapist or similar, who can do a full gait analysis on a treadmill or using force-plates measuring the forces and angles of the foot while running. An extra medial support and/or an orthotic device will be helpful for this problem.

Cavus foot (claw foot)

A cavus foot has a congenitally abnormal high longitudinal arch and the sole of the foot is distinctly hollow when bearing weight. A high arch is the opposite of a flat foot and less common (Fig. 22.9).

Cavus foot is relatively inflexible and has a limited articular range of motion (ROM). It is often combined with tight calf musculature and a tight plantar aponeurosis. The weight-bearing surface is relatively small, often concentrated to three points, i.e. the heel, the big toe and little toe. There is a risk of concentration of pressure resulting in abnormal loading conditions.

Symptoms and diagnosis

- The foot is less flexible, and its arch is hardly flattened at all under load.
- Hammer toes can develop (the toes are bent and cannot be straightened).
- The big toe is displaced downwards, which often leads to the formation of painful calluses.
- Pain on prolonged exertion.

Tip

Excessive cavus feet do not usually tolerate long-distance running very well.

Treatment

- Plan to reduce and redistribute plantar pressure loading with the use of foot orthotics and specialized cushioned footwear, such as specially made arch supports with good shock-absorbing properties can be used. Shoes with 1 cm (0.5 in.) heel wedges of a semi-rigid material can be of value in relieving calloused areas and spread the loading.
- Static stretching exercises of tight and weak muscles can be carried out on a board inclined at an angle of about 35°. The athlete then performs strengthening exercises with alternating toe and heel raises.
- Any plantar callosities (calluses) should be debrided, and the shoes should be modified to relieve pressure and distribute the load over the sole of the foot.

Extrinsic factors

Extrinsic factors such as faulty training programs or slippery roads can cause foot injuries (see Chapter 3).

Hindfoot, heel problems

- Hindfoot discomfort can be localized to the heel or to the medial and lateral aspects of the calcaneus. Medial symptoms can be caused by nerve entrapments or injuries to the flexor tendon groups.

- Tarsal tunnel syndrome (p. 546) can be caused by entrapment of either the posterior tibial nerve or one of its branches, or of the medial and lateral plantar nerves under the flexor retinaculum.
- A tear or tendinopathy of the tibialis posterior tendon (p. 528) can also cause proximal arch pain. Pain can radiate distally into the longitudinal arch and may be associated with swelling and thickening of the tendon.
- A tear or tendinopathy of the flexor hallucis longus tendon (p. 530) can also cause pain on the medial side of the hindfoot.

Heel pain has many causes, including nerve entrapment, plantar fascia injury and stress fractures. Heel pain can also be caused by painful heel pad syndrome, plantar fasciitis (see below) or rupture of the plantar fascia (Fig. 22.10). A calcaneus stress fracture can cause pain on weight bearing and is characterized by distinct tenderness elicited by compression of the medial and lateral aspects of the heel. Nerve entrapments are not uncommon.

Heel fat pad pain syndrome – sore heel

The heel cushion is composed of elastic adipose tissue surrounded by a fascia of connective tissue attached to the skin. The fascia forms a spiral fibrous septum with U-shaped compartments oriented vertically, creating a multiple array of small compartments containing fat. The resulting structure is designed to resist compressive loads (Fig. 22.11).

Unlike the skin on the top (dorsum) of the foot, the skin of the sole of the foot cannot slide backwards

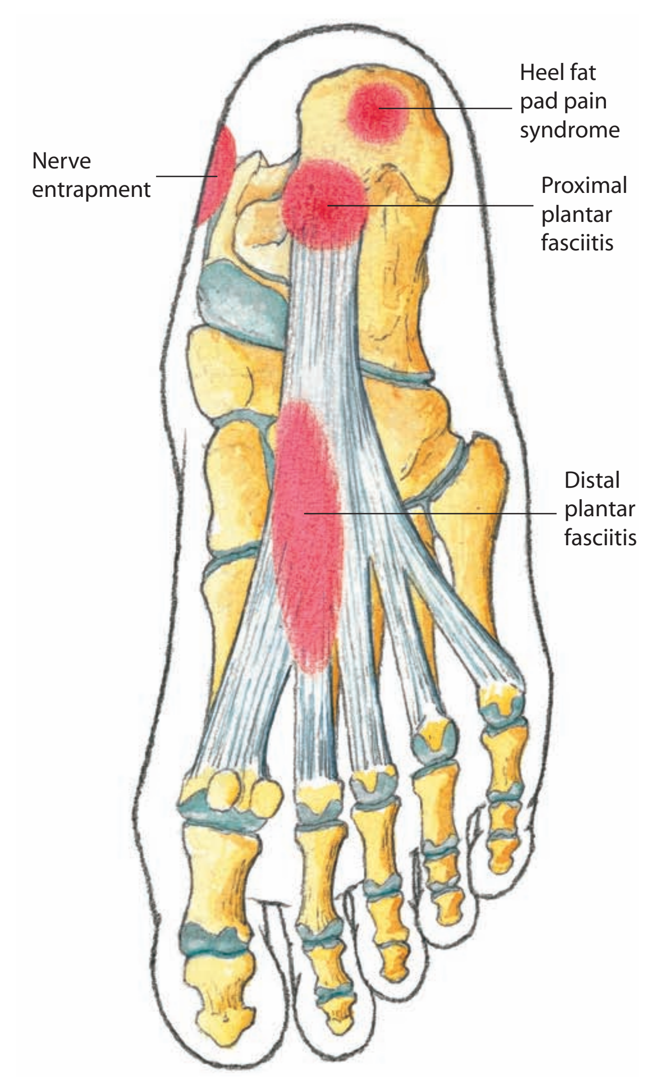


Figure 22.10 Heel pain can have many causes. Frequently painful areas are marked in red.

Figure 22.11 Pain in the heel cushion. **a)** Repeated jumping can cause a rupture of the connective tissue that surrounds and forms the fat; if these walls holding up the fat cells are pressed outward, the protective effect of the fat cushion decreases; **b)** localization for tenderness under the heel.

and forwards over the tissues beneath. Repeated jumps landing on the heels on a hard surface, as performed by hurdlers, long-jumpers and triple-jumpers can tear or stretch out these connective tissue bands/fascias. The fat in the compartments is pressed outwards from the area of the heel that is in contact with the running surface, reducing the protective effect of the fat cushion to unload the underlying bone. With less protection, the skin and underlying bone become more sensitive to pain during loading. After the age of 40 years the adipose tissue often gradually deteriorates, creating a softer, thinner heel pad.

The athlete often complains of diffuse plantar heel discomfort, that is worse when running and landing on hard surfaces. There is no radiation of this pain. If the ruptures in the connective tissue bands are minor and recent, there is only local tenderness in the heel cushion (Fig. 22.12); however, in long-standing cases the underlying bone can be felt beneath the skin, and the condition is then very difficult to treat. It must therefore be prevented.

Partial relief can be achieved by using shorter steps when running to decrease the load on the heel; but the mainstay of prevention is the use of shoes that are suitable for the surface and have a heel padding/cushioning that absorbs most of the shock and distributes the forces well. Supportive cushions may be inserted under the heel. Shoes with a heel cup can contain and centralize the remaining fat tissue to enhance its protective ability. An arch support can also reduce the pressure on the heel. A heel pad support, which centralizes and supports the soft tissue, is often of great value, especially in chronic cases.

Figure 22.12 Taping of a painful heel cushion. Suitable materials include non-elastic sports tape, kinesio tape. Keep the foot at a 90° position. (For full taping instructions see Fig. 5.14.) (Courtesy of Tommy Eriksson, Swedish Track and Field Association.)

Heel pad inflammation and bursitis

Trauma to the foot or overuse can occasionally cause inflammation of the heel pad. Between the calcaneus and the heel cushion there is a small bursa that can become inflamed and painful after impact loading, as in basketball or running. Due to this inflammation the fat pad can become so tender that the athlete cannot withstand weight-bearing loads. Running and sometimes even walking becomes impossible for the injured athlete, and rest is recommended.

This condition most often occurs in middle-aged adults and athletes, but can occur at any age. It may be bilateral in 10–15% of cases. Long-distance runners with cavus feet seem to have this injury more often.

On examination the heel pad is tender and firm. This injury is generally self-limiting with conservative treatment. Heel cups or an arch support with a notch for the painful area may be effective.

Plantar fasciitis: heel pain syndrome (heel spur), ('plantar fasciopathy')

The arch ligament, plantar fascia or plantar aponeurosis is a thick fibrous band of connective tissue that runs forwards from the plantar medial aspect of the calcaneus to blend with ligaments attached to the toes. When the heel is lifted during take-off or running uphill, the angle between the toes and the metatarsals increases and the aponeurosis is stretched (Fig. 22.13).

Plantar fasciitis is common. It is estimated to affect 1 in 10 people at some point during their lifetime and most commonly middle-aged people (between 40 and 60 years of age) are affected.

As the toes are bent more, the aponeurosis becomes more stretched and the longitudinal arch is thereby stabilized. However, a taut aponeurosis also becomes a potential injury site. During a vigorous take-off, a rupture can occur in the origin of the plantar aponeurosis or in the short flexors of the toes. Injuries can also occur during a fast turn, which causes increased load on the tissues of the sole of the foot. Plantar fasciitis can also be the result of overuse. In a more chronic injury there are signs of scarring, inflammation, or structural breakdown more consistent with a degenerative process. Perhaps it is time to change the name to plantar fasciopathy or fasciosis.

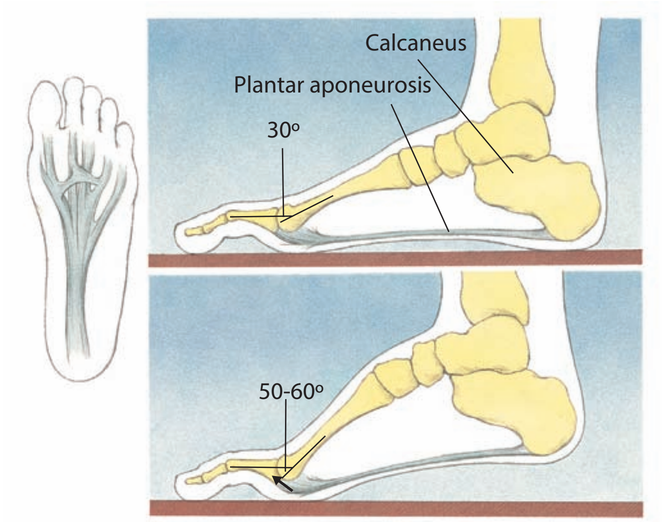


Figure 22.13 Plantar fasciitis ('heel spur'). When running uphill, the angle between the toes and the hindfoot increases, so that plantar fascia is stretched in a longitudinal direction with increasing load on the attachment on the heel bone (calcaneus).

Athletes who have excessive pronation of the foot are more likely to develop an overuse injury or a tear in the origin of the plantar aponeurosis. When, as a result of the pronation, the arch is stretched and the toes spread out, the aponeurosis is subjected to increased strain. Prolonged sporting activity in shoes that do not provide sufficient support for the arch can also contribute to plantar fascial pain. However, no clear link between heel pain syndrome and flat foot (pes planus) or claw foot (pes cavus) has been established, and the cause of plantar fasciitis is still unclear. This explains why so many names have been given to this condition.

Plantar fasciitis may also occur in the mid-foot (Fig. 22.13).

Symptoms and diagnosis

- The discomfort is insidious at onset.
- During initial activity, pain can be experienced at the calcaneal origin of the aponeurosis, but tends to disappear with continued activity. At rest the problems abate.
- Morning stiffness and a painful limp when the athlete gets out of bed and starts to walk are common. This stiffness goes away after a short warm up.
- These athletes may experience pain when standing on their toes and walking on their heels.
- Occasional numbness may be experienced along the outside of the sole of the foot.
- Focal tenderness and sometimes swelling of the medial aspect of the calcaneus where the aponeurosis inserts may be present (Fig. 22.14).

Figure 22.14 **a)** Local tenderness on the heel bone where the plantar fascia inserts; **b)** stretching of the foot sole should include the Achilles tendon as well as the plantar fascia (photo, Anette Heijne).

- Associated tightness of the Achilles tendon is common.
- Heel pain is more commonly seen in the shorter leg of athletes with a leg-length discrepancy.

- Medical imaging such as ultrasonography or magnetic resonance imaging (MRI) is not routinely needed. It should be noted that findings of plantar aponeurosis thickening may be absent in symptomatic individuals or present in asymptomatic individuals.
- An X-ray sometimes shows edema and/or a heel spur (bony outgrowth), which arises as an irritant reaction to the stretching of the aponeurosis attachment at the calcaneus. The heel spur originates from the origin of the flexor digitorum brevis muscle and is directed distally and sometimes in the plantar direction. Only 3% of patients with plantar fasciitis have a plantar heel spur, compared with 15% of asymptomatic patients; the exact relationship between plantar fasciitis and the heel spur has therefore not been defined.
- A triple-phase bone scan can be helpful to support the diagnosis. The delayed phase of the bone scan may be abnormal with a mild focal uptake at the level of the insertion in about 60% of the patients. The diagnosis is, however, mainly clinical.

Treatment

The athlete should:

- Cool the heel with ice if the injury is acute.
- Support the injured foot with crutches if there is pain on weight bearing.
- Learn about the injury: it is important to note that the injury is usually self-limiting.
- Modify training to avoid abuse: high impact activities should be avoided, and cycling and swimming can be substituted for running.
- Carry out static stretching exercises as a preventive and rehabilitative measure; this stretching should include the Achilles tendon as well as the plantar fascia (see Fig. 22.14B).
- Use taping to unload the area, or apply a heat retainer sock or insole (Fig. 22.15).

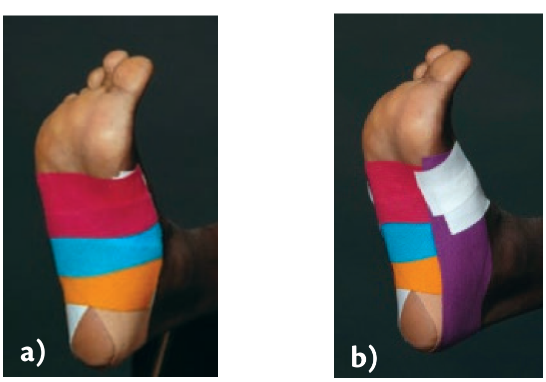


Figure 22.15 a, b) Taping of a 'heel spur' (plantar fasciitis). For full taping instructions, see Fig. 5.15. (Courtesy of Tommy Eriksson, Swedish Track and Field Association.)

- Check if the sports shoes may be causing an increased load on the aponeurosis (the shoes may be too stiff or too soft).
- Use a shock-absorbing heel cup in the shoe.

The physician may:

- Educate the patient about the injury, its chronic (but self-limiting) nature, and its extended healing time.
- Prescribe an orthotic arch support with a notch (unloading area) corresponding to the painful area; this is an effective method to reduce plantar fasciitis pain for at least up to 12 weeks.
- Prescribe a heel cup. Heel cups can be of different types:
  - ✓ a viscoelastic material that deforms slowly on cup compressive load;
  - ✓ a harder plastic cup that surrounds the heel and compresses and centralizes the fat of the pad to allow the padding to absorb the impact load better;
  - ✓ soft felt or hard plastic materials forming a heel cup and medial longitudinal arch support combination to help unload the plantar fascia.
- Prescribe a night splint or molded plastic ankle orthosis (a foot orthosis with the ankle fixed in 5° of dorsiflexion). This will hold the fascia in a stretched position throughout the night to decrease morning stiffness.
- Prescribe anti-inflammatory medication, which may have effect in some patients.
- Prescribe physical therapy, including one or more of the following: contrast baths, whirlpool, phonophoresis, iontophoresis and massage. These can often give some short-term relief but their long-term effects are limited.
- Give a corticosteroid injection. This should be given from the medial side and injected close to the bone, between the bone and the fascia. A direct injection in the heel pad should be avoided since it may cause heel pad fat hypotrophy. Such an injection may give effective pain relief for up to 1 month, but there seems to be very limited effect after 3 months.
- Dry needling is a treatment being tried out today.
- Extracorporeal shockwave therapy (ESWT) is an effective treatment modality for plantar fasciitis pain unresponsive to conservative nonsurgical measures for at least 3 months, according to several prospective randomized studies. There is scientific evidence suggesting pain relief for up to 1 year.[1]
- Carry out surgery if problems persist despite adequate conservative therapy of more than 6–12 months and is regarded as a last resort. Surgery can involve different procedures. The most common procedure

is the plantar fascia release, where the plantar fascia is cut away from its insertion on to the calcaneus. Endoscopic techniques and minimally invasive approaches are being developed and are improving, with about 80% good results today. Those who had symptoms longer than 2 years seem to have poorer results with endoscopy.

- The injury should be treated early to avoid prolonged problems. Most cases are self-limited and will improve within the span of 6 months with conservative treatment. Even with appropriate treatment, return to sports activity after a chronic injury may take 6 months or more. After surgery the return to sports activity is usually 2–3 months but can be longer. Some tenderness at the wound site may remain for a long time. An occasional complication of surgery is injury to the medial calcaneal nerve, which can result in a painful neuroma or heel pad numbness. The athlete needs to be aware of the risks before undergoing surgery.

Nerve entrapment (compression) syndromes

The most common entrapment of nerves is tarsal tunnel syndrome, which is caused by increased pressure either on the posterior tibial nerve or one of its branches, or on the medial and lateral (medio-lateral) plantar nerves. Heel pain can also be caused by entrapment of the first branch of the lateral plantar nerve (Baxter's nerve).

Tarsal tunnel syndrome (posterior tibial neuralgi)

Just below the medial malleolus there is a tunnel called the tarsal tunnel through which the medial and the lateral plantar nerves runs. One of the nerves in the tarsal tunnel is the tibial nerve, which gives sensation to the bottom of the foot (Fig. 22.16).

Excessive pronation of the foot increases the load on tissues surrounding the flexor tendons, and can cause inflammation and swelling, resulting in entrapment of these nerves (tarsal tunnel syndrome). Inflammation may also be caused from pressure by a posterior bony prominence of the talus.

The affected athlete feels pain arising from the area of entrapment. It radiates distally along the inside of the foot and along the sole towards the toes; this is the area that the nerves supply. There is direct focal tenderness over the nerve as it passes beneath the flexor retinaculum. Tapping the nerve at that area can cause a burning, tingling sensation that radiates out to the plantar aspect of the foot. The diagnosis can be verified by electromyographic (EMG) and nerve conduction studies. However, a normal study does not exclude the diagnosis.

Treatment of this injury is by an arch support with a medial heel wedge, which will decrease the tension on the nerve. Corticosteroid injection into the tarsal tunnel can be beneficial temporarily. Surgical release of the tarsal tunnel can provide relief of the symptoms in 90% of cases. Return to sports is possible within 6–8 weeks.

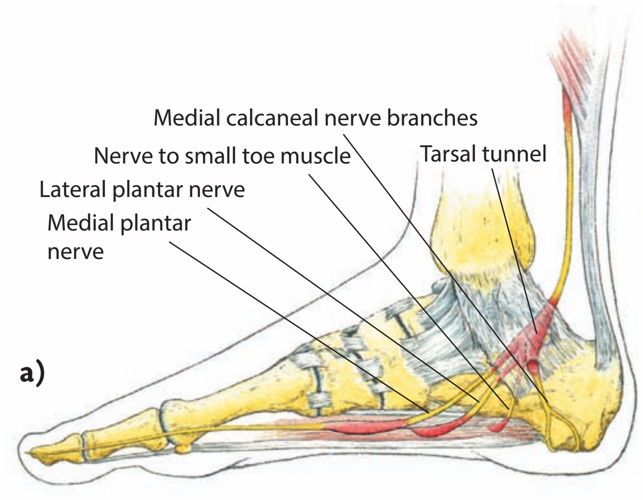
Entrapment of the first branch of the lateral plantar nerve (Baxter's nerve)

Some physicians estimate that entrapment syndromes of the branch of the lateral plantar nerve accounts for approximately 20% of chronic heel pain. This entrapment occurs as the nerve changes from a vertical to a horizontal direction around the medial plantar aspect of the heel (Fig. 22.17).

This nerve entrapment occurs most often in athletes such as sprinters and in ballet dancers, who are often on their toes. The medial calcaneal nerve branches that innervate the plantar medial aspect of the heel are not involved with entrapment of the first branch. Inflammation and spur formation at the insertion of the flexor digitorum brevis muscle into the heel can cause swelling and compression of the nerve along the plantar fascia.

This injury may cause pain towards the end of the day, or after prolonged activity. The clearest diagnostic sign is maximal tenderness where the nerve is compressed. As plantar fasciitis may predispose to this injury, there may be some tenderness over the proximal plantar fascia where it inserts into the calcaneus. Some weakness may be experienced.

The treatment includes rest, anti-inflammatory medications and physical therapy. Corticosteroid injections can be given. A shock-absorbing heel cup can decrease the inflammation in the area. In athletes with excessive pronation, a longitudinal arch support can decrease compression of the nerve. In athletes with prolonged symptoms surgery gives relief in 85% of cases, with return to sports activities within 3 months.



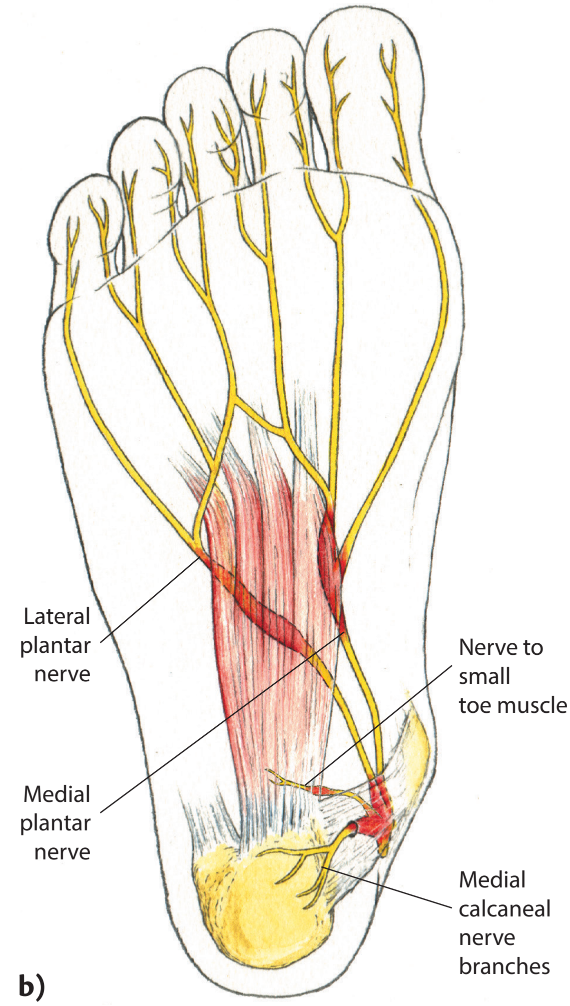


Figure 22.16 Nerves in tarsal tunnel. **a)** The posterior tibial nerve passes through the tarsal tunnel and divides into the medial branches one being the calcaneal nerve, which supplies the heel; when it becomes compromised it can cause numbness and pain in the heel. The posterior tibial nerve then divides into the medial and lateral plantar branches. Shortly after the division the lateral plantar branches out with its first branch, which innervate the abductor muscle to the little toe (Baxter's nerve); **b)** areas in the sole of the foot where trapped nerves can occur along the tibial nerve and its branches; **c)** a painful point where the first nerve leaves the tarsal tunnel on the medial side of the calcaneus.

Entrapment of the medial plantar nerve (jogger's foot)

The medial plantar nerve crosses deep to the adductor hallucis muscle, passing through the 'knot of Henry' and continuing along the medial border of the foot. Entrapment occurs at the 'knot of Henry', especially in athletes with hyperpronation of the foot (Fig. 22.17).

Athletes who have a forefoot that is pointed outward (abduction), or have the heel externally rotated (valgus), also have a predisposition to this problem. An athlete with previous ankle injuries or chronic ankle instability can also have this problem. The pain radiates distally into the medial toes and may also radiate proximally into the ankle. The pain is worse with running on curves and uphill. Tenderness occurs at the medial plantar aspect of

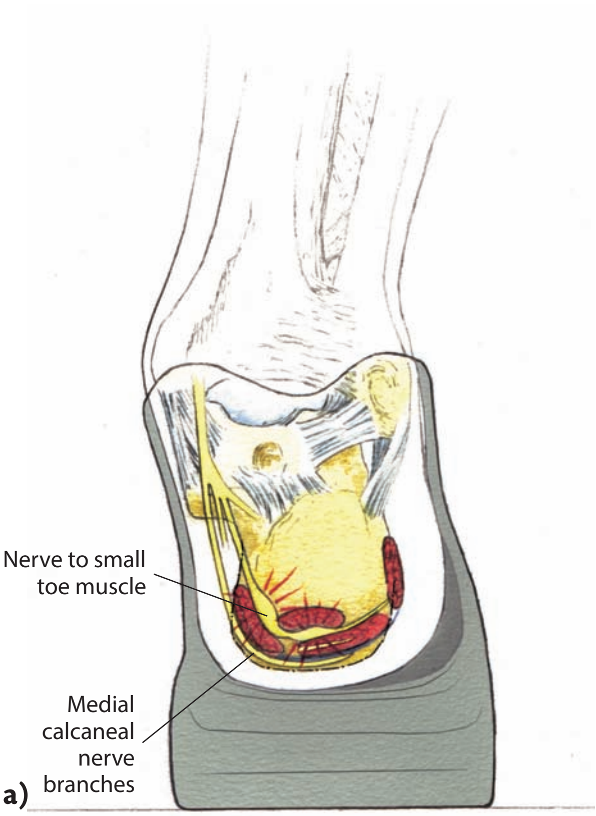


Figure 22.17 Entrapment syndrome of the medial plantar nerve. **a)** Sole of the foot with the nerve seen from behind; **b)** a finger showing where the tendon of the long flexor digitorum crosses over the tendon of the long hallux flexor, the 'knot of Henry'. Soreness can be experienced over the medial part of the heel.

the arch. Decreased sensation on the medial aspect of the foot can occur after running.

Conservative treatment is by the use of a medial longitudinal arch support or a heel lift. Surgery can be successful, with return to sports within 6 weeks.

Stress fractures of the calcaneus

Stress fractures are found in otherwise healthy individuals from the age of 7 years onwards (p. 150). Stress fractures of the calcaneus are relatively uncommon but occurs with intense jumping and running.

Symptoms and diagnosis

- Pain in the heel occurs during activity.
- There is very distinct tenderness and local swelling. Diffuse pain can be elicited by compression of the heel from both medial and lateral sides. Pain is not localized only to the plantar aspect of the heel.
- An X-ray of the injury shows no fracture in about half the cases. If there is still a suspicion that the injury is a stress fracture, another X-ray may be taken 2–3 weeks later when healing tissue (callus) can be seen around the fracture.
- If the X-ray does not prove the existence of a fracture, MRI or a bone scan can confirm the diagnosis.

Treatment

- Weight-bearing is permitted as tolerated; crutches are usually needed initially.
- A shock-absorbing heel pad can be beneficial.
- Treatment otherwise is as described on p. 153.
- The injured athlete can resume sporting activities to the full extent when free of symptoms. This usually occurs 6–8 weeks after symptom onset, but only after the injury has healed radiographically.

Fractures of the talus

The talus (ankle bone) can be fractured in motor sports, parachuting, football, downhill skiing, ski-jumping, high jumping and indoor sports. This injury is rare and difficult to treat, and is likely to be complicated by injuries to the blood vessels that provide nutrients to the talus. The loss of blood supply can prejudice healing and complications are common.

Fractures of the calcaneus

In traumatic injury and falls from a height, fractures of the calcaneus can occur. The injured person finds it difficult to stand on the foot because of pain and severe swelling. The treatment consists of rest with a varying degree of relief from weight bearing; sometimes surgery is considered. A fracture of the calcaneus can cause prolonged, and sometimes permanent, disability.

Tarsal coalition

Tarsal coalition is a condition of abnormal union of two or more bones in the foot. The coalition may be by bony, fibrous or cartilaginous tissue. The union of bones may cause symptoms by restricting the motion of one of the joints in the subtalar complex, imposing strain on the other joints and producing pain. Coalition sites are between the talus and the navicular bone, and between the talus and the calcaneus. Union may also occur between other bones. Talo-navicular coalition is unusual and can be seen at a very early age.

The calcaneal coalition, which is uncommon, can give symptoms of pain, stiffness and decreased pronation/supination in children aged 8–12 years. The diagnosis can be confirmed by X-rays if there is a bony union; sometimes a computed tomography (CT) or MRI scan is needed. Treatment includes the use of an orthotic support or a brace to decrease painful subtalar motion. Often surgical treatment is needed. Prolonged rehabilitation is required before return to sport is possible.

Midfoot problems

The midfoot consists of the tarsal and metatarsal bones: the navicular, cuboid, three cuneiforms and five metatarsal bones. Dense ligaments and fibrous capsules between these bones create marked stability and a rigid structure. Most motion occurs in the 'sports joint', the transverse tarsal joint. Isolated injuries of the midfoot are rare and atypical, requiring high-energy forces. Conditions affecting the midfoot involve sprains of the ligaments as well as arthrosis of the joints. The accessory navicular, an extra bone, can cause pain on the medial midfoot. Stress fractures of the navicular can also occur.

Distal plantar fasciitis

Distal plantar fasciitis presents with localized pain and tenderness of the midportion of the plantar fascia in the midfoot. It is much less frequent than conventional plantar fasciitis. The pain can radiate proximally or distally, but is most pronounced in the midfoot. This injury occurs more frequently in sprinters and middle-distance runners, who use their forefeet and toes more during running. On physical examination there is often a tenderness of the midfoot of the plantar fascia that is a little more diffuse than in conventional plantar fasciitis. Dorsiflexion of the toes can increase the patient's symptoms as the fascial fibers are stretched.

Treatment can include: circumferential taping, anti-inflammatory medication, physical therapy and plantar fascia stretching. A medial heel wedge or orthotics may decrease tension on the plantar fascia, but can sometimes increase the athlete's problems. This injury is usually self-limiting and can heal with conservative therapy. The prognosis is good.

In some cases a tear of the aponeurosis may occur. Most of these tears occur in athletes who have been treated with local steroid injections. These tears are most commonly treated conservatively but occasionally surgery is required.

Midtarsal sprains

The midtarsal joints hold a key position in the medial–lateral longitudinal arches; they also act together with the subtalar joints during inversion and eversion. Injuries range from non-displaced ligamentous injuries and subluxations to dislocations. Conservative treatment is indicated for undisplaced ligamentous injuries, with a short immobilization period and active mobilization of the ankle and the foot thereafter. All displaced midtarsal dislocations need anatomic reduction with internal fixation.

Tarsal navicular stress fracture

Tarsal navicular stress fractures occur most commonly in track and field athletes, especially runners and jumping athletes. There is no agreement of the risk factors involved, but some of the following are discussed: pes cavus, wide-heeled shoes, short first metatarsals, limited subtalar motion and limited ankle dorsiflexion.

The pain is insidious and localized to the arch. It presents itself as vague, aching pain in the midfoot with motion and weight bearing, and limited dorsiflexion of the ankle. The symptoms are vague and uncharacteristic, and diagnosis is often difficult. There may be tenderness localized to the navicular bone, but this is not always present.

Figure 22.18 Stress fracture of the navicular bone in the foot. **a)** Point of navicular tenderness locally; **b)** computed tomography shows a stress fracture of the navicular bone (arrow). (Courtesy of Prof. Lars Engebretsen, University of Oslo, Norway.)

Plain radiographs are often normal. The diagnosis is made by a positive bone scan. After this a CT scan should be obtained to provide anatomic detail and guide therapy (Fig. 22.18). MRI or plain tomography do not add significant information if bone scan and CT scan are available, but are reasonable alternatives. The fracture is usually sagittally oriented at the midpoint of the medial–lateral dimension of the bone.

Non-displaced fractures respond well to 6 weeks of non-weight-bearing cast immobilization or use of a walking boot. They usually heal in 6–8 weeks. If there is some displacement, surgery with open reduction internal fixation is indicated; however, there is a high complication rate with delayed union, non-union, or recurrence of the fracture requiring new surgery. Surgical intervention may be indicated in athletes who need quick healing to allow them to return to sport. Return to sporting activity is sometimes possible at 5–6 months after conservative treatment and 3–4 months after surgical treatment, depending on the type of surgery.

Diagnosis of this injury is often delayed, with an average time from onset to diagnosis of 4 months. Healing should be verified by radiographs before return to sport. A failure to begin treatment early may result in prolonged pain and complications.

Tip

Patients who experience vague arch pain during physical activity should be carefully examined, since these injuries are often difficult to diagnose and treat. An MRI should be done early. Radiographic confirmation of healing should be done before return to sport.

Lisfranc injury

Lisfranc joints are the joints between the five metatarsal bones and their corresponding midtarsal bones – the three cuneiforms and the cuboid bone (Fig. 22.1). The keystone that provides stability to the Lisfranc joint is the second metatarsal base. The Lisfranc ligament extends from the base of the second metatarsal to the medial cuneiform; injury to this ligament is uncommon, but must be treated appropriately or severe deformity and chronic pain may result.

Lisfranc injury is an injury of the foot in which one or more of the metatarsal bones are displaced from the tarsal bone. There are two mechanisms of injury. The direct mechanism is a simple crush injury to this region of the foot. The indirect mechanism, which is more common, is longitudinal compression with the foot in plantar flexion, typically in a backward fall with the foot trapped by the dorsum of the toes; similar injuries occur in road traffic accidents, falls from a ladder or stepping off a curbstone. A dancer may sustain this injury by overbalancing when en pointe, allowing the whole weight of the body to fall on the ligaments and capsule of the tarsometatarsal joints. These injuries can occur in sports such as windsurfing, wakeboarding, or snowboarding and also in American football, when the player is kneeling on the ground with toes and ankle dorsiflexed, and another player lands on his heel.

The diagnosis is reached by clinical examination and X-rays, where there may be a gap between the base of the first and second toes. An MRI scan is often helpful.

Treatment can sometimes be conservative, including early closed manipulation with maintenance of position by a plaster cast. Most commonly, however, surgical fixation with pins or screws is the treatment of choice to maintain anatomic reduction. Complications after tarsometatarsal dislocations are common and often serious, and many athletes are unable to return to demanding sports activities. Even if there are no complications, a return to sport is rarely possible before 9–12 months after the injury. Before a return to sport is contemplated, the athlete must demonstrate a full, painless ROM of the foot and ankle with no signs of chronic inflammation or arthrosis. Swimming and cycling can start earlier than high impact activities such as running.

Tip

An injury to the Lisfranc's ligaments is rare but requires skilled treatment and careful monitoring.

Metatarsal fractures

Fractures of the metatarsal bones are common. The injury mechanism is often a direct blow to the dorsal aspect of the foot caused by a heavy object falling (or a person jumping) on to the foot. Direct trauma results in a transverse neck fracture of the second, third or fourth metatarsals. Indirect forces often result in spiral shaft fracture. The symptoms from these injuries are characterized by pain on weight bearing. The diagnosis is suggested by marked tenderness on palpation of the metatarsal bones or pain with compression of the foot, and confirmed by X-rays (Fig. 22.19).

Treatment of the majority of isolated metatarsal shaft and neck fractures is non-operative. Displacement in the plantar or dorsal direction should be avoided as this will result in areas of increased weight-bearing load with the potential for developing skin problems. Early weight bearing in a rigid boot or cast is recommended. Return to sport is often possible 3 months after a conventional metatarsal fracture. The prognosis is good.

Figure 22.19 Fractures of the metatarsals; the person experiences pain when the foot is squeezed.

There are three distinct types of fracture at the base of the fifth metatarsal. Jones' fracture is a transverse fracture of the base of the bone caused by forefoot adduction and plantar flexion (Fig. 22.20).

Stress fracture

Avulsion fracture; this is caused by a forceful contraction of the peroneus brevis tendon in response to a sudden inversion injury of the foot. These fractures can be treated symptomatically in a cast or a walking boot. In widely displaced fractures and delayed union, surgery may be indicated.

Metatarsal stress fractures, or fatigue fracture ('march fracture')

About 20% of all stress fractures of the lower extremity are located in the metatarsals, with the second and third metatarsal bones being the most common sites

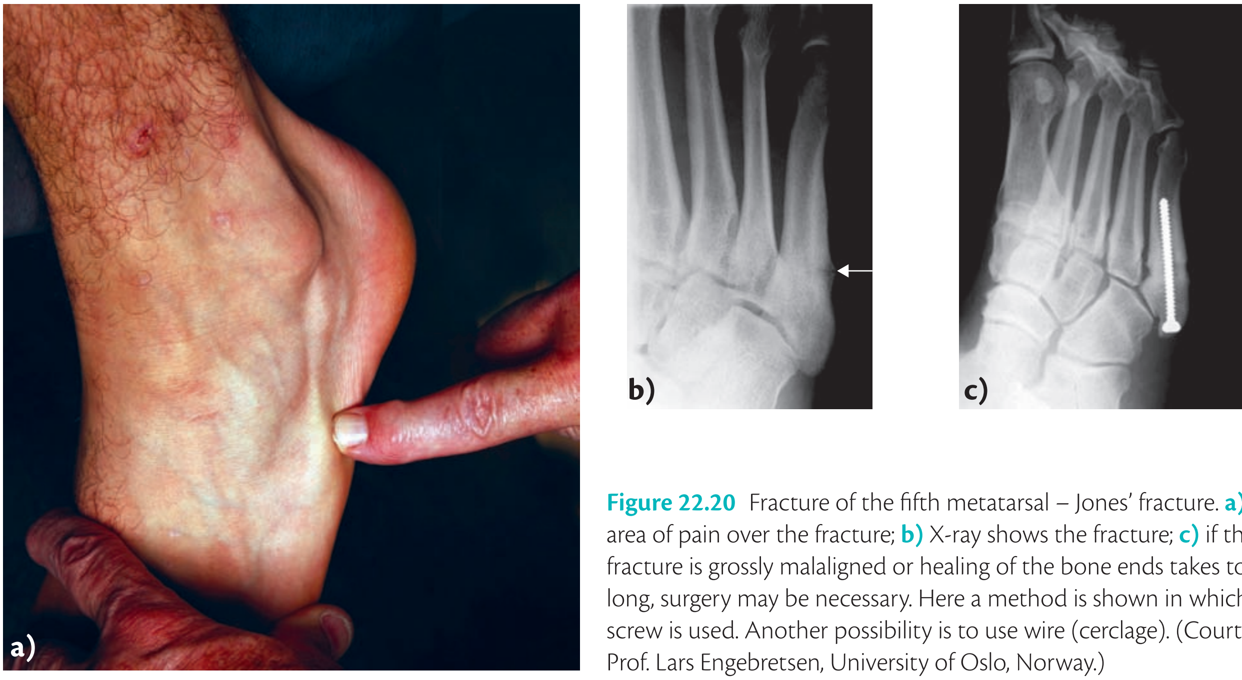


Figure 22.20 Fracture of the fifth metatarsal – Jones' fracture. **a)** Local area of pain over the fracture; **b)** X-ray shows the fracture; **c)** if the fracture is grossly malaligned or healing of the bone ends takes too long, surgery may be necessary. Here a method is shown in which a screw is used. Another possibility is to use wire (cerclage). (Courtesy of Prof. Lars Engebretsen, University of Oslo, Norway.)

Figure 22.21 Stress fracture of the fifth metatarsal bone. X-ray of stress fracture of the fifth metatarsal (Courtesy of Prof. Lars Engebretsen, University of Oslo, Norway.)

(see march fracture, p. 551). The symptoms are insidious and gradual, and it can take 1–2 months or more before a stress fracture can be verified by X-ray (see Fig. 8.6). Bone scans within 1–2 weeks can confirm the diagnosis. These stress fractures are treated non-operatively with limitation of activities for 4–6 weeks; however, running in water may be beneficial.

Stress fractures of the proximal fifth metatarsal require special attention. These fractures are localized to the proximal part of the bone distal to the tuberosity and the peroneus brevis insertion. The majority occur because of repetitive stress, with a high incidence among basketball players but also in football/soccer, handball, tennis etc.

There is marked discomfort along the lateral border of the foot, which may occur 1–2 weeks before a true stress fracture develops. There is a significant incidence of late union, non-union, and re-fracture, with consequent long-term problems for athletes.

For the acute fracture, a non-weight-bearing cast or walking boot for 6–8 weeks can be tried. Union must be radiographically confirmed before this treatment is stopped; it is then followed by 6 weeks of limited activity. Because of the high rate of failure to heal, there is an increasing indication for early internal fixation with an intramedullary screw; this markedly decreases the healing time. The surgery is limited and exposure of the fracture site is not necessary. A gradual return to weight bearing can be possible in 2 weeks, with return to sports as soon as pain and tenderness are gone, usually in 4–8 weeks (Fig. 22.21).

Chronic or delayed union can also be treated by screw fixation or other internal fixation techniques. If there is sclerosis (bone thickening), open curettage (removing tissue by scraping or similar) and bone grafting are recommended. Return to sport can then be possible at 3 months.

Overuse injury or tear of the peroneus brevis tendon

Inflammation and partial tears at the site of the fifth metatarsal bone attachment of the tendon of the peroneus brevis muscle are not uncommon in football/soccer players. Sometimes the tendon sheath can be inflamed, resulting in crepitus. Pain is felt over the upper part of the fifth metatarsal bone. When the injury is in its acute stage, anti-inflammatory medication can be used. If necessary, a plaster cast or a walking boot is applied. In other respects the injury is treated according to the advice given on p. 528. Often there is concomitant ligamentous instability of the lateral ligaments of the ankle (see p. 502).

Tip

This injury can easily be missed because it may not show well on an MRI.

Insufficiency of the longitudinal medial arch (flat foot)

Feet show many individual differences. The longitudinal arch may be flat, but the foot can still be functional. However, if the foot is under excess load because of incorrect loading, excess body weight or prolonged standing, the arch can collapse to a greater degree and result in a flat foot. In cases of very low arches, the medial edge of the foot is lower than the lateral edge. This causes the metatarsal bones and toes to rotate outwards (Fig. 22.7).

Symptoms and diagnosis

- Often there are no problems at all.
- Pain can occur due to overuse, causing aching in the feet and lower legs.
- When there is repeated load, e.g. during running, pain can occur in the foot, lower leg overload of the posterior tibial tendon insertion, knee and groin.
- A feeling of fatigue in the feet can occur.
- Calluses can form on the sole of the foot at areas of increased load.

Prevention

- Flexibility training and static stretching of the ankle joints and calf muscles should be performed.
- Foot and toe strengthening exercises may be helpful.
- The athlete should use shoes with good construction of the outer sole, inner sole and heel counter.

Treatment

- Orthotics.
- Taping.
- Rest from painful activities.
- In certain cases the affected athlete must take a break from running, but can still maintain physical fitness by cross-training activities such as swimming and cycling. Extreme cases of flat foot may require surgical treatment.

Insufficiency of the anterior transverse arch

The anterior transverse arch provides elastic support to the forefoot. The middle metatarsal bones and the toes flex down towards the floor, when the anterior transverse arch is loaded during the supporting and take-off phases of gait. A slackening of the ligaments between the metatarsal bones can occur. If this happens, the arch loses its shape and load-absorbing ability. The foot then becomes broader, and the metatarsal bones and toes acquire a fan-like spread.

Symptoms and diagnosis

- Pain is felt when the anterior transverse arch is loaded.
- Calluses form under the ball of the foot as a result of the skin being exposed to increased pressure.
- Eventually the big toe can angulate and be positioned across the other toes (hallux valgus, p. 554).

Treatment

- A shoe orthotic device with a pad for the anterior transverse arch should be used. In cases of hallux valgus pressure can create a bursa (bursitis) and a bony formation (a bunion) on the medial side of the big toe. Continued pressure, often from poorly designed shoes, can lead to inflammation in the bursa (bursitis).

The condition can secondarily cause 'hammer toe' deformities: that is, all the toes except for the big toe lie in a permanently bent position in the proximal interphalangeal joints. This can cause increased pressure on the nerves running between the third and fourth, and the second and third toes (Morton's metatarsalgia), and/or painful calluses (corns) can form over the top of the bent toes.

- In hallux valgus and hammer toes, surgery may be necessary.
- Gripping exercises with the toes are prescribed.
- A general exercise program should be started.

Spurs on top of the foot

Sometimes spurs (bony prominences, bony overgrowth or osteophytes) occur on the top or sides of the foot. A spur can increase in size or become inflamed. They are usually caused by pressure from shoes that are too narrow or laced too tightly. The spurs most often appear on the dorsum of the foot anterior to the ankle, and are sometimes composed of separate bones. Foot mobility is often normal, but the affected person cannot walk in shoes. Tenderness can be caused by inflammation in a bursa that has formed over the spurs. An X-ray shows either a small bony prominence, or sometimes an extra bone.

The treatment for a painful spur is an alteration of the shoe. Sometimes the bony prominence can be removed surgically.

Inflammation of the sheaths of the extensor tendons of the toes (extensor perisynovitis)

The long muscles that extend the toes are attached to the anterior aspect of the tibia along with the muscles that dorsiflex the ankle. The tendons from these muscles cross to the foot at the ankle, with the toe extensors along the dorsum of the foot to the toes. These tendons and their sheaths can be subjected to increased pressure from sports shoes that are ill-fitting or laced too tightly. They can also be overused by running in hills or in sand. Inflammation of the area causes pain on the top of the foot, which worsens during running. Tenderness can be elicited along the course of the tendons. In acute tenosynovitis (peritenonitis), crepitus can sometimes occur.

Treatment

- The athlete should rest actively, and avoid abusing the foot.
- Anti-inflammatory medication may be helpful.
- The shoes should be altered. Sometimes a piece of felt or foam rubber with a notch to unload the painful area can prevent pressure from being applied by the tongue of the shoe.
- When the problems are prolonged, a corticosteroid injection along the sheath of the tendon may be helpful. This should be followed by 2 weeks of rest.
- In chronic cases surgery is an option.

Forefoot and toe problems

Toe fractures, claw toes, hammer toes and hard and soft corns are common forefoot problems. When an athlete complains of forefoot pain, the examiner should check for the presence of associated callosities. If no callosities are present, the examination should focus on possible neurological problems. If neither of these conditions is present, joint problems such as instability or arthrosis (osteoarthritis) should be looked for.

Hallux valgus

The big toe (hallux) can normally be angled laterally away from the midline by up to 10°. If the angle is greater than 10° the condition is called hallux valgus (Fig. 22.22).

In such cases of displacement, a bony growth (bunion) forms on the medial side of the foot where the angle is greatest. This bunion is covered by a bursa that can sometimes become inflamed and extremely painful as a result of exposure to abnormal pressure.

One cause of hallux valgus is a depressed anterior transverse arch. Another is excessive pronation, with imbalance and contracture of the muscles of the big toe. Other contributory factors are thought to be ill-fitting shoes and angulation (displacement) of the first metatarsal bone.

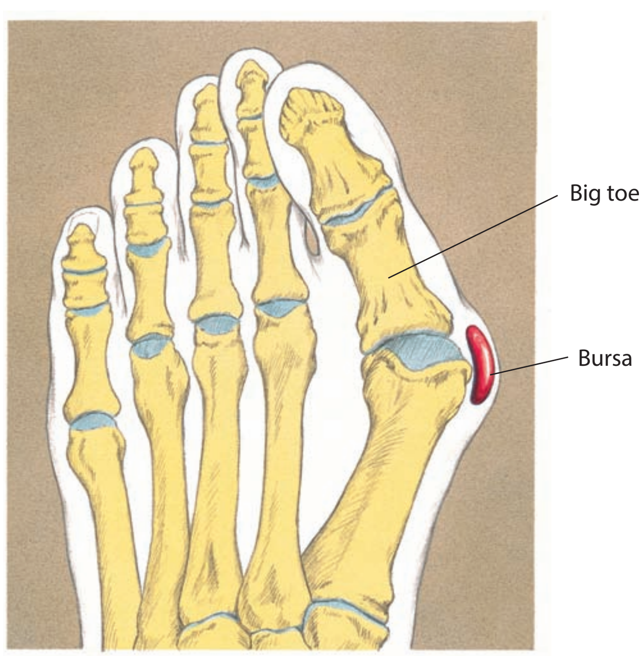


Figure 22.22 Hallux valgus with a bursa (in red). A bunion is formed outside the bone.

Symptoms and diagnosis

- The big toe is angled more than 10° outwards and may be pressed against the second toe. The second toe may in turn be pressed against the third toe, so that an increasingly faulty foot posture is present.
- A callus often occurs on the sole of the foot under the second metatarsal bone.
- There may be problems with shoe wear.
- Skin redness and tenderness can occur on the medial edge of the foot where the angle is greatest.

Treatment

The athlete should:

- Wear shoes with a wide toe box.
- Put a piece of soft felt or a rubber pad between the big toe and the second toe.

The physician may:

- Prescribe arch supports with pads under the anterior transverse arch.
- Prescribe shoes shaped to match the bunion.
- Recommend surgery only when the problems are severe. The operation can consist of removal of only the bunion and bursa, or if the angle between the first and second metatarsals is large, a wedge osteotomy, where the bone is cut to change the angle. The healing time for the former procedure is 4–6 weeks and for the osteotomy 3–4 months.

Hammer toe

Hammer toe is characterized by a flexion contracture (Fig. 22.23), which is an inability to extend the toe at the proximal interphalangeal joint (the joint between the toe bones) of the second, third or fourth toe. It is mostly caused by wearing poorly fitting shoes, that can cause the toe to adopt a flexed position.

In the early phases the deformity is flexible (i.e. can be passively corrected), but with time it will become fixed. This contracture can be caused by insufficiency of the anterior transverse arch (p. 553) or by wearing shoes that are too small. Painful corns and calluses will appear over the prominent joint. Occasionally there can also be a painful callus at the tip of the toe.

The treatment includes relieving pressure over the painful area by wearing shoes with a larger toe box. Support for the transverse arch may be indicated if it is flattened. Padding can be used as necessary. Shaving of painful calluses can temporarily relieve discomfort. Sometimes surgical intervention is necessary. After surgery return to jogging can be possible after 8 weeks.

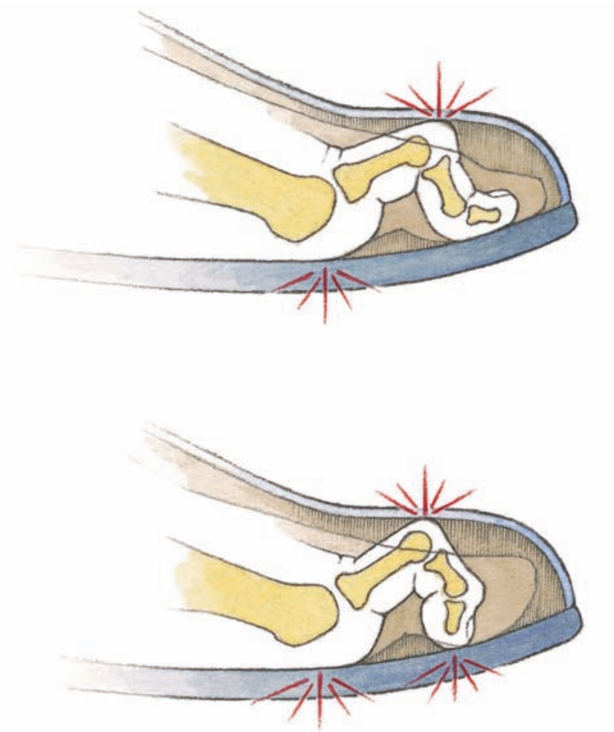


Figure 22.23 Hammer toe. This is a flection contracture in a tendon, i.e. an inability to extend the toe at the interphalangeal joint.

Hallux rigidus (stiff big toe)

Hallux rigidus can occur after repeated minor injuries to the articular surfaces of the metatarsophalangeal joint of the big toe. Early degenerative osteoarthritis, with chronic pain and discomfort, can then develop. The mobility, especially dorsiflexion, of this joint is then impaired. The affected athlete finds it difficult to run or walk normally. Long-distance runners may complain that pain from the big toe makes them unable to run the required distances. The lack of dorsiflexion (Fig. 22.24) means that the athlete is forced to compensate by rolling off the lateral aspect of the foot, which will result in other areas of injury. The diagnosis is mainly made by clinical evaluation, specifically limitation of dorsiflexion of the first metatarsophalangeal joint.

Forced dorsiflexion will usually reproduce the athlete's discomfort. Palpation can often demonstrate a rigid bone on the dorsolateral side of the metatarsal head (Fig. 22.24A). Sometimes swelling can be present. An X-ray of the metatarsophalangeal joint or the big toe can often show limited changes, but may demonstrate dorsal spurs (osteophytes) due to degenerative arthritis (p. 556 Fig. 23.23b).

Treatment includes the use of a larger toe box to relieve the pressure. Sometimes a stiffer shoe with a steel shank or rocker-bottom sole can be used. A build-up

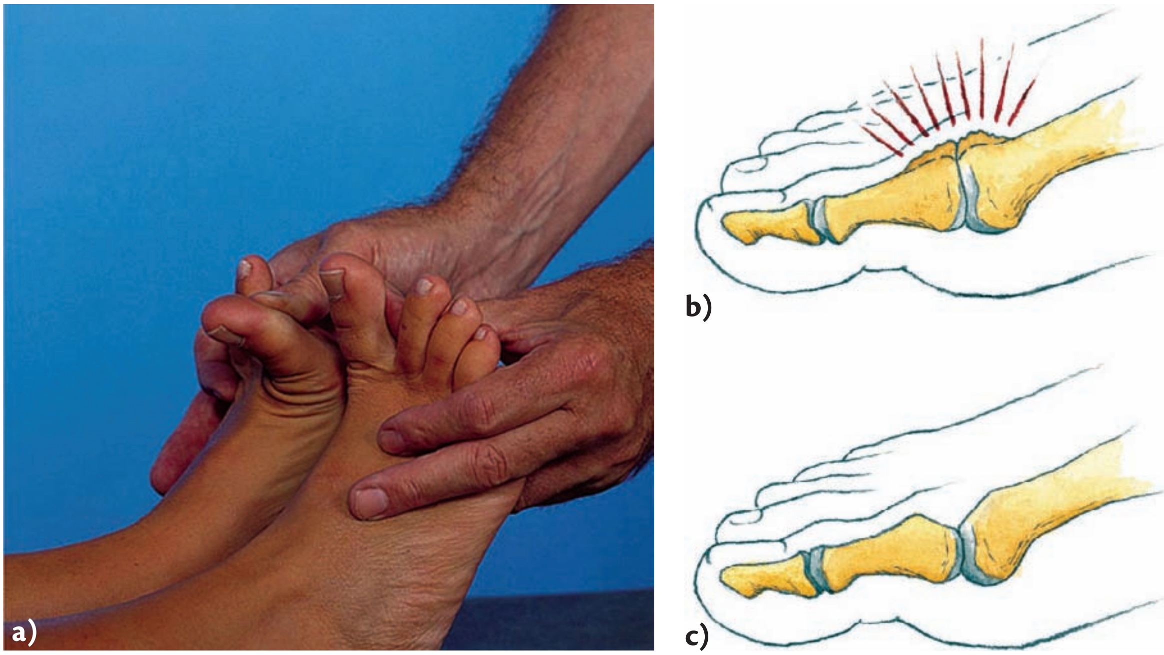


Figure 22.24 Hallux rigidus, i.e. inability to dorsiflex the big toe. **a)** Reduced ability to dorsiflex; **b)** ossification at the top of the big toe (first metatarsal joint); **c)** surgical removal of osteophytes.

to allow a 'rolling off' motion can be helpful; however, this is difficult for athletes to use. Occasionally non-steroidal anti-inflammatory medication can be helpful. Sometimes the athlete has to change to another sport, like cycling or swimming, to relieve the joint. Operative treatment of hallux rigidus is sometimes necessary. In athletes, removal of dorsal spurs can sometimes restore motion and prolong the athlete's active life, but it will not remove the cause of the injury. More extensive surgical procedures are available, but the results vary. There is no reliably effective treatment for this injury.

'Turf toe' syndrome – metatarsophalangeal joint sprain

Turf toe syndrome occurs when a player's shoe grips the surface during a sudden stop, and the foot slides forward in the shoe, causing a vigorous dorsiflexion of the big toe (Fig. 22.25).

The ligaments under the first metatarsophalangeal joint (the joint at the base of the big toe) and the joint capsule are stretched or sprained, when the big toe is hyperextended and the articular surface is injured. It is a common injury in American football, especially on artificial all-weather surfaces, and may occur in football/soccer, basketball, rugby, squash, badminton and tennis. These injuries are common and are responsible for a large number of missed practice sessions.

The symptoms are swelling and tenderness at the base joint of the big toe, with pain on stretching and bending the toe (Fig. 22.25). The athlete localizes the area of maximal pain to the undersurface of the big toe. Radiographic examinations must be done to exclude a fracture.

The immediate treatment includes cooling, compression, bandaging, elevation of the foot, and relief from weight bearing. After 2–4 days the injured athlete can again bear weight. Unrestricted motion is allowed, except that a walking boot is used to immobilize the toe when walking. The injured joint can also be stabilized by taping and a shoe with a rigid sole (sometimes a metal plate) can be helpful in limiting joint motion. The injured athlete should allow at least 2–4 weeks of rest from sporting activities; although in running sports rehabilitation may take 2–3 months. Some athletes have persistent symptoms for many years, but can still continue their sport.

Fracture of the sesamoid bones

The two sesamoid bones under the metatarsophalangeal joint of the big toe are the most vulnerable to fracture. These bones lie within the tendon of the flexor of the big toe. A fracture can occur either by direct impact or when the big toe is forced to bend vigorously upwards, as in take-off or landing on the flexed toe (Fig. 22.26).

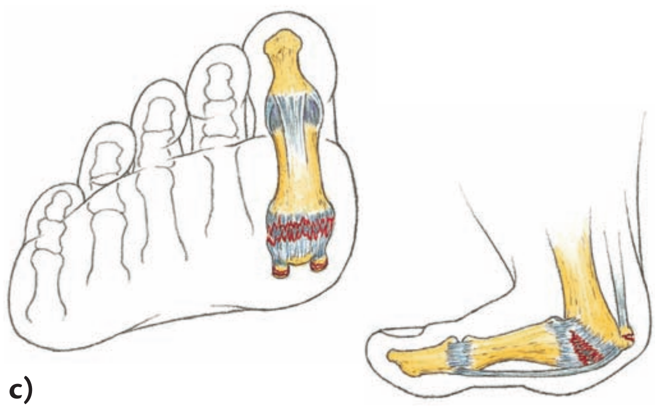


Figure 22.25 'Turf toe' syndrome is a painful condition after a sharp stop, with the player's shoe fixed to the surface, so that the foot slides forward in the shoe with a sharp upward bending of the big toe. **a)** In American football, this injury is not unusual (with permission, by Bildbyrån, Sweden); **b)** this injury occurs by forcing the big toe to bend upwards unnaturally with great force; **c)** due to injury to ligaments in the big toe joint, the joint articular surface is damaged and the joint capsule is stretched or ruptures.

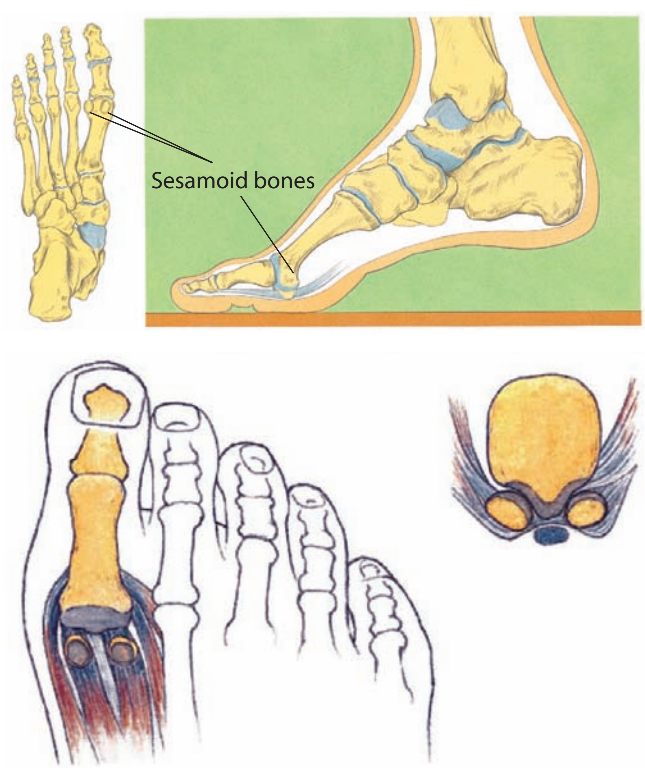


Figure 22.26 Fractures of the two sesamoid bones under the big toe joint.

Sometimes inflammation can occur in the tendon sheath surrounding the sesamoid bones due to uneven pressure distribution in the area.

Symptoms and diagnosis

- The athlete cannot run on the toes and has pain on take-off.
- Local tenderness and swelling occur.
- Pain occurs when the toe is bent upwards.
- If there is a fracture, an X-ray may confirm the diagnosis. However, these fractures are often difficult to see on plain films.

Treatment

- A walking boot or a plaster cast should be worn for several weeks.
- If the injury does not receive medical attention until a late stage and/or the fracture has not healed, surgery may be considered. Surgery may consist of removal of all or part of the sesamoid bone.
- The injury often affects athletes with high arches and a tight arch ligament. Surgical measures can sometimes be taken to reduce the tension in the arch ligament.

Morton's syndrome

When the foot plantar flexes and the toes dorsiflex during push-off, the nerves between the second and third metatarsals, and the third and fourth metatarsals, can be compressed by the ligament between the bones (Fig. 22.27).

Additional compression can come from the metatarsal bones as a result of ill-fitting shoes or a depressed anterior arch. The plantar digital nerves that join between the metatarsal heads can become irritated by this compression and form a local nerve swelling (neuroma). This occurs most commonly between the third and fourth metatarsals. Each nerve transmits the sensitivity and pain from the lateral side of one toe and the medial side of the adjacent toe, where the athlete may feel pain and numbness. This condition is known as Morton's syndrome.

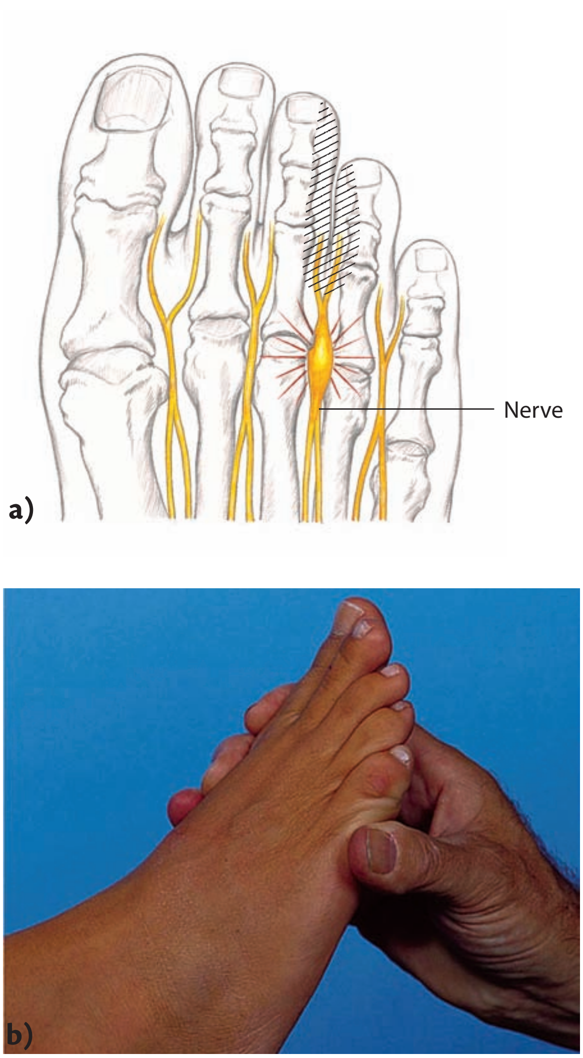


Figure 22.27 Morton's syndrome. **a)** Nerves between the second and third, and third and fourth metatarsals can be pressed together by ligaments between the bones; **b)** compression of the metatarsals may trigger pain in the affected toes.

Symptoms and diagnosis

- The injured athlete usually complains about recurrent pain from the lateral side of one toe and the medial side of the next. It is generally the third and the fourth toes that are affected.
- The symptoms are often compared to an electric shock.
- Sensitivity can be impaired on the adjacent sides of the two affected toes.
- The pain is sometimes relieved by walking barefoot.
- By compressing the metatarsal bones, pain can be triggered in the affected toes (Fig. 14.28).
- Local tenderness may be elicited between the toes (metatarsal heads) when a thin object, such as the back of a pen, is pressed against the skin.

Treatment

The athlete should:

- Rest and relieve pressure on the toes.
- Wear wide-fitting shoes.
- Avoid activities, that include pushing-off; swimming and cycling are good alternatives.

The physician may:

- Prescribe anti-inflammatory medication for 1–2 weeks.
- Prescribe an orthotic arch support with a metatarsal pad to spread the metatarsal bones and thereby ease the pressure on the nerve.
- Prescribe physiotherapy.
- Give an injection of local anesthetic solution and a small amount of cortisone.
- Operate to remove the neuroma from between the metatarsal heads. Return to sports is possible within 2–3 months. This is a very effective treatment, but there will be a permanent loss of sensation to the adjacent sides of the affected toes.

Fracture of the toes

Fractures of toes occur frequently in many sports, especially kicking sports. Fractures of the big toe are the most serious, especially if a joint is involved. If there is displacement, the bone ends must be realigned, after which the injury is treated with immobilization for about 4 weeks. Fractures of other toe bones heal without any treatment other than rest, provided there is minimal displacement. A 3–5 week break from training that involves the toe is necessary. Swimming, skiing and weight training of the rest of the body may be continued.

Toenail problems

Ingrowing (ingrown) toenails

The nail is considered ingrowing when the side of the nail cuts into the skin next to the nail. An ingrowing toenail is a common complaint amongst athletes, usually caused by ill-fitting shoes pressing the skin against the edge of the nail. The big toe, which has a broad nail, is most often affected.

Preventive measures are essential. Shoes should be big enough, well-fitting and comfortable, and tight socks should not be worn. Careful foot hygiene is necessary. The toenails should be cut regularly, at least once a week, and cut off straight, as they can grow down into the nail fold if the sides of the nail bed are trimmed to a curved outline. Nails that are too thick should be thinned.

The basic treatment includes using a cotton wool bud to push the skin fold over the ingrown nail down and away from the nail. This may be repeated each day for a few weeks, allowing the nail to grow. The nail should not be cut. It should be allowed to grow forward until it is clear of the end of the toe. Then, the nail should be cut straight across. It is essential to keep the skin from growing over the edge of the nail.

Ingrowing toenails may be associated with bacterial infections invading the cuticles. This may cause extreme discomfort. Such infections should be drained and the area kept dry and treated with a local antiseptic and possibly an antibiotic powder. Antibiotics taken by mouth may also be of value. If ingrowing toenails cause persistent problems, surgery can be resorted to. A number of different approaches may be used. Ideally, the whole nail should not be removed, although this may sometimes be necessary. As the nail grows back it grows back thicker and the problems can become even worse. At surgical treatment, not only the part of the nail that is problematic, but also the nail bed should be removed. Excision of the nail bed ensures that the nail does not regrow.

Black nails (‘tennis toe’, ‘football/soccer toe’)

Black (bruised) nails can occur as a result of a blow to the nail, being trodden on, wearing shoes that are too narrow or the toe-nails being left too long. Bleeding occurs in the nail bed and appears as a black spot or patch under the nail. Bruised nails occur in most sports; in running they can be caused by the toenails being jammed against the anterior part of the shoe, especially when the shoes are too small, or when the athlete is running downhill.

Bleeding in the nail bed tends to be painful because the blood gathered under the nail exerts pressure on the tissues. This pressure can be released (after cleaning the nail), by making a hole with a clean, sharp knife, a red-hot needle or a straightened paperclip (Fig. 22.28).

This is by no means as alarming as it sounds. The blood drains out spontaneously through the hole, which is then protected with a dressing to prevent the nail bed from becoming infected. This procedure preserves the nail, which would otherwise fall off after 2–3 weeks because of disruption of its blood supply. Once an injured nail becomes loose and begins to separate from its attachment to the cuticle, there is a risk of infection occurring and it is wise to seek medical advice.

Anyone who has had a bruised nail should consider how the injury occurred, and if the shoes are at fault, should change them.

Subungual exostosis

In cases of repeated impact to a toe, for example when a basketball player’s toe is trodden on repeatedly, an exostosis (bony outgrowth) sometimes develops from the tip of the affected toe under the nail and thereby impinges on the nail bed. This happens below the nail, hence the term subungual. This usually affects the big toe, and is very painful and highly sensitive to pressure and further impact. In many cases the nail has to be removed to relieve the pressure, an alternative being to remove the bony outgrowth surgically.

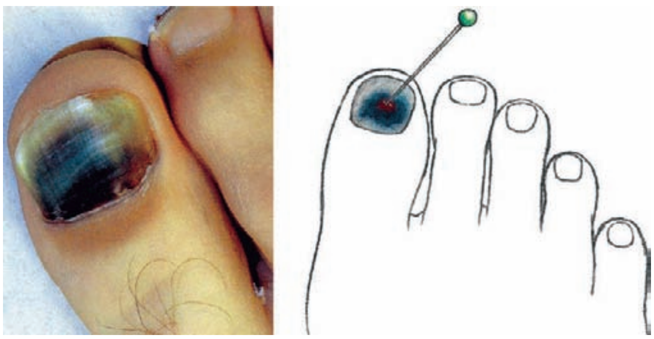


Figure 22.28 Bleeding in the nail bed. The bleeding can be removed by making holes in the nail, with for example a sharp needle.

Skin conditions

Calluses

The skin thickens in response to pressure to form a callus. Pressure on the feet can be caused by shoes that are laced too tightly or are too narrow, or by some anatomical variation. Calluses can occur at many different sites, the most common being:

- The heel.
- The ball of the foot, especially in those who push-off with the second toe.
- Under the big toe and the little toe at cavus feet.
- The top surface of 'hammer' or otherwise bent toes.
- The medial side of the big toe where there is an exostosis at that point.

Calluses on the foot are treated by relieving pressure. If necessary they can be trimmed with a sharp knife or filed with a foot file by an athletic trainer (Fig. 22.29).

Sometimes calluses are recurrent, and then treatment is a question of removing the triggering cause, for example an exostosis, or altering or replacing faulty shoes. This usually prevents further problems.

Skin outgrowths

Skin outgrowths are a kind of callus that forms between the toes, usually the fourth and fifth toes, as a result of pressure from shoes that are too narrow. Treatment consists of wearing shoes with a wider fitting at the same time as protecting the affected area from further pressure, e.g. by the use of rings of felt or foam rubber placed around the outgrowths.

Figure 22.29 Calluses on the feet are common.

Athlete's foot (tinea pedis)

Athlete`s foot is a skin infection of the foot caused by fungus. The reason can be inadequate foot hygiene. When the feet are not dried thoroughly after showers or baths, fungal infections (mycosis) may develop (Fig. 22.30).

The fungus causes the skin between the toes to become soggy, cracked and whitish in appearance, and often has an offensive smell. Athlete's foot causes itching, peeling or cracking of the skin. The condition is infectious and can spread from one individual to another via floors on which people walk barefoot, such as those of locker rooms, showers and swimming baths.

Prevention

- Regular washing of the feet with soap and water followed by thorough drying.
- Regular, frequent changes of socks
- Socks washed in 60°, otherwise the fungus is not killed.
- Porous shoes that allow circulation of air and evaporation of moisture should be used.
- Avoidance of walking barefoot in locker rooms, etc.
- Anti-fungal drugs in the form of over-the-counter medication can be tried as they are often effective.

Treatment

The physician may:

- For superficial skin infections prescribe anti-fungal cream, drops or ointment.
- For more serious infections oral tablets or injections may be required. The application should be used regularly as directed and treatment continued for weeks after the skin appears to have returned to normal. Infections in the toenails may take months to clear.

Verrucas (warts)

Verrucas are warts caused by a virus and can be transferred from one individual to another via floors of showers and locker rooms where people walk barefoot. The incubation period is 1–6 months. Warts are most often located on the sole of the foot, are round or oval in shape and have a crack or dark spot in the middle. They can generally be distinguished from calluses, although this may be difficult when a verruca appears in a weight-bearing area and both conditions are present.

Warts cause pain when pressed against underlying tissue, and can also be painful when pressed from the

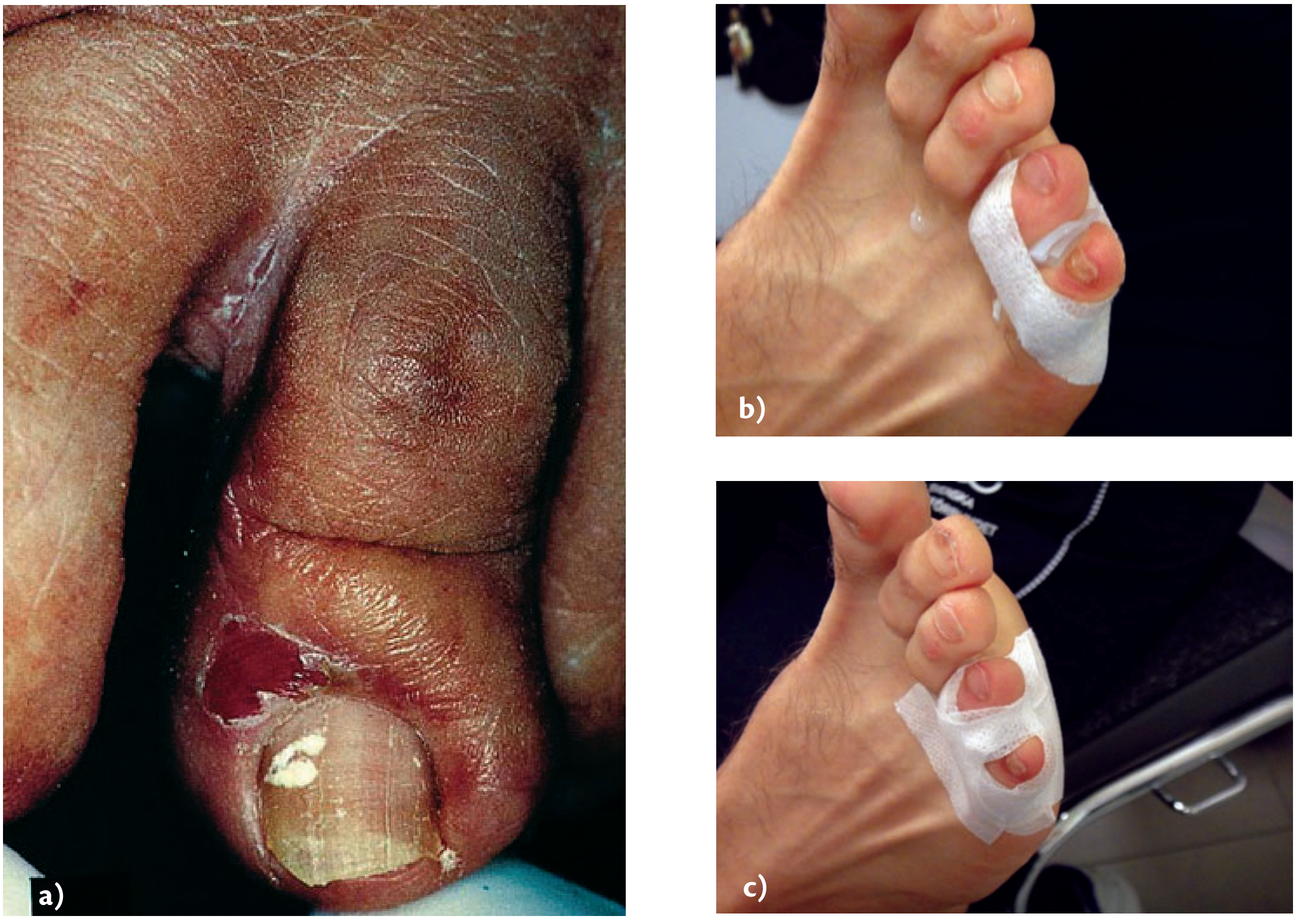


Figure 22.30 Fungal foot infections (tinea pedis). **a)** A well-developed case of athlete's foot; **b)** topical treatment of athlete's foot with ointment and covered with bandages; **c)** the player is ready to return to game.

sides. They may become infected by bacteria, and rarely this infection may spread to the bloodstream.

Approximately 50% of all warts will disappear without treatment within 2 years. Tenderness and bleeding in a wart is a sign that it has begun to heal. Because warts are caused by a virus the body gradually builds up resistance and this causes the warts to eventually disappear. Treatment should be initiated as soon as the warts are found, so that the spread can be prevented. Warts are harmless but they are very contagious.

A physician should be contacted if an undiagnosed abnormal bulge or lump in the skin is found with discoloration or bleeding.

Tip

Athletes with warts must wear slippers or such when in showers and locker rooms.

Treatment

The athlete should:

- File or rub down the verruca with an emery board as far as possible, perhaps after soaking the foot in hot water for 10–15 minutes.
- Treat the wart with a proprietary wart preparation containing salicylic acid. The instructions for use should be followed with care and the normal surrounding skin protected. Treatment may have to be continued for several months.

The physician may:

- Cut or burn away the wart if necessary.
- Recommend a treatment that freezes the warts to the core with a single treatment, after which the warts fall off within 10–14 days. This can be done in the home.

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23

Growing Athletes – Special Considerations

Regular training of children and adolescents is becoming more common in sport. Competitive sports are furthermore encouraged with ever-increasing intensity at ever-decreasing ages (Fig. 23.1). In certain sports, such as figure skating, swimming and gymnastics, children start regular training when they are 5–6 years old. Even in contact sports, such as football/soccer, ice hockey, bandy and handball, training and competition are beginning at earlier ages. In certain sports training for 2–4 hours, 5 or 6 days a week, is not unusual.

The early specialization where children are forced to choose between sports at an early age has become more common in recent years. Several negative consequences can be seen such as early exclusion due to increasingly demanding training and competition. Training involving one side of the body more than the other can be called one-sided or asymmetric training, such as the repetitive service motion in tennis, where the player hits with one arm holding the racquet above the head and the other arm is not as active. Repeated action such as running

Figure 23.1 a–c) Young athletes mostly love their sport and are very competitive. They dream of future successes. Sports like running, wrestling, tennis, football/soccer, etc. are popular at all ages. (**c**) photo, Henrik Peterson.)

on one side of the road can be problematic as the roads are often canted. This may result in one leg being functionally shorter than the other and this may in the long term cause overuse problems.

Are there any long-term advantages in allowing children to start regular training and competitive activity at such an early age? Children's play has always included running and jumping, which form a natural basis for sporting activity, but the increased demands and increased intensity of regular training can have a negative effect on an adolescent, and caution is needed. In some sports, swimming and tennis for example, studies have shown that very few winners of junior competitions become successful seniors – in other words, it is difficult to predict future development. Many young boys and girls give up their sporting activities too early because they are no longer enjoying themselves.

Tip

Children and adolescents should be given the opportunity to try different sports rather than concentrating exclusively on one. In principle, sports for children and adolescents should be fun and should not mean painful, hard training. The principles adults use in training cannot be directly applied to growing individuals, but must be adapted to their actual level of development.

The risks of allowing adolescents to train and compete regularly can be looked at from different angles: physiological, psychological and orthopedic, and the effects of sport can be divided into three groups:

- Effects on the development of the musculoskeletal system.
- Injuries due to accidents (traumatic injuries).
- Injuries due to overuse.

Effects on development

The development of the musculoskeletal system in growing individuals is governed by their ability to adapt in response to a changed or recurrent load, during training or following injury. Adaptation as a result of prolonged one-sided training can cause permanent changes, exemplified by the tennis player who, at an early stage, begins asymmetrical training and loading of the racquet arm. This can result in development of a 'tennis shoulder', with an increase in the size of bones and muscles and increased laxity of the joint capsule, ligaments and tendons around the shoulder of the racquet arm. This often results in a dropping of the shoulder and a relative lengthening of the arm. In extreme cases an S-shaped curve (scoliosis) can develop in the thoracic spine.

Another example of the effects of training can be seen in young gymnasts. Training repeated over a long time increases the range of movement in the vertebral column, bringing about permanent changes in vertebral bodies and in the pelvis with increased mobility between the bones that form the pelvic girdle. We do not yet know with certainty what these changes will lead to in the long run, so it is essential that intensive regular training in children and adolescents takes place under medical supervision. At the same time, one-sided and repetitive training must be avoided. Rules that reward abnormal mobility, e.g. as in the scoring of gymnastic competitions, should be changed.

Tip

The training of children and adolescents should be all-round and comprehensive.

Traumatic injuries

Children and adolescents are injured more often than adults, but their injuries are usually less serious (Fig. 23.2). This may partly be due to the fact that children are physically smaller than adults, so that less force is involved in the injury. Children's tissues are significantly different from those of adults: their bone structure is more resilient and adaptable, and their muscles, tendons and ligaments are relatively stronger and more elastic. Unlike the situation in adults, the articular cartilages have some blood supply, enabling injuries in those areas to heal to some extent.

The skeleton is the most vulnerable structure in adolescents. Though the bones are adaptable to various stresses (and in this respect are superior to those of adults), they are not as adaptable as the cardiovascular system and the muscles. In children and adolescents who participate in regular training, the musculature can develop more rapidly than the skeleton, which may be hazardous because of the unusual stress it imposes. Because of the resilience of the tissues, overuse injuries are relatively rare in children and young people, although in recent years

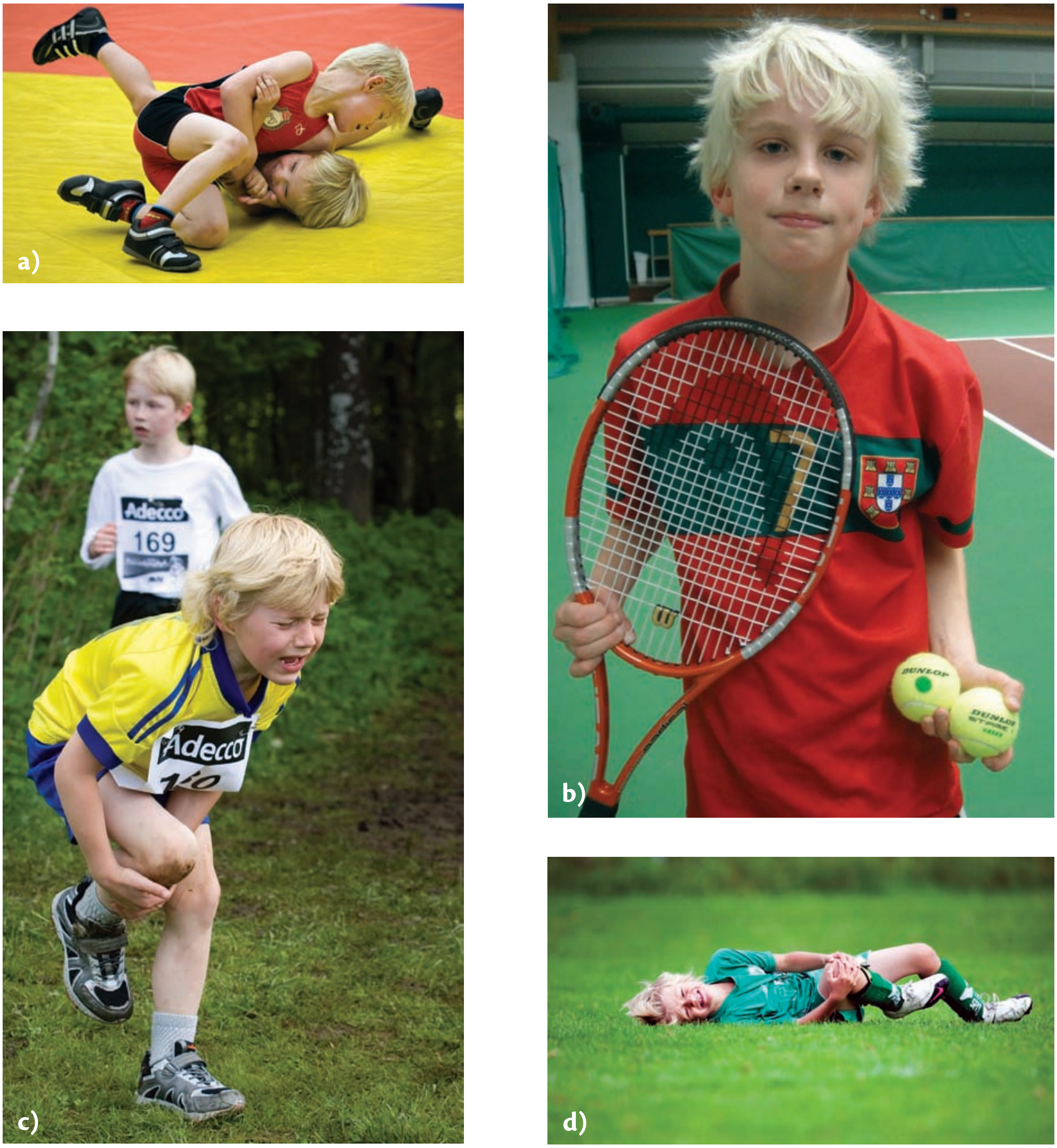

Figure 23.2 a–d) Children active in sporting activities mostly have lots of fun and enjoy themselves. Occasionally they may experience some discomfort during sport and exercise. (**c, d)** with permission, by Bildbyrån, Sweden.)

their incidence has been increasing, probably because of more intensive training in younger children.

Injuries to the growth zones

Growth in length of the skeleton takes place in the growth zones or epiphyseal cartilages (Fig. 23.3). In the femur 70% of the growth occurs in the lower epiphysis and 30% in the upper. Corresponding figures for the lower leg are 55% and 45% respectively. The epiphyseal cartilages are weaker than the rest of the skeleton and are susceptible to injury.

The age of the skeleton has a role in determining the effect of physical training on the epiphyseal cartilages. Hormone factors are also important. The epiphyseal cartilages are at their weakest during puberty and towards the end of the growth period, when they are beginning to lose their elastic properties.

Epiphyseal cartilages are weaker than normal tendons and ligaments in adolescents, and an impact that would cause a total tear of a major ligament in adults, tends in adolescents to cause an avulsion of the epiphysis or the bony insertion (apophyses) of the ligament. So an impact against the side of the knee joint in children and adolescents may cause an epiphyseal injury or a bony avulsion of the ligament insertion, while a similar impact in an adult would tear the soft tissue of the medial collateral and anterior cruciate ligaments. When tears of major ligaments are suspected in adolescents, X-rays should be taken so that the epiphyseal cartilages can be checked and any skeletal injuries discovered.

The epiphyseal cartilage (growth zone) is weaker than the fibrous (connective) tissue of the joint capsules, so that dislocations of major joints resulting from accidents are less common than injuries to the epiphyseal cartilage in children and adolescents.

In 10% of cases, injuries to the growth zone can disturb normal growth in length. The effects vary. While an injury to an epiphyseal cartilage is healing, bone growth on the affected side is halted, but the undamaged bone on the opposite side continues to grow. In cases of injury to the growth zone of the lower part of the femur this can mean a difference in length of more than 25 mm (1 in.) between the two sides. Sometimes an injury is partial and only the undamaged part of the cartilage grows, causing the leg to be crooked or angulated.

Growth zones can slip in relation to the bone (epiphysiolysis) (p. 381). The injury is not uncommon in the hip joint, in which the femoral head can gradually or suddenly slip from the shaft. Epiphysiolysis should be treated by surgery.

Common fractures

Bone tissue is softer in adolescents than in adults, and the younger the person the less likely the bone is to break (Fig. 23.4). For this reason, fractures in children show different characteristics. The skeleton also has a better blood supply in children than in adults, which reduces the time needed for fractures to heal. Treating fractures in children and adolescents involves principles different from those in treating adults:

The fractures heal better and fewer visible signs remain in children and young people than in adults. An X-ray of a fracture taken 18 months after the injury will show perfect healing and no sign of a fracture in an adolescent, while a change in the shape of the bone is often seen in an adult.

Fractures heal faster in adolescents than in adults, and therefore children and young people do not have to wear a cast for so long.

Children and adolescents sustain different types of fractures from adults (Fig. 23.5). Bones that are still growing are much more flexible than adult bone and

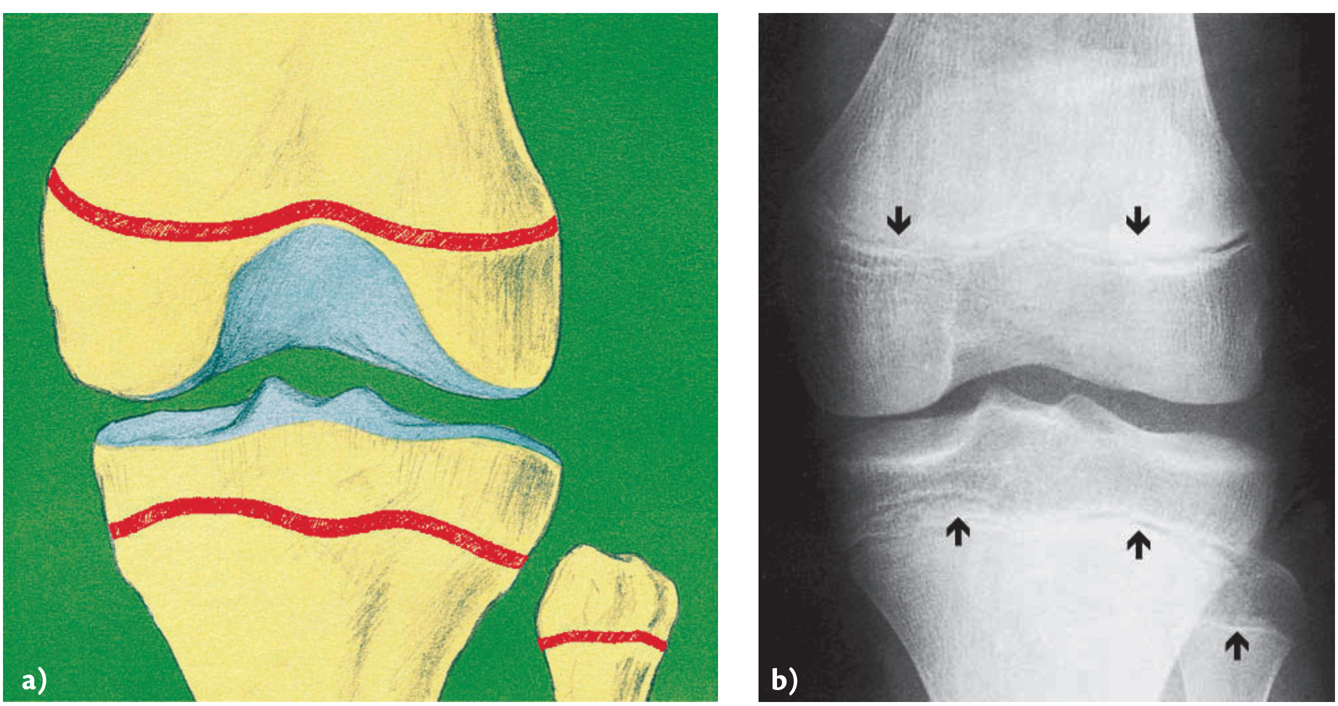

Figure 23.3 Growth zones. **a)** Growth zones in the distal/lower part of femur (thigh bone) and in the proximal/upper part of tibia (lower leg), where most growth in the lower extremities occurs; **b)** X-ray of the growth zones around the knee joint, i.e in femur, tibia and fibula.

can therefore be bent quite vigorously before breaking. An example of this is the 'greenstick' fracture, which is an incomplete fracture, which can occur in the forearm in children mostly under 10 years of age. In a greenstick fracture one side of the fracture has broken and one side is bent. The structural integrity of the convex surface may then be broken resulting in a fracture of this surface. However, the bone is not broken completely and the concave surface remains intact. This fracture is treated in a cast for 4–6 weeks.

Figure 23.4 Horse riding is a popular sport but has some risk for injury. (Photo, Henrik Peterson.)

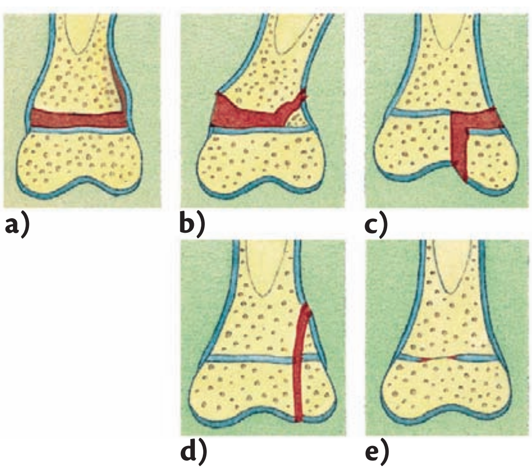

Figure 23.5 Different types of fractures can occur in the growth zones (the physes or epiphyses. These terms are used as synonyms, but the epiphysis is the real name for the joint surface bearing bones in femur´s (and tibia´s) upper (proximal) and lower (distal) ends respectively). **a)** Through the physis (epiphysis, growth zone, epiphyseal cartilage); **b)** through the physis and out through the metaphysis (the area next to the epiphysis towards the middle of the femur/diaphysis); **c)** through the physis and through the epiphysis into the joint; **d)** starting in the joint up through the epiphysis and then out through the metaphysis; **e)** compression injury through the physis.

Avulsion fractures

In adolescents the strength of the tendons, ligaments and the muscles is greater than that of the bones, while this situation is reversed in adults. This means that children and adolescents usually suffer skeletal injuries as a result of accidents or overuse. The bony attachment of the ligament or muscle (apophyses) is torn away from its origin, instead of the muscle–tendon or ligament itself tearing. Such avulsion fractures are often located in the growth zones of the flat bones and are most common in the front of the pelvis and in the ischium, where the posterior hamstring muscles have their origins (Fig. 23.6). Avulsion fractures often occur suddenly during hard, rapid loading of the muscles.

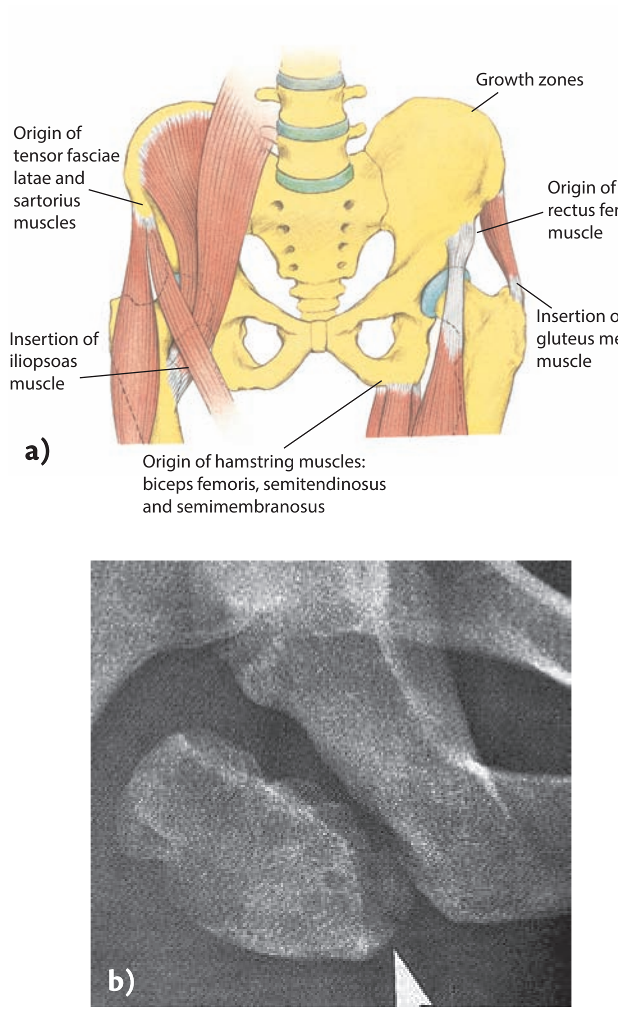

Figure 23.6 Avulsion fracture. **a)** Common locations for avulsion fractures of the bone; **b)** X-ray of a missed large avulsed fragment at the insertion of the hamstring muscles on the pelvic bone (ischial tuberosity).

When an adolescent has suffered accidental injury and tenderness, swelling and effusion of blood are present in the injured area, an X-ray should be taken. If bone attachments have been torn away and displaced to such an extent that they cannot heal to their original site, surgery should be considered in order to reposition and fix the fragments. A large displacement of the fragment can impair future functioning of the ligaments or muscles if the injury is not treated correctly.

Sometimes it is not fragments of the bone that are torn away, but only the periosteum to which the tendon or ligament is attached. This can cause a loss of function in the muscle or ligament, but is not visible on X-ray. For this reason, functional testing of muscles and joint stability is of the utmost importance to make the correct diagnosis and choose the correct treatment. Magnetic resonance imaging (MRI) can be helpful.

An injury caused by an avulsion fracture can be more serious than a straightforward rupture of a muscle or tendon, since it has the same implications as a fracture. Injuries due to avulsion should therefore be distinguished from muscle ruptures that often occur in adults, who have been subjected to similar violence. Healing times are longer for avulsion fractures than for ruptures of a muscle and can be anything from 1 month to 6 months depending on treatment. It is essential that avulsion fractures are diagnosed at an early stage so that adequate treatment can be started. If these injuries are neglected, the result can be chronic pain and impairment of joint or muscular function, resulting in instability or impaired mobility.

Tip

Adolescents with tenderness, swelling and effusion of blood in the injured area after trauma should be X-rayed.

Injuries due to overuse

Injuries resulting from overuse in adolescents usually affect the apophyses, which include the parts of the skeleton that constitute the attachments of tendons, ligaments, muscles or joint capsules.

Apophysitis

Apophysitis is an overuse injury of an apophysis in the skeletally immature athlete. In a muscle and tendon unit there are certain areas at high risk of injury: these are the attachments of muscle and tendon to bone, the muscle and tendon tissue itself, and also the point at which muscle and tendon merge (the muscle–tendon junction). In adults, the muscle or tendon tissue itself is often injured by trauma, while the corresponding trauma in adolescents causes injuries to the attachments of the muscle or tendon to bone. Studies have shown that physical training increases the strength of tendons and ligaments faster than that of their attachments.

Apophysitis (inflammation of an apophysis) resulting from overuse occurs mainly in specific sports, such as football/soccer, handball, basketball, volleyball, American football, long jump and high jump, that involve a great deal of jumping and bending of the knees, thus exposing the apophyses to great tensile stress and overloading (Fig. 23.7).

The site at which apophysitis most often occurs is that of the attachment of the patellar ligament to the tibia (Osgood–Schlatter disease, p. 458). Overloading of the apophysis causes inflammation in the attachment of the tendon, which manifests itself as pain, tenderness and swelling. An X-ray may show fragmentation of the bone under the attachment of the tendon. Apophysitis also often occurs in the attachment of the Achilles tendon to the calcaneus (apophysitis calcanei, p. 496).

In cases of apophysitis it is essential that the affected athlete rests at an early stage, avoiding the movements that trigger pain, until no more pain and discomfort are felt. The condition can otherwise be of a long duration.

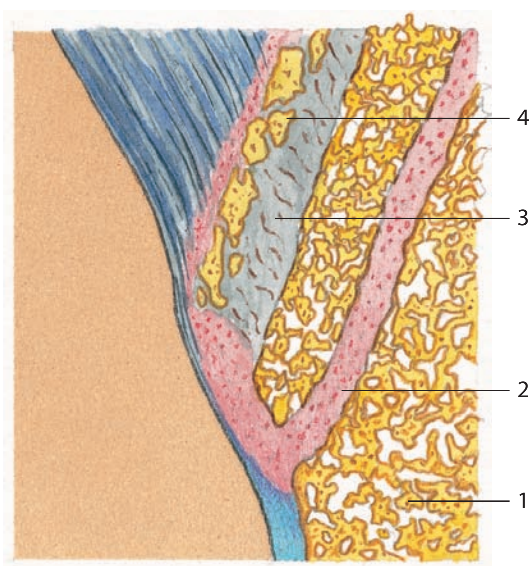

Figure 23.7 Schematic enlargement of the changes occurring at an injury in the apophysis (attachment of the muscle/tendon into bone); 1: Metaphysis (transmission zone) in the tibia; 2: growth plate or physis (epiphyseal cartilage); 3: space between fibrous tissue and fibrous cartilage; 4: bone fragment.

The most common cause of apophysitis is one-sided training. Here it is appropriate to warn against excessive strength training by young, growing people. When strength training is carried out with a heavy load, the strength of the muscles develops faster than the strength of the skeleton and can result in apophysitis and also in avulsion fractures. Growing individuals should therefore practice strength training using only their own body as a load or only light weights.

Stress fractures

One-sided loads on the skeleton can lead to stress fractures or fatigue fractures, when intensity and load are too high and the recovery time too short such that the adaptive ability of the body is insufficient to cope. Stress fractures can affect children who begin athletic training as early as the age of 7 years. The frequency of stress fractures in adolescents is increasing. The injury can be caused by frequently repeated movements under normal load, e.g. long-distance running, or by movements of a lower frequency but with a higher load, e.g. weightlifting. The most dangerous combination, however, is a high load and a high frequency. In principle, stress fractures can occur in any bone of the body, but are most common in the lower limbs. They occur mainly in the metatarsal bones, and in the tibia, fibula, femur, hip and pelvic bones and vertebral bodies. Stress fractures should always be suspected in people who are subjected to repeated movements or heavy loads and who complain of pain on exertion (Fig. 23.8).

Figure 23.8 a, b) There is a risk for stress fracture in the skeleton of the spine after repeated movements in sports such gymnastics, which may include major spine extensions and flexion (see p. 351). (With permission, by Bildbyrån, Sweden.)

Usually there is no pain or discomfort at rest. Local tenderness and swelling over the painful area are found and a clinical examination usually leads to the diagnosis. If no fracture is discovered on X-ray examination, it should be repeated 3–4 weeks later if the symptoms persist. The diagnosis can then be confirmed. A bone scan or MRI can confirm the diagnosis at an early stage.

The risk of stress fracture can be reduced primarily by increasing training gradually, but also by varied training alternating with regular rest so that the body has time to recover. The surface that athletes use in training can also be of importance, and the construction of the shoes is vital. Anyone running on a hard surface should always wear shoes with good shock-absorbing properties. When there is a change from a hard to a soft surface or vice versa, the intensity of training should be reduced during the transition period.

Articular cartilage injuries

The collagen tissue of the articular cartilage has less tensile strength in adolescents than in adults; thus children and young people can injure the articular cartilage more easily than adults as a result of sprains and direct blows. A prolonged extreme load on the knee joint, e.g. in downhill skiing or sailing, can result in injuries to the articular cartilage of the patella. In this condition, chondromalacia patellae (p. 446), pain arising from the inner surface of the patella or around the patella, is triggered mainly by running uphill and downhill and by squatting. The articular cartilage of the patella softens and debris gathers. Since the cartilage does not contain any nervous tissue it is not clear why pain is triggered, but it may originate from the synovial membrane or subchondral bone. The causes of chondromalacia patellae are not known for certain either, but anatomic background factors such as patella alta, increased Q-angle and patellar instability or patellofemoral dysplasia should be looked for (see p. 449); however, the early condition responds to heat therapy and isometric training of the anterior and posterior thigh muscles.

Another cartilage injury that occurs in adolescents is osteochondritis dissecans (p. 164), in which a part of the articular cartilage and bone that has been damaged breaks away and can become free, moving inside the joint where it causes problems.

The diagnosis of these cartilage injuries is made with the help of arthroscopy, bone scan or MRI.

Training young athletes

The most decisive stage of an athlete's life from a medical and orthopedic point of view is probably the moment of decision to concentrate on one particular sport, with all that that entails in the way of prolonged and planned intensive training. It would be desirable for a young athlete's physiological qualifications for the sport in question to be analyzed, but unfortunately there is as yet no sound medical basis for a reliable judgment (Fig. 23.9).

Regular, targeted training is now starting at younger and younger ages. Training methods that have been developed for adults are directly applied to children without adapting them either to suit their age or to suit individual variations. With regard to training and competitive activities for adolescents, the trainer and the coach must be aware of the risks that exist for children in the long term as well as in the short term.

Tip

Sport must remain joyful play for children and a means of maintaining physical health for adults.

Training activities must therefore be questioned: should we allow the young athletes to train as hard as they do today in order to reach the top level, and are the optimal training methods and techniques being used?

Tip

Children are not miniature scale models of adults. They mature at different rates, and puberty can occur any time within a span of about 4–6 years. This physiological inequality in development is often forgotten and not always respected by coaches and managers.

Physical fitness training

Physical fitness training is no more effective for young people aged 10–20 years than for any other age group. The anaerobic energy-producing capacity – the ability to produce energy in the absence of oxygen – is lower in children aged 10–12 years than in teenagers. Regardless of age and this capacity, however, young people can benefit from taking part in activities that demand anaerobic

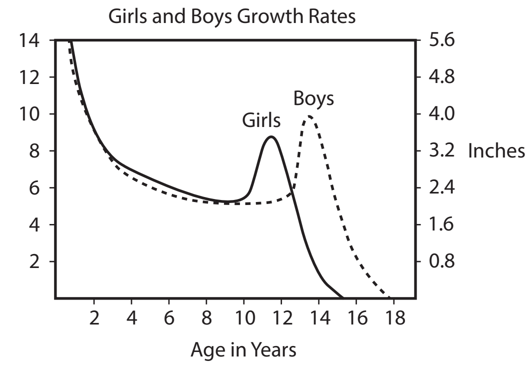

Figure 23.9 Growth curves for children. It is important to be aware of the large variations among growing individuals between the ages of 10 and 15 years. There may be differences in chronological compared to biological age of up to 3–5 years.

energy, and children do not seem to feel tiredness in the same way that adults do.

Tip

However, recent findings indicate that adolescents do not lose anything by delaying systematic physical fitness training until they are in their late teens.

Strength training

In growing children the internal organs are able to adapt to great loads, while the musculoskeletal system can easily be damaged. The effects of training in children and young people are seen mainly in the muscles, the cells of which increase in size. This increase in size is directly related to the length and intensity of the training program. The muscles become strong when they are trained and lose their strength rapidly when the training ceases.

Children and young people respond to muscular strength training because there is relatively more effect on the musculature than on the skeleton. Under normal circumstances their muscles are not used for strength-requiring activities to the same extent as those of adults, and strength training in growing youngsters therefore has a more obvious effect on their musculature. In adolescence great increases in strength are characteristic of both men and women, but in the early teens the increase in strength is distinctly less than the increase in body size. Athletes in their early teens are therefore not quite as strong as their body size might indicate.

There are a number of different types of strength training (Fig. 23.10). In isometric training the ability of the muscle to exert power increases, but its stamina does not increase as much as in dynamic training. In adolescence the attachments of tendons and muscles

Tip

In strength training with heavy loads, muscular strength develops faster than the strength of the skeleton, which can lead to avulsion fractures.

in particular are vulnerable, and therefore children and young people should be cautious about isometric work with a load, which means that the muscles are working without appreciably changing their length. Light dynamic work, such as running and walking, when the muscles are working by lengthening and shortening, is in most cases sufficient.

Training with heavy weights should be avoided by individuals who are still growing. The load on the vertebral column during weight training, for example, can be so great that the vertebrae are affected. Only the weight of the body should be used as a load in strength training; systematic strength training with heavy weights should only be permitted when the skeleton has stopped growing, which in girls happens at about the age of 14–16 years and in boys at 17–18 years. Before that a growing youngster can perhaps use light weights, but the training intensity should only be stepped up by increasing the number of exercises carried out.

Tip

A strength training program should be drawn up according to the growing youngster's age, maturity, body build, physical fitness and sex. Time for tissue recovery is very important.

Figure 23.10 Early strength training with weights should be carried out with great care and under knowledgeable expertise and leadership. **a)** Large loads increase the risk for damage to the growth zones and they can be injured (with permission, by Bildbyrån, Sweden); **b)** training with the athlete's own body weight, e.g. with pushups, is a safe and tested technique in weight-training (photo, Henrik Peterson); **c)** in some sports, such as wrestling, strength training is part of the sport as such (with permission, by Bildbyrån, Sweden).

The International Federation of Sports Medicine (FIMS) has issued a position statement on resistance training for growing individuals. Its recommendations are given here with permission.

The available evidence suggests that resistance training can result in significant strength improvements in both children and adolescents, and that such programs can be performed safely if several important safety aspects are adhered to:

- No resistance training program should be started without the proper supervision of a certified strength and conditioning professional.
- The child should be taught the proper technique for each exercise.
- Exercise equipment being used should be safe and suitable for the child's size.
- High training intensities should be avoided, and maximal intensities should not be performed before the child reaches 16 years of age, or Tanner Stage 5.
- All progressions in training intensity should be made very gradually.
- Resistance training should be used as a supplemental form of physical activity and should not be used in place of the child's normal activity.
- Resistance training programs for children should be designed to meet the needs of the particular sport of the child or adolescent.
- All exercises should be performed throughout the full range of motion of each muscle in a controlled manner.

- Fast, sudden and ballistic movements during the exercise should be avoided.
- Warm-up and cool-down exercises should be performed prior to and after all training sessions.

Some sports medicine organizations in the USA and the UK recommend early and extensive strength training for children. In the USA some recommend strength training for children 2–3 times per week, 20–30 minutes per session; 6–15 repetitions per set and 1–3 sets per exercise should be performed. The load should be increased if the child can perform 15 technically correct repetitions. These recommendations do not differ significantly from what could be recommended for an adult beginner.[1] We are doubtful of the advisability of this extensive early strength training.

They are many who believe that strength training in youngsters aged 8–10 years contributes to the prevention of sports injuries. It should be noted that there are no scientific studies that have shown this.

Tip

General advice we want to give about strength training in children and growing individuals:

- There are wide variations in growth in 10–15-year-olds, as mentioned above and there may be differences of up to 4-5 years in chronological and biological age. Body weight can differ by 15 kg and length 20 cm in children with the same chronological age.
- The increase in muscle mass usually takes place during the growth spurt and may cause temporary imbalance. A weight of 30 kg during squatting can cause stress reactions in apophysis, epiphyses and the subchondral bone. Caution with heavier weights is recommended.
- Strength training should be individualized and sport specific.
- All weight training should begin with proper warm-up.
- Squats should not exceed 90° in strength training.
- Strength training of growing individuals should include coordination, stability, movement, agility, flexibility and balance training. Large muscle groups should be included if possible.
- Body weight training is usually sufficient as load, but light weights can be used. It is then better to increase the number of repetitions than increasing the weight. However, limit the number of repetitions when cells do not withstand loads over prolonged periods.
- Therefore, take frequent breaks during resistance training.
- Strength training should be safe. Please ask for advice and help when needed.

General mobility training

A considerable part of an adolescent's mobility training consists of basic movements, which are carried out more or less automatically, such as moving the body and maintaining the balance. This type of movement is hereditary and is controlled by instincts, which are passed on genetically and gradually develop during childhood. Balance, for example, is not fully developed until the age of 9–10 years. Whether physical training can influence development in a positive or negative direction is not known. In most sports there are complex patterns of movement that have to be learned with the aid of the pre-existing instinctive knowledge. When such a pattern has been developed it is difficult to change, so it is important to learn it correctly from the start. The nervous system can incorporate new patterns right into the teenage years. It is undesirable to incorporate incorrect information into the nervous system before it is fully developed, as it would subsequently be difficult to alter, which is why technique training should be led by a trainer.

Training in different age groups

5–9 years: play, technique and all-round training

Training of children aged 5–9 years should above all be full of variation and fun, i.e. the play and joy element should predominate. Light fitness training including different ball games is suitable. All-round training should be the aim. Technique training should be introduced now, as children of this age are very receptive to learning (Fig. 23.11).

In this age group resistance and technique training can improve strength without providing concomitant muscle hypertrophy. The training increases the number of motor neurons, which are nerve cells located in the spinal cord and whose fibers control the muscle contractions.

Tip

The improvement in strength in young children is facilitated by neuromuscular learning.

10–11 years: general basic training, technique training and all-round training

Training of children aged 10–11 years should include technique and coordination exercises, since this is an excellent time for improving reflexes and mobility technique by training. Play elements are important

Figure 23.11 a–d) Training at very young ages should be focused on play. At around 5–9 years of age some technique training may start. (**b, c)** with permission, by Bildbyrån, Sweden.)

features in the training, but systemic fitness training and anaerobic training are not meaningful during this period.

12–14 years: general fitness training, learning of technique and tactics

During the age period 12–14 years, which partly coincides with puberty, there are rapid changes in growth and maturity, both physically and mentally. The training must be adjusted to the maturity of the individual youngster.

Tip

The body is in a sensitive stage of development, both physically and mentally, and this must be taken into account.

The play element should be given ample scope. Technique training can also be carried out since the ability to learn continues to be high during this period of growth. Some specialization can begin in the sports for which the young athletes have shown talent. They can be introduced to tactical methods.

15–16 years: preparation for specialized training

In young people aged 15–16 years basic physical fitness must be built up, and therefore regular fitness training should become a habit. Anaerobic training can now begin. Comprehensive gymnastics and flexibility training are of great importance during this period, since growth often makes young people stiff and rigid. Strength training can start when the muscles and skeleton allow an increased load. At this age young people can start to learn the correct lifting technique, but should only use light weights.

Tip

Heavy loads should not be used, as the skeleton has not yet stopped growing.

The strength training should be intensified by increasing the number of times an element of exercise is carried out, not by increasing the load. It is important that the athletes spare their backs from overload by using the correct lifting technique. During this period, specialization in different sports can be undertaken.

Over 16 years of age: specialized training

Young people who are over 16 years old can participate in specialized training that does not differ appreciably from that of adults. Growth in girls tends to be complete by the age of 16–18 years while the development of boys continues up to the age of 18–20 years.

The role of training

When it comes to training and competition for adolescents there has to be an awareness of the risks these entail, both in the short and in the long term. Knowledge of the special characteristics of the musculoskeletal system in growing youngsters is therefore of great importance. There is a need to question training methods, which make such hard, monotonous, and regular demands, that sport becomes agony rather than the enjoyable pastime it should be. The aim should be to encourage a large number of young people to become active athletes so that a vast pool will be available from which top athletes can be produced in the long run.

Tip

A lasting interest in sports should be nurtured in adolescence so that in adulthood sport is regarded as a means of maintaining physical health and fitness for the whole of one's life.

During the years when adolescents are at their most receptive and find it easy to learn, the stress should be on technical training which can be made interesting and stimulating. Hard physical training and specialization, for those who have the ambition to go far, should start at a later stage.

Adolescents are different from adults, and it is important to remember this when harder and harder training of young children is beginning to be the norm (Fig. 23.12). Age groups create a classification that is purely chronological and ignores the complete physiological picture of a growing youngster.

Tip

It is quite common for there to be a difference in maturity of more than 5 years between young people in the same age group.

Thus, a group of children aged 11–12 years can include youngsters whose biological maturity is on the same level as that of a 16-year-old. All training of children and young people must therefore be individual. Coaching courses must be mandatory so that those who train and manage growing young people are well prepared for their task.

In the world of sport there is a widespread conception that training will more beneficial and efficient if it starts at the very young ages. There is however no science supporting this theory. The question is rather whether too hard and intensive training at an early age can have any adverse effects in later life. Apart from anything else, such training is one reason why many young individuals may give up sport.

Intensive training of children and young people with the aim of making them into top-level athletes should not begin without a medical screening and examination, and then their progress should be supervised by a physician.

Anyone involved in training growing young people should have a sound knowledge of the physical development of children and adolescents.

Figure 23.12 Children are not small copies of adults. (**a)** with permission, by Bildbyrån, Sweden; **b)** photo, Henrik Peterson; **c)** photo, Julia Tinder; **d)** with permission, by Swedish Football Association.)

Tip

Training programs for children and young people must be drawn up individually. Development (biological maturity) can vary by 4–5 years in youngsters of the same chronological age. The training should be adjusted to the individual, not the individual to the training.

Reference

1. Policy statement on Strength Training by Children and Adolescents by the American Academy of Pediatrics. *Pediatrics* 2001;107:1470–2, revised 2008.

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24 Outdoor Activity Risks and Sports During Extreme Conditions

Outdoor activities

Prolonged physical outdoor activities place great demands on the human being, who can be subjected to stresses that he/she is not used to or expects.

When medical problems arise during outdoor activities, it may take a long time (hours to days) to reach a place with medical expertise available. Additionally, mobile/cell phones usually do not work well in remote places, for example in the mountains. The climate can be challenging; for example, in Scandinavia and Canada the weather can be both cold and windy, with great differences between winter and summer. An injury or illness during outdoor activities can quickly become serious and even fatal.

Tip

It is therefore important to have a good first aid kit packed and to be physically well prepared for the planned activity. Some basic education in acute treatment of certain problems is always of value.

Preventive measures

Basic physical fitness

Anyone traveling to remote places should first build up a good basic physical fitness. A long hike should not be attempted without practicing its unfamiliar aspects, such as carrying a full backpack.

Equipment

The equipment carried must be carefully chosen to meet the demands of the hike. Shoes should always be well worn-in and the backpack should fit well. Comfortable and appropriate equipment is a prerequisite for an enjoyable stay out in the open, and a change of clothes should always be carried. Generally, no special equipment is needed on simpler hikes.

For advanced hiking in rough terrain, for example in mountains or similar demanding environment, a pair of well-worn, water-tight, stable or robust shoes (hiking type boots) are essential. A walking stick can sometimes be very helpful.

Tip

Well-fitting, well-proven and appropriate equipment are essential for a rewarding stay in the outdoors.

Health

Although a stay in the open is often pleasant and health promoting, a strenuous hike not only may fail to restore health and strength, it may demand more than it gives in return. Anyone who has recently suffered a bad cold, bronchial or similar infection should not indulge in a long, demanding hike. In such circumstances, staying in the area and taking short day trips with rests is more likely to be beneficial (Fig. 24.1).

Body heat

It is vital to learn how to conserve body heat, particularly in the winter. Body heat is maintained by metabolizing food and by muscular work and using the right clothing. During stays in the open, demands are increased and a hungry person feels the cold more easily, so a high-energy food intake is recommended. Alcohol and tobacco should be avoided. Damp clothes should not be allowed to dry on the body, as this causes heat to be lost by evaporation.

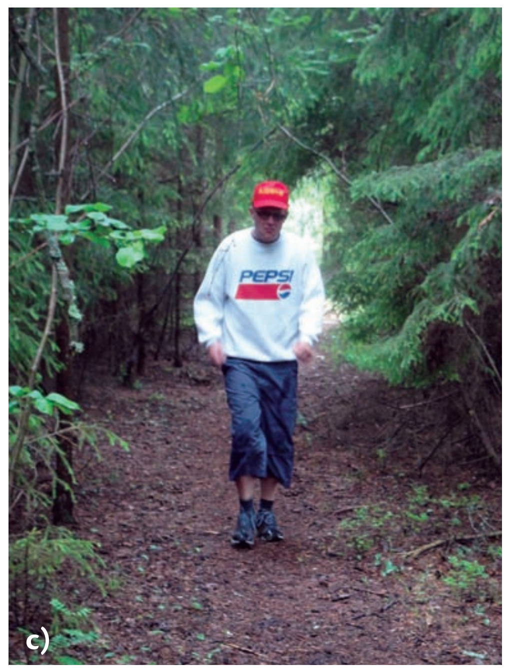

Figure 24.1 Being out in nature during spring, summer and fall can often be a wonderful and sometimes exciting experience. It requires, however, adequate preparation and appropriate equipment. Here some examples of popular outdoor recreational activities. **a)** Picking mushroom is a very popular activity in countries such as Sweden, which is rich in forests and allows open access to all land; **b–c)** outdoor walking/running in a group or singly is popular (with permission, by Bildbyrån, Sweden).

Blisters and wounds

Blisters are recurrent problems on long treks. The treatment of blisters is discussed on p. 190 and wounds are discussed on p. 189. Prevention of blisters and wounds is advisable on a long trek. It is recommended to have washed the feet. Moisturizing the feet the night before with a skin ointment and wearing dry socks without holes is recommended.

Insect bites or stings

Insect bites can mean anything from a small prick of a mosquito to a sting from a wasp, which may hurt. These are usually harmless but can cause itching, swelling and redness. If stung it is recommended to try to avoid scratching. The symptoms disappear rapidly. A locally applied steroid cream usually works well to prevent irritation, and if the reaction is severe a physician may prescribe an anti-histamine.

In deciduous forest areas with high grass and dense undergrowth tick bites can be a problem, especially in summer. Tick bites carry the risk of contracting Lyme disease (caused by the bacteria *Borrelia* sp.) and tick-borne encephalitis (TBE), which is a viral infectious disease involving the central nervous system. Boots and long pants are recommended. An entire body examination should be done after hiking in high grass. Initial treatment involves cleaning the wound. Mouth parts from the insect should be removed with tweezers if they remain in the skin. Wash with alcohol afterwards. A physician should be contacted if the swelling increases or signs of infection show. Long-lasting problems are observed in 10–20% of infected patients.

Sprains of the knee and ankle

Ligament injuries to the knee and ankle joints often occur during outdoor activities (Fig. 24.2). These injuries are discussed in Chapters 19 and 21. Generally, nothing can be seen but swelling, and it is usually then impossible to replace the shoe because of the swelling and discomfort. High boots are an excellent support for the ankle joint.

Tip

Anyone who sprains an ankle while far from help should not remove the shoe to examine the injury, particularly in winter.

Injuries due to overuse

During prolonged exertion such as hill walking, overuse problems can occur, especially when the person is unfamiliar with the type of activity that is involved. Walking downhill may cause pain around the kneecap (patellofemoral pain syndrome, p. 446), while long walks uphill and running on sandy beaches can result in Achilles tendon problems (p. 491).

If a heavy backpack is carried on a long walking tour, the straps can press against the shoulders (Fig. 24.3) and exert increased pressure on the suprascapular nerve (p. 258). When using a modern backpack (rucksack) on a longer hike to carry loads over 10 kg (22 lb), it is recommended to unload a large part of the shoulder weight to padded hip belts, leaving the shoulder straps mainly to stabilize the load. The hips are then absorbing more weight instead of the shoulders and back.

Tip

Before any activity of this sort, careful preparations are essential. Equipment should be chosen carefully and well worn-in, and unfamiliar activities such as carrying a full backpack should be practiced.

Figure 24.2 Outdoor life includes many different types of activities that can be exciting and be carried out in many different ways. **a)** Walking downhill on a mountain, especially if there are no trails can be very strenuous for the lower extremities including the knees (photo, Kerstin Samuelsson); **b)** mountain climbing is a tough sport with well trained individuals (with permission, from DJO, LLC. All rights reserved).

Lighter backpacks are usually used when hunting, fishing and undertaking lighter outdoor activities. Some bags have a frame included, where the frame's function is to be used as a seat.

Fractures

For general symptoms and treatment, see p. 148. Fractures should always be treated by a physician, so during remote outdoor activities, it is usually the responsibility of the injured person's companions to arrange transportation.

Fractures should be immobilized by splinting. Skis, sticks or straight branches can be used in the absence of anything better. The splinting should include the joints on either side of the fracture. If the femur is fractured, for example, the hip and knee should be stabilized, and the splint should extend from the armpit down to the foot. If a suitable splint is not available, a broken leg can be supported by strapping it to the other leg, and a broken arm can be strapped to the body. If it is badly displaced it may be necessary to realign a broken leg by straightening it longitudinally before immobilizing and transportation.

Apart from the splinting, as little as possible should be done to fractures out in the open, and transfer to a hospital should not be delayed.

Figure 24.3 a, b) A modern backpack (rucksack) is equipped with a system of straps as it is constructed to unload a large part of the shoulder weight to padded hip belts, leaving the shoulder straps mainly to stabilize the load. There is also a tight stretched netting panel, which prevents contact between the metal frame and user's back.

General rules for care and transport of injured people

If a severe injury occurs in a remote area, the injured person should be placed in a sheltered position and kept warm. Something warm, like an anorak or survival bag, should also be placed underneath the person's body. If it is likely to take more than 4 hours to reach a hospital, the patient should be given something hot to drink and, if necessary, something to relieve the pain, and kept calm while waiting for transport. Keeping the injured calm is of importance.

It is difficult to move a seriously injured person, and the transport should be carefully prepared. If a stretcher, sledge or boat is available, it should be brought to the scene of the injury, and during the transport it should be made as comfortable as possible for the injured person. Do not hesitate to call for helicopter help in cases of severe injury, such as fractures. If a neck or spinal cord injury is suspected, appropriate immobilization and cervical spine transport precautions are necessary.

Sports during extreme conditions

Sport in cold conditions

Frostbite

'Frostbite' is a collective name for injuries that are caused by exposure to low temperatures, which may mean temperatures above as well as below freezing point. The physiological regulation of body temperature is influenced by factors such as caloric intake, humidity, alcohol, disease and choice of clothing (Fig. 24.4).

The extent of the frostbite depends on the temperature, the length of exposure and the wind-chill factor. In temperatures above freezing, dampness is also a factor. 'Lifeboat foot', 'air-raid shelter foot' and 'trench foot' are examples of conditions caused by sitting still in cold and humid conditions.

Increased wind speed increases the likelihood of frostbite. The significance of the wind factor is shown by having the same risk of frostbite at 0° and a wind speed of 20 m/s as at -20° and no wind. The true temperature at different wind speeds is shown in Table 24.1.

When the outside temperature is -10°C (14°F) and the weather is calm, it is tempting to go out skiing; but if the wind force is 10 m/s, the effective temperature is -30°C (-20°F). Note that the same effect is exerted by wind rush in motorcycle racing. Simply turning one's face into the wind gives a good idea of wind speed.

Local frostbite

Local frostbites can be classified into different degrees:

- **First-degree frostbite**. The skin becomes white and numb, though the victim does not always notice what is happening. At normal room temperature, the skin may assume a bluish-red discoloration. Usually a gradual onset of local stinging pain occurs, but this may be absent if the cold is extreme. Even first-degree frostbite makes the affected body part extra cold sensitive for the rest of their lives.
- **Second-degree frostbite** is characterized by dark-blue skin and numbness. Sharp pain is experienced when the body part is warmed up. Within hours to days blistering can occur, as in a burn. Circulation in the skin can still occur. Slow healing takes place over a few weeks.
- **Third-degree frostbite** includes deep tissue damage when the extracellular fluid freezes and crystallizes. Cell death can occur and blood circulation is interrupted. The tissue dies and must be removed surgically to prevent gangrene. Third-degree frostbite can lead to several weeks' bed rest.
- **Fourth-degree frostbite** is a completely frozen solid body part, which often later requires amputation.

Treatment

The injured person should:

- Shelter behind a companion, in a survival bag or in something similar.

Table 24.1 Wind-chill factor

Temperature in °C (°F) at increasing wind speeds				
In still air	**5 m/s**	**10 m/s**	**15 m/s**	**20 m/s**
0 (32)	−5 (24)	−15 (6)	−18 (1)	−20 (−5)
−10 (14)	−21 (−7)	−30 (−20)	−34 (−28)	−36 (−33)
−20 (−5)	−34 (−28)	−44 (−51)	−49 (−58)	−52 (−64)

Figure 24.4 a, b) When the outside temperature is −10°C (14°F) there is a risk for frostbite.Increasing wind speed increases the likelihood of frostbite. It is often helpful to cover the risk areas of the face as well as possible. Here some examples show how some top athletes cope with the low temperatures sometimes combined with heavy wind. (With permission, by Bildbyrån, Sweden.)

- Use body heat to warm the affected area. A warm hand can be placed against a frostbitten cheek or nose. A chilled hand can be put in the armpit or on the warm skin of the abdomen. A chilled foot can be placed against a companion's abdomen.
- Never use snow to rub or massage frostbitten skin.
- Never warm up in front of an open fire as the sensitivity in the frostbitten part may have been impaired and severe burns can result.

A companion or leader should:

- Provide the injured person with dry, warm clothing and a warm drink.
- Force the injured person to keep moving to increase body temperature
- Take the injured person indoors, or, in cases of extensive frostbite, to hospital.

Frostbitten feet should not be rewarmed until evacuation from the area is possible. It is possible to walk on frostbitten feet without much further damage; but once the feet are rewarmed, the pain makes walking impossible.

In cases of local frostbite the injured person can be warmed in a hot bath (40°C, 104°F), if this is feasible. This treatment should not be used, however, in anyone suffering from general hypothermia.

Complications

If blisters appear a few hours or days after the skin has suffered a local cold injury they should be left untouched. The surface of the blister is the best protection against infection. The long-term effects of frostbite can be extreme sensitivity to cold in the skin that has been damaged, together with stinging pains and sweating.

Hypothermia

This is a condition, when the body's core temperature drops below the level that is required for normal body functions, including metabolism. It can be defined as any body temperature below 35.0°C (95.0°F). People suffering from hypothermia become progressively weaker and more indifferent. They are overcome by tiredness, and can fall asleep and ultimately die because of their reduced body temperature: it may seem much more pleasant to give up and fall asleep than to fight and overcome the cold.

A symptom of hypothermia is muscle tremors, which disappear at about 32°C (90°F) body temperature. Thereafter, effects on consciousness and muscle functions occur. There is a risk of dying because of reduced body temperature, since a temperature below 27°C (80.6°F) may cause lethal cardiac arrhythmias. The person is usually dead at body temperatures below 25°C (77°F).

Treatment

If the patient is conscious the following rules apply:

- The patient should be provided with dry, warm clothes.
- The patient should be forced to move about and activate the muscles.
- A warm, sweetened drink should be given. Too hot a drink causes the blood vessels of the skin to dilate so that even more heat is lost, the core temperature is lowered further and the heart may be damaged.
- The patient should, if possible, be taken indoors as soon as possible.
- Warming should be carried out slowly at normal room temperature. Heating packs and warmed blankets should not be used to rewarm the patient.
- The patient should be taken to hospital as soon as possible.

If the patient is unconscious the following rules apply:

- Do not attempt to give anything to drink.
- Remove wet clothes.
- Warm the patient slowly at room temperature with the head at a lower level than the feet. Breathing and pulse should be checked.
- Warm blankets and heating pads can be used until the patient is transported to hospital.
- The patient should be taken to hospital as soon as possible where warming can be carried out under controlled conditions.

Tip

Basic rules to keep warm include that the body should be kept clean and dry and that the clothes on the body should be loose fitting, to allow adequate circulation.

Sport in hot climates

Training and competition in hot climates can cause great problems for athletes, and anyone training or competing in such environments should be aware of the risks and appropriate preventive measures.

Many factors are important to maintain the body's temperature balance, i.e. balance between heat production and heat loss. Factors of importance are outdoor temperature, wind conditions, solar radiation, solar reflection from objects in the environment, humidity and altitude. An athlete's physical and mental status and level of fitness, age and weight are important for the ability to maintain temperature homeostasis (Fig. 24.5). Adequate fluid intake is crucial for the body's ability to regulate temperature. Clothing should be airy, of bright colors and allow air flow. The time for training and competition is a risk and the longer and more intense the activity, the more heat is generated and the greater water loss occurs (Fig. 24.6). Acclimatization in the new location for 5–14 days can be of great value and reduces risks.

The temperature of the body, generated by muscle work and metabolic heat, is regulated by evaporation, radiation and convection. Evaporation is the most important method of heat loss. For effective control of body heat by evaporation, the athlete must drink sufficient amounts of liquid. Heat convection will cease in air temperatures above 38°C (100°F); evaporation will cease when water vapor pressure is over 40 mmHg (5.3 kPa); the lower the wind speed, the lower the rate of sweat evaporation. The direct solar radiation is maximal at midday (11:00–16:00) when training and competition should be avoided. Solar reflection from the environment is higher at that time. High altitude causes increased stress on the circulatory, respiratory and muscular work, as a result of reduced oxygen content in the air.

Elevated body temperature has both physiological and psychological consequences for the athlete whose performance is affected. When heat regulation in the body is exposed to extreme stress the athlete can react with muscle cramps, exhaustion and heat stroke with coma, that can end in death.

Some known accepted scientific facts on heat/sport parameters include:

- The scientific evidence regarding competition and training in hot climate is incomplete and therefore there are few regulations that limit these activities.

Figure 24.5 Cooling can be done in many ways, such as with a large cold pack. (With permission, by the Swedish Athletic Association.)

Figure 24.6 a, b) Tennis players often play in high temperatures and can use ice and take a break to cool down. It is essential to drink a lot of fluid during the breaks. (With permission, by Bildbyrån, Sweden.)

- There is no specific temperature that has been identified as a risk level that can cause heat stroke (heat illness); the effect of participating in activities such as tennis or running in temperatures over 35°C (95°F) has been disputed by medical experts.
- After a 10 minutes break with rest the core temperature goes down by 1°C, especially in those who are not acclimatized.
- There are well-defined preventive techniques available in sports like football/soccer and tennis. A very important preventive measure is to have the athlete in a very good physical condition, i.e. is aerobically fit.
- Educational materials need to be developed in parallel with more research.
- Sports activity in high heat should be postponed to when the temperature is acceptable.

Tip

Sports in high temperature should be avoided, especially as the knowledge about the medical risks is limited.

Heat illness

The traditional classification of heat illness defines three categories: heat cramps, heat exhaustion and heat stroke.

Heat cramps

Heat cramps are associated with prolonged exercise. They are intermittent, of short duration and often excruciating. Heat cramps affect the muscles that work most intensively. In runners and football/soccer players, the calf muscles are most commonly affected, and in racquet players, the arm muscles are affected. The exact mechanism of heat cramps is unknown, but they may be due to intracellular water and electrolyte disturbances after dehydration. This theory, however, is now challenged as there are many who believe that cramp is mainly caused by abnormalities in the neuromuscular control at the spinal level, in response to exhausting and long-lasting exercises. In tennis experience has shown that most players respond well and in a timely fashion to ice, stretching and rehydration with oral salted sports drinks.

Tip

Muscle cramps may occur in situations without heat impact, but the heat can be a trigger. Cramps should therefore not only be seen as an environment problem.

Heat exhaustion

With any type of exercise in hot or humid environments there is a risk for an exertional heat illness. During training and competition in a hot climate, the athlete may suffer from fatigue and exhaustion, including a continuum from pure fatigue and confusion to a state of temporary unconsciousness or feelings of dizziness (postural hypotension) during training/competition. There are two forms of heat exhaustion: water depletion and salt depletion, the former being the major threat to athletes. During strenuous muscle work in warm environments, the athlete may lose 1–2 liters (2–4 pints) of body water per hour in sweat. If this loss is not replaced by water intake, dehydration will occur. Intracellular (inside the cell) fluid volume decreases and the osmotic concentration (the volume of water contained in a solution) of the extracellular (outside the cell) fluid increases, drawing water from the cells into the extracellular space. Severe dehydration may cause circulatory collapse and kidney failure. The athlete experiences fatigue, dizziness and poor muscle coordination, and may become delirious or (in severe cases) comatose.

The athlete should drink water to prevent dehydration. When in a dehydrated state, fluid should be administered intravenously; it is not necessary to give electrolyte solutions during the early stages of dehydration.

Several sports are trying to prevent dehydration and cramping occurring under hot conditions. To do this some International Federations in football/soccer (FIFA), tennis (ITF, ATP, WTA) and volleyball (FIVB) have for some time been measuring the wet bulb globe temperature (WBGT) to assess environmental heat stress as it considers wind, humidity and solar radiation.

The female tennis professional organization, WTA, a few years ago introduced a rule that a 10 minute interval must be introduced between the second and third sets if the temperature is high, i.e. a WBGT of 28°C (82°F). Research has shown that this technique will lower the body temperature by 1°. WTA has found no indication that the players have abused this new rule, but instead found that the standard of tennis in the third set is improved.

Tip

A 10 minute break from competition can be effective, because this can lead to lowered core temperature by 1°C.

Table 24.2 Risk evaluation (moderate, high, extreme) related to ambient dry temperature or wet bulb globe temperature (WBGT)

Ambient dry temperature (degrees)	WBGT	Risk of thermal injury
25–31.9°C (77–89.4°F)	24.0–29.3°C (75–85°F)	Moderate
32–38°C (89.6–100°F)	29.4–32.1°C (85–89.9°F)	High
38°C and above (>100°F)	32.2°C and above (>90°F)	Extreme

Heat stroke

If the body's heat regulation system cannot keep the temperature within the normal range, heat stroke may occur. This is rare in sports. It will cause tissue damage, including inactivation of enzymes, and damage to cell organelles and cell membranes. Distinctive features are serious central nervous dysfunction and multiple organ failure. Heat stroke can occur in long-distance runners, cyclists, tennis and football/soccer players, and especially in American football players, who wear protective padding that interferes with evaporation.

The athlete may become confused and delirious; this may be followed by convulsions and coma. The body temperature will increase to 41–42° C (106–109°F) and the skin may look and feel dry and hot, owing to the cessation of sweating. There is a 50–90% mortality rate associated with this condition.

Treatment

- Cool the athlete as soon as possible with tepid water and air movement.
- Ice packs can be used to assist with cooling.
- Send the athlete to a physician or a hospital to continue the cooling process and to restore the water and electrolyte balance.

Complications

- Damage to the liver, with jaundice.
- Damage to the kidney, with renal failure and acidosis.
- Minor myocardial injury; arrhythmia may be present.
- Hypotension and collapse of the circulatory system.
- Watery diarrhea resulting from electrolyte imbalance.
- Damage to the brain.

Acclimation to high heat is essential. An acclimatization period of 7–10 days is normally required for, for example, a British athlete competing in Australia. Tennis players participating in the Australian Open try to play 1–2 tournaments in the same area beforehand to prepare as well as possible. It is clearly shown that it is important to be physically fit, i.e. aerobically fit, as this will help faster acclimatization in a warm climate. Long-distance travel can also affect performance and the time difference has an effect.

During strenuous sporting activity at high temperature and high humidity and the vapor pressure exceeds 40 mmHg, caution is recommended, i.e. generally sport should not be allowed. Dehydration is a dangerous condition that can be easily prevented by adequate hydration.

Tip

Acclimatization to high temperatures is a key factor in preventing all forms of heat stroke. As a minimum, 1 week of acclimatization is required for proper effect. Good fitness contributes to a more rapid acclimatization in a hot climate.

High altitude

Air density and barometric pressure decrease at high altitudes. The partial pressure of oxygen in the air decreases in proportion to the barometric pressure. Those taking part in endurance sports must be aware of this relationship.

At an altitude of 3000 m (10000 ft) and above, the partial pressure of oxygen falls to a level at which intellectual function may be affected, and at much lower altitudes the ability to do aerobic work is reduced. Anaerobic work and pulmonary ventilation increase and lactic acid production will begin sooner.

These negative effects of high altitude can be decreased by acclimatization, which increases the hemoglobin concentration in the blood. The optimal time for acclimatization varies depending on the altitude but usually athletes need about 2–4 weeks before competition at high altitude.

Altitude training is used at competition level, because the athlete can improve endurance by effects on the heart's size, the number of red blood cells and a more efficient use of oxygen by the muscles is stimulated.

The effect of altitude training is dependent on the time that the athlete has been at high altitude. The increased quantity of red blood cells from being at high altitude has a positive effect in the first days after returning to the lowlands. After 2 weeks the effect is marginal. In some cases the high altitude also has a favorable impact on athletic performance in sports such as long jump and sprint, where air resistance is normally an obstacle. Most sports are, however, limited by altitude because of the oxygen demand.

Skin injuries from solar radiation

The solar radiation that the skin is exposed to during stays in sunny locations and in the mountains or on the sea is far more intense than the average athlete is used to. A period of 15 minutes in the strong spring sun is enough to cause sunburn. To avoid sunburn it is necessary to become accustomed to the sun gradually and be properly dressed. Sunscreens or sun filter lotions with a high protection factor should be used for the skin, and salve for the lip.

The Food and Drug Administration (FDA) in the USA has released new rules for sunscreens. Spending time in the sun increases the risk of skin cancer and early skin aging. To reduce this risk, consumers should regularly use sun protection measures including: "Use sunscreens with broad spectrum SPF values of 15 or higher regularly and as directed, limit time in the sun, wear clothing to cover skin exposed to the sun; for example, long-sleeved shirts, pants, sunglasses, and broad-brimmed hats and reapply sunscreen at least every 2 hours, more often if you're sweating or jumping in and out of the water".[1]

Exposed parts such as the forehead and nose can be protected with a peaked cap or a piece of paper.

Degrees of burns

- **First degree**: the skin is red. Damage is confined to the superficial layers of skin. This heals in a couple of days without treatment.
- **Second degree**: blisters form on the skin. If they burst, a sterile bandage and possibly a medicated compress should be applied. If the burn covers a skin area greater than 5 cm^2 a physician should be consulted.
- **Third degree**: all the layers of the skin are destroyed, and the victim should definitely consult a physician. During the early stages of a burn it can be difficult to judge whether it is second or third degree.

Snow blindness – a form of photokeratitis

Snow blindness is caused by ultraviolet (UV) rays reflected off ice and snow. UV rays penetrate even when the weather is hazy and cloudy. Eye damage from UV rays is particularly common around the poles but also in high mountains where the thinner air provides less protection from UV rays and the bright sunlight can be reflected from snow or ice. Fresh snow reflects about 80% of the UV radiation. Snow blindness may also refer to freezing of the cornea's surface. Skiing, snowmobiling and mountain climbing are activities commonly associated with this condition.

The injury may be prevented by wearing eye protection that blocks most of the UV radiation, such as appropriate snow goggles for alpine skiers or sport sunglasses with interchangeable lens rated for sufficient UV protection. For cross-country skiers these glasses should have large lenses and side shields as they need to react quickly to different light conditions as the athletes move in and out of forests or valleys. Clear lenses provide protection from the wind and snow in low light conditions and dark lenses provide protection from UV damage and glare.

Figure 24.7 Goggles or sports sunglasses are often used as the eyes never get accustomed to the strong ultraviolet radiation in snowy or icy landscapes or on sun-glittering waters. **a)** Recreational young skiers should have goggles offering good protection (photo, Kerstin Samuelsson); **b, c)** top-level cross-country skiers often need to react quickly to different light conditions as they move in and out of forests or valleys; they often cover their eyes with sport sunglasses with side shields (with permission, by Bildbyrån, Swden).

The sunglasses should be used at all times, as the eyes never grow accustomed to the strong UV radiation encountered during visits to snow-covered regions or when sailing (Fig. 24.7).

Symptoms

- The affected person feels 'gritty' discomfort, swelling and pain in the eyes towards evening.
- The whites of the eyes become red, and the victim is disturbed by strong light.
- When the injury is severe, the affected person has to be led as if blind.

Treatment

- The injured person's eyes must be protected from light. This is achieved by fitting a pair of sunglasses with small pieces of cardboard in which holes have been made for the pupils, so that the wearer can only just see to move around.
- Eye drops or eye ointments that have a relaxing effect on the ring muscle of the iris may be prescribed.
- Generally sun blindness lasts for 1–2 days and does not result in any lasting disability.

Reference

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25 Disabled Athletes' Injuries

Athletes with a disability broadly can be divided into three disability groups: people with physical disabilities, with intellectual disabilities and the deaf. Disabilities include impairments, which refer to a functional problem for a patient, activity limitations and restrictions. There are an estimated 500 million people with disabilities around the world, roughly representing 10% of the world's population. 170 million of these have some form of mental disability. Many of these people like to practice sport for fun and recreation while a smaller part is active at the elite level.

The emergence of sport for disabled

Sport for the disabled emerged in Britain and Germany in the circumstance of WWII, when a large number of war-wounded were in need of physical rehabilitation. Stoke Mandeville Hospital in the UK, which opened in 1944, was the pioneer for the rehabilitation of spinal cord injuries and sport was introduced as a key part of rehabilitation. Sir Ludwig Guttmann organized a sports competition for wheelchair athletes at Stoke Mandeville in 1948, inspired by the Olympic Games held in London that year.

Sport for persons with disabilities is usually administered by the respective national disability associations. Some associations have a long tradition, such as the Swedish Association for Deaf Sports, which was founded in 1912. The international organization for the hearing impaired is the International Committee of Sports for the Deaf, with the first Summer Deaflympics held in Paris in 1924. The disabled version of the Olympics, the Paralympics, takes place 1–2 weeks after the regular competition in the same location. The Paralympics is organized by the International Paralympic Committee (IPC), formed in 1989 (Fig. 25.1).

Disabled athletes are divided into different groups and classes based on their level of impairment. Experts group the athletes into classes for their sport. Disabled athletes compete in the same sports as other athletes but with adjustment for the disability, and are an opportunity to show that a disabled athlete can compete at much the same level as an athlete without disabilities (Fig. 25.2). However, there are also sports that have been developed to be disability sports, including goal ball.

The IPC recognizes six different impairment groups. These are:

- Amputees.
- Athletes with cerebral palsy (CP).
- Blind or visually impaired athletes.
- Spinal cord injured athletes.
- Athletes with an intellectual/learning disability.
- Other athletes with a physical impairment, who do not fit into any of the above five groups.

The IPC has worked out a classification code, which details policies and procedures that should be common to all sports, and sets principles to be applied by all sports within the Paralympic movement. International standards complement the code through providing technical and operational requirements for classification.

The English Federation of Disability Sport (EFDS) works for the disabled people in sport throughout England. There are around 11 million disabled people

Figure 25.1 a–c) The paralympics attract the elite athletes with disability. (With permission, by Bildbyrån, Sweden.)

Figure 25.2 a–c) Other examples of sport by athletes with disability. (With permission, by Bildbyrån, Sweden.)

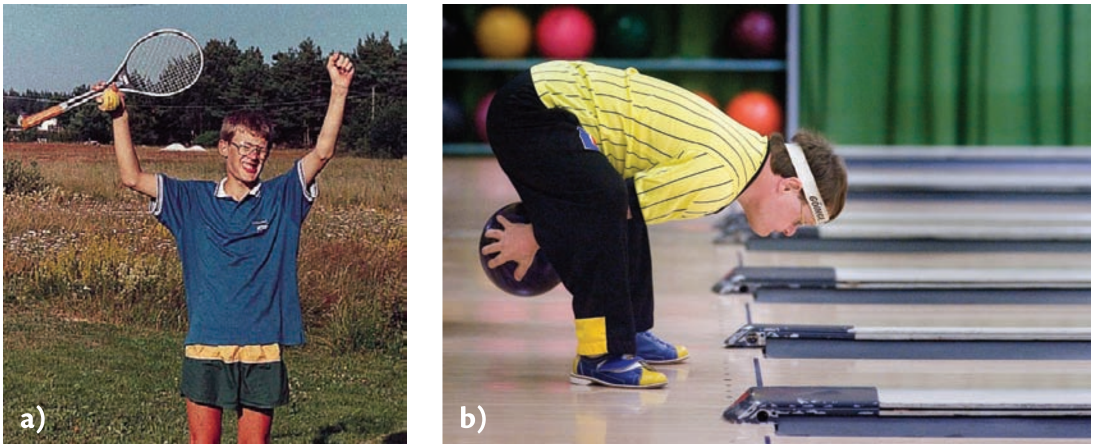

Figure 25.3 Sports are incredibly important for the social togetherness. **a)** The joy of playing tennis can be great; **b)** bowling is a social game and can be played with varying technique (with permission, by Bildbyrån, Sweden).

in the UK. Only two in ten disabled people in England are currently active. EFDS works to increase the sport participation opportunities at all levels in relation to the disability social model.[1]

Types of disabilities

Broadly speaking, there are different types of disabilities: physical disabilities as a result of amputation, paralysis after birth, back and brain injuries; visual and hearing impairment; mental retardation; mental disability; medical disability, such as heart disease, lung problems (asthma etc.), diabetes and hemophilia.

Although disabled people may have received excellent training in a hospital or special centers, they are still likely to have significant limitations and may lose some of their acquired skills when they return to the community. Sporting activities, graded according to level of skill and type of disability, offer a chance to continue training and acquire new skills outside the hospital (Fig. 25.3). Sport also offers enormous benefits in social and psychological terms (Fig. 25.4). Sports activities for disabled people are organized in most countries, and participation is generally free of charge.

Tip

All disabled persons should have the opportunity to take part in sporting activities, according to their capabilities and qualifications, under appropriate medical supervision and in cooperation with physical therapists or trained sports coaches.

Figure 25.4 a–c) Wheelchair sports allow great possibilities for athletes with a disability in the lower extremities. (With pemission, by Bildbyrån, Sweden.)

Sports injuries in disabled athletes do not differ substantially from those suffered by other athletes (Fig. 25.5). The most common injuries are pressure sores and blisters, crushing injuries and ligament, muscle and skeletal injuries.

The disabled athlete's chances of avoiding injury depend on the nature of the disability. Certain disabilities, such as wasted muscles with impaired muscular strength, or paralysis with loss of sensation, make recognition and diagnosis of injuries more difficult.

Physical disability

Physical disability refers to permanent paralysis injuries or motor disorders, amputations, deformities and advanced joint stiffness. There is a loss of a person's bodily functions such as walking, gross motor skills and loss of a part of the body such as after an amputation.

Paralysis

Paralysis is defined as the inability to voluntarily contract muscles. The paralysis can be caused by injury to the central nervous system (CNS), the peripheral nervous system or in the muscle. Paralysis can be classified by which body parts have been affected:

- **Hemiplegia**: half-sided paralysis affects both the arm and leg on one half of the body and occurs most often after stroke (bleeding or clot in the brain).
- Paraplegia: both legs are fully or partially paralyzed. Arising from damage to the spinal cord from segments C8 and down.
- Diplegia: refers to paralysis affecting symmetrical parts of the body. This condition may arise in children due to CP. As paraplegic, but also some effect on the arms. Symptoms may get worse but the neurological part does not change.
- Quadriplegia: both arms and legs are fully or partially paralyzed. Arises in cases of injury to the cervical spinal cord or as a result of CP i.e. a paralysis resulting from damage in the CNS, such as in CP. Palsy is a paralysis of any degree. People with spastic (increased muscle tone) CP are well represented in disabled sports such as boccia, table tennis, swimming and athletics.

Brain injury

Language disorder (aphasia), perceptual disturbance, i.e. changed body image, depersonalization, increased emotionality and dementia with general impairment of a person's intellectual (cognitive) functions including memory can be symptoms of damage or disease of the brain.

Figure 25.5 a, b) Disabled athletes often participate in sports not without risk. (With permission, by Bildbyrån Sweden.)

Traumatic spinal cord injuries

Registries are available in Sweden and Iceland. The incidence of traumatic spinal cord injury in Sweden is approximately 100–120 new cases per year, of which 75–80% are men. The most common cause is traffic injuries (in over half of cases) (see Chapter 16 on back injuries). In the USA, the incidence of spinal cord injury has been estimated to be about 40 cases per 1 million people per year, or around 12,000 cases per year.[2] Men are at more risk for spinal cord injury than women.

People with spinal cord injuries are well represented in disabled sport, such as in wheelchair basketball (paraplegic), wheelchair tennis, wheelchair rugby (quadriplegic), alpine skiing, athletics, table tennis and sports shooting.

Consequences of paralysis can often be sensory impairments to different degrees, which is a severe disability and that means increased risk for pressure sores.

Bladder and bowel dysfunction

Bladder disturbance, impaired bladder filling sensation and the inability to voluntarily pass urine is common in spinal cord injuries. This increases the risk of incontinence and infection. A great number of disabled people have problems with urinary tract infections because of paralysis, impaired bladder sensation, and constant sitting. The symptoms of a urinary tract infection can be slight or absent, so regular bacteriological checks on the urine should be made.

Skin damage

Pressure sores

People with paralyzed legs are often dependent on crutches or a wheelchair and often have impaired sensitivity over the buttocks. Sitting for a long time causes pressure that can result in the development of pressure sores. These start as small red spots that do not look particularly ominous, but if overlooked because of impaired sensitivity, may progress rapidly to create a deep sore that takes a long time to heal.

Prevention is of paramount importance. The athlete should not remain sitting for too long but should regularly be lifted out of the chair. Before each competition or training session the coach should examine the athlete and look for signs of pressure sores. If any skin redness is detected, the area in question should be relieved from pressure, by using a rubber ring or by using alternative sitting positions. The skin area should be washed with soap and water, dried thoroughly, rubbed with surgical spirit, and exposed to the air. If a sore has appeared a physician should be consulted.

Blisters

Many disabled athletes have to use aids such as corsets, prostheses and various types of bandages. The pressure from these aids can cause redness and blisters, and the athlete should be examined for these conditions before and after training and competition. General principles concerning the treatment of blisters can be found on p. 190.

Contusion injuries

In wheelchair sports, basketball in particular, the wheelchairs come into close contact with each other and rapid maneuvers are necessary. The athlete's fingers can be jammed both in and between the wheelchairs (Fig. 25.6). Such injuries are characterized by swelling and tenderness, and abrasions may be present. The swelling should be treated as soon as possible by applying ice and then bandaging.

Figure 25.6 a, b) Skin injuries from crushing or jamming incidents can occur in wheelchair sports. (With permission, by Bildbyrån, Sweden.)

Injuries caused by wheelchairs are difficult to prevent, but changes in their construction, such as protective frames fitted at the same height as the handle and situated on the same level regardless of wheelchair model, might be beneficial. The skin injuries from crushing or jamming incidents can be prevented if the athlete wears gloves or applies non-irritant tape to exposed areas.

Impairment due to injuries

Fractures

Impaired mobility or paralysis is inevitably accompanied by some degree of weakening of the skeleton. Furthermore, in such cases the muscles are often so wasted that they provide little protection for the bones. Fractures can therefore occur relatively easily, especially when unexpected loads are applied. Such fractures are often extensive with considerable splintering in the fracture area. Minor fractures may not be discovered immediately if the athlete has impaired sensitivity.

Athletes who wear support braces should loosen them during sporting activities in case they act as levers and contribute to a fracture. The treatment of fractures is described on p. 149.

Injuries to muscles, tendons and ligaments

As muscles affected by paralysis atrophy or become hypotrophied, their functions are taken over by other muscles that as a result become stronger from increased use. Arm and shoulder muscles are often remarkably well developed in people who depend upon wheelchairs. The risk of overuse of tendons and tendon attachments is increased by the additional demands made upon specific muscle groups. Guidelines on treatment are given on p. 177. Impaired muscle strength often places greater loads on ligaments and increases the risk of ligament injury.

Back and shoulder problems

Anyone who is confined to a wheelchair spends a large part of the time sitting, and back problems with more or less constant aching are common. A corset can often be beneficial but can be uncomfortable to wear for any considerable period, especially in summer.

People in wheelchairs often suffer from shoulder pain as a result of repetitive movements in the shoulder joint.

Joint diseases

Several joint diseases can cause disabilities:

- Rheumatoid arthritis (RA) (see p. 166). The condition is estimated to affect over 580,000 people in England/Wales and an estimated 1.5 million adults in the USA.
- Osteoarthritis involves changes in articular cartilage and can cause pain, swelling and poor function. It is often the elderly who are affected, but younger people can have osteoarthritis after cruciate ligament or cartilage injuries in the knee joint (see p. 441).
- Various back problems, e.g. herniated disc, Bechterew, spinal stenosis (see Chapter 16), can cause pain, weakness and stiffness and prevent a normal functional pattern due to pain, malalignment and stiffness.
- Hemophilia means a reduced ability of the blood to clot and stop bleeding. Repeated hemorrhages in the joints can damage them seriously.

Amputations

Amputations in younger persons as a result of accidents are not unusual in developing countries, not least because of a rapid increase in traffic density and industrial injuries (Fig. 25.7). In the western world there are a number of amputations in the older part of the population because of cardiovascular disease, circulatory

Figure 25.7 a–c) Amputee elite athletes.

disorders, atherosclerosis and diabetes, but these decrease as the care of these conditions is gradually improved. There are still some amputations performed, as a treatment for tumors in both young and elderly.

Amputations are most commonly performed on the lower leg or thigh. It is much more beneficial to amputate the lower leg compared with a thigh amputation because it is much easier to walk and to much better manage the daily activities with a lower leg prosthesis. There may be some discomfort or stump/prosthetic problems after surgery, i.e. the amputation, due to the delicate relationship between stump and prosthesis.

Phantom pain – or pain from amputation – occurs in approximately 50–80%. These pains are perceived as coming from the removed body part and is due to peripheral nerve damage after the surgery. The symptoms can appear early after an amputation. Medication is commonly used, but electrical stimulation in the form of transcutaneous electrical stimulation (TENS) may be of value. These symptoms can sometimes be difficult to treat.

Amputation neuroma – a knob-like thickening of nerves – can occur in the stump end which can cause pain on pressure. A local anesthetic can be used to confirm the diagnosis and a small procedure where the neuroma is removed, will contribute to good relief.

Skin injuries such as blisters on the stump, are common. This is because the prosthesis does not always fit so well on the stump. Some stumps are not well designed and fitting a prosthesis can be problematic. An adjustment of the prosthesis is often effective. Sometime a re-operation to create a better stump, including shortening of the bone in the stump can be the solution.

Tip

Persons who undergo an amputation are often interested in participating in sports, which they often need.

General medical complaints

General medical conditions, including heart disease, high blood pressure, asthma, diabetes and hemophilia, do not preclude sporting activity, but it should be undertaken only with the advice and supervision of a physician and/or physical therapist. Those suffering from medical disorders have tended to hold back from participating in physical exercise because of a belief that it could be dangerous for them, but it is now well known that exercise can in fact be beneficial. It is likely that the number of people who participate in sport despite their medical history will increase in the future.

Acquired disabilities

Polio

Polio is now rare in large parts of the world, due to child vaccination programs. Polio is an acute viral infection that destroys motor nerve cells (neurons) in the spinal cord. This leads to different types of paralysis of the muscles that these nerves innervate. Sensory nerves are not affected. Complete function can return in some muscles, while others remain paralyzed and strongly weakened.

Multiple sclerosis

Multiple sclerosis (MS) is a common cause of acquired disability. Women are affected more often than men. The disease attacks the CNS and usually appears in 20–40-year-old people. The cause of MS is unknown and there is no known cure. Vision impairment, numbness, coordination problems and paralysis occur.

Intellectual disability

The intellectual functioning level is measured by an IQ (intelligence quotient) test. The average IQ is 100. WHO defines intellectual disability as:

If a person has an IQ of less than 70–75, i.e. well below average, that person is considered intellectually disabled.

- Deficits in or reduction of adaptive behavior, i.e. skills necessary for day-to-day life, such as being able to eat and dress, communicate and interact with others and similar.
- Onset before the age of 18.

Causes of intellectual disability include genetic-hereditary defects, chromosomal abnormalities, such as Down syndrome, hypoxia damage in the uterus and in connection with birth or brain damage later in life, etc. Intellectual disability is thought to affect about 1% of the population.

Special Olympics

This group often has some difficulty in finding friends and is in real need of an active group community. Eunice Kennedy Shriver in the USA started a day camp for children with intellectual disabilities in 1962 because she was concerned about children with intellectual disabilities having nowhere to play. The idea quickly

Figure 25.8 a–c) Athletes in the Special Olympics.

developed further. The first International Special Olympics Summer Games were held in 1968. Athletes in a competition are classified into different divisions (groups) dependent on the athlete's capacity. Today there is an increasing focus on participating in physical activity and recreational sports. Special Olympics performs a fantastic job in taking care of this large group of wonderful and affectionate people (Fig. 25.8). Special Olympics today provide training and competitions for more than 4.2 million athletes with intellectual disability in 170 countries. A wide variety of activities exist in both summer and winter sports, such as football/soccer, hockey, athletics, skiing, boccia, etc.

Tip

Sports and joint activity is of great importance for people with intellectual disability. Physical activity contributes to important emotional and psychological benefits, as well as preventing obesity and contributing to higher self-esteem.

Attention deficit hyperactivity disorder and similar

Attention deficit hyperactivity disorder (ADHD) is a psychiatric disorder, where the affected persons have significant problems with attention, hyper- or impulsive activity. ADHD is diagnosed approximately three times more in boys than in girls. The true cause in the majority of cases is unknown. The management usually involves both counseling and medications.

Other similar disorders include diagnoses such as attention deficit disorder (ADD), deficit of attention, motor control and perception (DAMP), Tourette's syndrome, Asperger's syndrome, autism, obsessive compulsive disorder (OCD), language and speech disorder and dyslexia. These impairments are biologically determined, often overlap with onset in childhood and lead to varying degrees of learning difficulty, adaptability and behavioral problems. When difficulties affect the individual's development and ability to function in society, they constitute a disability. This group can participate in disabled sport at competitive level in football/ soccer and hockey, with certain restrictions.

Visual impairments

People with impaired vision (see p. 118) can compete in both special sports for the blind and also in other disabled sports such as athletics, swimming and judo.

Classification of disabled sports

A proper and transparent classification is a prerequisite for gaining acceptance and fairness. The active are assumed to be able to compete on equal terms. The trend in disabled sport is towards fewer classes. However, it is a difficult balance because fewer classes may create an unfair competition system and disadvantage those with severe functional limitations. However, many classes can lead to limited competition and then the credibility of disabled sport can decline. A classification should be based on the special character of the respective sport, which is why the classification will normally be based on function rather than diagnosis. For details contact the IPC.

Tip

Sports and physical activity are of great value for people with movement and other disabilities. This group need and deserve all the support and encouragement there is!

References

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Index

Note: page numbers in *italics* refer to illustrations.