Basic Athletic Training

Course Pack B

Conditions of the Lower Extremity

SECTION

IV

CHAPTER 14

Lower Leg, Ankle, and Foot Conditions

STUDENT OUTCOMES

1. Identify the major bony and soft-tissue structures of the lower leg, ankle, and foot.
2. Identify the various ligamentous structures that support the lower leg, ankle, and foot.
3. Identify the plantar arches and explain their function.
4. Describe the motions of the foot and ankle and identify the muscles that produce them.
5. Explain the general principles to prevent injuries to the lower leg, ankle, and foot.
6. Describe a thorough assessment of the lower leg, ankle, and foot.

7. Describe the common injuries to and conditions of the knee in physically active individuals (including sprains, dislocations, contusions, strains, bursitis, and vascular and neural disorders).
8. Explain the management strategies for common injuries and conditions of the lower leg, ankle, and foot.
9. List the various types of fractures that can occur at the lower leg, ankle, and foot and explain their management.
10. Explain the basic principles associated with rehabilitation of injuries to the lower leg, ankle, and foot.

INTRODUCTION

Because of the essential roles played by the lower leg, ankle, and foot during sport and physical activities, injuries to this region are common. Sport participation often places both acute and chronic overloads on the lower extremity, leading to sprains, strains, fractures, and overuse injuries. In particular, basketball, soccer, and football participants sustain a high incidence of injury to this region.[1–3] Lateral ankle sprains are the most common of all sports-related injuries, accounting for approximately 25% of injuries to the musculoskeletal system.[4] Increasingly, it is being recognized that repeated ankle sprains can result in functional instability of the ankle, which predisposes the individual to further injury.[5]

This chapter begins with an anatomical review and biomechanical overview of the lower leg, ankle, and foot. Next, prevention of injury is discussed, followed by a step-by-step injury assessment of the region. Finally, details on specific injuries and their management, including examples of rehabilitative exercises, are provided.

ANATOMY OF THE LOWER LEG, ANKLE, AND FOOT

The lower leg, ankle, and foot are composed of numerous bones and articulations (Fig. 14.1). They provide a foundation of support for the upright body, enabling propulsion through space, adaptation to uneven terrain, and absorption of shock.

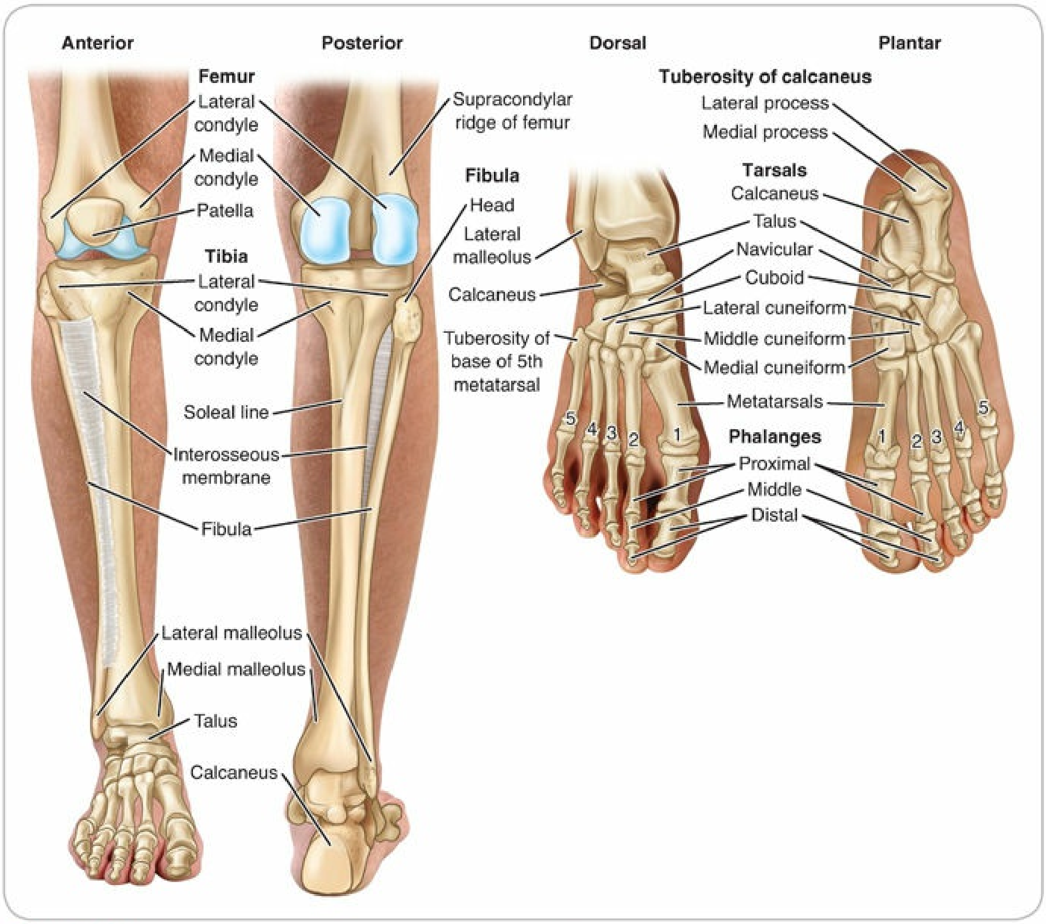


Figure 14.1. Skeletal features of the lower leg, ankle, and foot.

Forefoot

The three major regions of the foot are the forefoot, midfoot, and hindfoot. The forefoot is composed of 5 metatarsals and 14 phalanges, along with numerous joints. In conjunction with the midfoot region, the forefoot forms interdependent longitudinal and transverse arches to support and distribute body weight throughout the foot.

Metatarsophalangeal and Interphalangeal Joints

The metatarsophalangeal (MTP) joint is a condyloid joint with a close-packed position in full extension. The proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints are hinge joints that also have a close-packed position in full extension (**Fig. 14.1**). Numerous ligaments reinforce both sets of joints. Each MTP joint is surrounded by an articular and fibrous joint capsule, the plantar side of which is reinforced by the plantar fascia and thickened portions of the capsule (i.e., plantar ligament). The medial and lateral joint capsules are reinforced by collateral ligaments. The PIP and DIP joints are reinforced by the plantar and dorsal joint capsule and the collateral ligaments. The toes function to smooth the weight shift to the opposite foot during walking and help to maintain stability during weight bearing by pressing against the ground when necessary. The first digit is referred to as the hallux, or "great toe," and is the main body stabilizer during walking or running.

The first MTP joint has two sesamoid bones, which are located on the plantar surface of the joint to share in weight bearing. The sesamoid bones serve as anatomical pulleys for the flexor hallucis brevis muscle and protect the flexor hallucis longus muscle tendon from weight-bearing trauma as it passes between the two bones.

Tarsometatarsal and Intermetatarsal Joints

The deep transverse metatarsal ligament interconnects the five metatarsals. Both the tarsometatarsal and intermetatarsal joints are of the gliding type with the close-packed position in supination. These joints enable the foot to adapt to uneven surfaces during gait.

Midfoot

The midfoot region encompasses the navicular, cuboid, and three cuneiform bones as well as their articulations. The navicular, like its counterpart in the wrist, the scaphoid, helps to bridge movements between the hindfoot and forefoot.

Transverse Tarsal Joint

The transverse tarsal (or midtarsal) joint consists of two side-by-side articulations—namely, the calcaneocuboid joint on the lateral side and the talonavicular on the medial side. Collectively, these two joints are called the transverse tarsal joint, because they are adjacent and function as a unit.

The calcaneocuboid joint is a saddle-shaped joint with a close-packed position in supination. The joint is nonaxial and permits only limited gliding motion. It is supported by the bifurcate ligament, the plantar and dorsal calcaneocuboid ligaments, and the long plantar ligament. The most important of these, the long plantar ligament, extends inferiorly between the calcaneus and the cuboid and then continues distally to the base of the 2nd, 3rd, and 4th metatarsals, contributing significantly to transverse tarsal joint stability.

Because the talus moves simultaneously on the calcaneus and navicular, the term talocalcaneonavicular (TCN) joint often is used to describe the combined action of the talonavicular and subtalar joints. The TCN is a modified ball-and-socket joint with a close-packed position in supination. Movements at the joint include gliding and rotation. Three ligaments support the joint—namely, the plantar calcaneonavicular (spring) ligament inferiorly, the deltoid ligament medially, and the bifurcate ligament laterally (**Fig. 14.2**).

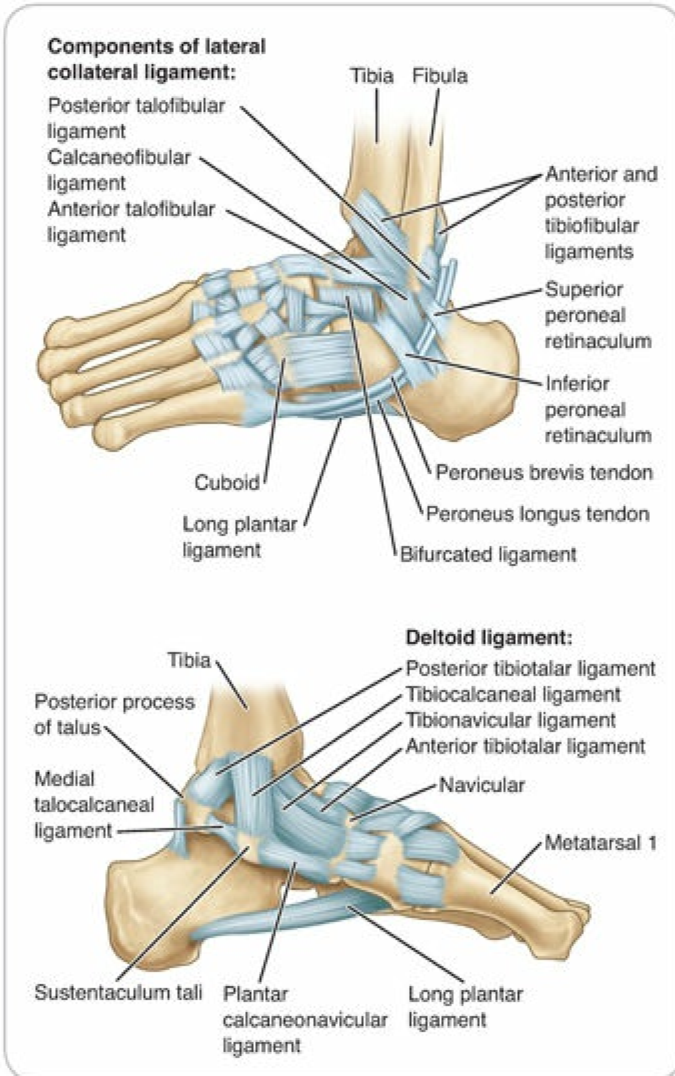


Figure 14.2. Ligaments supporting the midfoot and hindfoot region. Lateral view (top). Medial view (bottom).

Because the subtalar joint is mechanically linked to the TCN and transverse tarsal joints, any motion at the subtalar joint produces similar motions at the transverse tarsal joints. For example, when the TCN is fully supinated and locked, the midfoot region is supinated and rigid. When the TCN is pronated and loose packed, the midfoot region is mobile and loose.

Other Midtarsal Joints

The remaining joints of the midfoot region include the cuneonavicular, cuboideonavicular, cuneocuboid, and intercuneiform. These joints provide gliding and rotation for the midfoot with a close-packed position in supination.

They are bound together by several ligaments. When the midfoot (i.e., TCN) is locked in supination, these joints function in a compensatory manner to pronate the forefoot and increase stability. When the hindfoot is pronated, these joints supinate the forefoot to keep the foot flat on the surface.

Hindfoot

The hindfoot includes the calcaneus and talus. Rising off the anteromedial surface of the calcaneus is the sustentaculum tali, which largely supports the talus. Located on the inferior surface of the sustentaculum tali is a groove through which the flexor hallucis longus tendon passes. The peroneal tubercle projects out of the lateral side of the calcaneus and splits the two peroneal tendons as they course inferior to the lateral malleolus. The peroneus brevis tendon runs superior to the tubercle; the peroneus longus tendon runs inferior to the tubercle.

The talus is saddle-shaped and serves as the critical link between the foot and the ankle. It has several functional articulations, the two most important of which being the talocrural joint and the subtalar joint. Both serve a unique role in the integrated function of the lower leg, ankle, and foot.

Talocrural Joint

The talocrural (i.e., ankle) joint is a uniaxial, modified synovial hinge joint formed by the talus, tibia, and lateral malleolus of the fibula. The concave end of the weight-bearing tibia mates with the convex superior surface of the talus to form the roof and medial border of the ankle mortise. The fibula assists with weight bearing, supporting approximately 17% of the load on the leg[6]; serves as a site for muscle and ligamentous attachments; and forms the lateral border of the ankle mortise. The lateral malleolus extends farther distally than the medial malleolus; hence, eversion is more seriously limited than inversion. The dome of the talus is wider anteriorly than posteriorly. Therefore, the joint’s close-packed position is maximum dorsiflexion.

Although the joint capsule is thin and especially weak anteriorly and posteriorly, a number of strong ligaments cross the ankle and enhance stability

(Table 14.1). The four separate bands of the medial collateral ligament (more commonly called the deltoid ligament) cross the ankle medially. The anterior tibiotalar and tibionavicular ligaments are taut when the subtalar joint is plantar flexed, whereas the tibiocalcaneal and posterior tibiotalar ligaments are taut during dorsiflexion. Forces producing stress on the medial aspect of the ankle typically cause an avulsion fracture of the medial malleolus rather than tearing the deltoid ligament.

TABLE 14.1 Ligaments of the Talocrural Joint

	PROXIMAL ATTACHMENT	DISTAL ATTACHMENT
MEDIAL COLLATERAL LIGAMENTS		
Anterior tibiotalar	Anteromedial aspect of medial malleolus	Superior portion of medial talus
Tibiocalcaneal	Apex of medial malleolus	Calcaneus directly below medial malleolus
Posterior tibiotalar	Posterior aspect of medial malleolus	Posterior portion of the talus
Tibionavicular	Distal and slightly posterior to the anterior tibiotalar	Medial aspect of the navicular
LATERAL COLLATERAL LIGAMENTS		
Anterior talofibular	Anterolateral surface of lateral malleolus	Talus near the sinus tarsi
Calcaneofibular	Posterior apex of lateral malleolus	Courses 133° inferiorly and posteriorly to attach on calcaneus
Posterior talofibular	Posterolateral border of lateral malleolus	Posterior talus and calcaneus

The lateral side of the ankle is supported by three ligaments. The anterior talofibular ligament (ATFL) is taut and resists inversion during plantar flexion and limits anterior translation of the talus on the tibia. The calcaneofibular ligament (CFL) is taut in the extreme range of dorsiflexion and is the primary restraint of talar inversion within the mid-range of motion (ROM). The posterior talofibular ligament (PTFL) is the strongest of the lateral ligaments and limits posterior displacement of the talus on the tibia. The relative weakness of these lateral ligaments as compared with the deltoid ligament, coupled with the fact of less bony stability laterally compared with medially, contributes to a higher frequency of lateral ankle sprains.

Subtalar Joint

As the name suggests, the subtalar joint lies beneath the talus, where facets of the talus articulate with the sustentaculum tali on the superior calcaneus. Obliquely crossing the talus and calcaneus is the tarsal canal, a sulcus that allows attachment of an intra-articular ligament. Because no muscles attach to the talus, the stability of the subtalar joint is derived from several small ligaments. The talocalcaneal interosseous ligament lies in the tarsal canal, divides the subtalar joint into two articular cavities, serves as an axis for talar tilt, and contributes substantially to joint stability, particularly during supination (Fig. 14.3). Four small talocalcaneal ligaments form interconnections between the talus and calcaneus, and the CFL and tibiocalcaneal fascicle of the deltoid ligament add support. The close-packed position for the joint occurs under vertical loading with internal rotation.

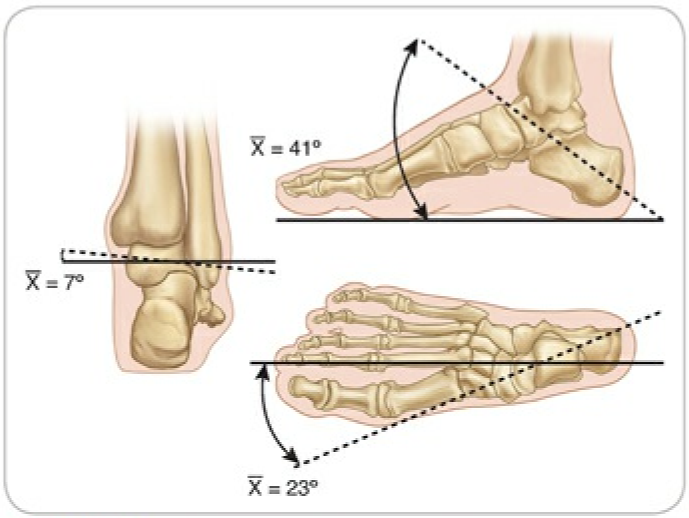


Figure 14.3. Subtalar joint. The axis of rotation at the subtalar joint lies oblique to the sagittal and frontal planes.

The subtalar joint behaves as a flexible structure, with motion occurring only through stretching of ligaments during weight bearing.[7] Motion at the subtalar joint involves "male" ovoid bone surfaces sliding over reciprocally shaped "female" ovoid bone surfaces. The subtalar joint functions essentially as a uniaxial joint with an orientation roughly in line with the inversion/eversion axis of the foot, although the orientation of the subtalar joint axis varies appreciably across individuals.[8]

Tibiofibular Joints

The tibia and fibula articulate at both the proximal and distal ends (Fig. 14.1). The proximal, or superior, tibiofibular joint is a plantar synovial joint that is tightly reinforced with anterior and posterior ligaments. The inferior, or distal, tibiofibular joint is a syndesmosis, where dense fibrous tissue binds the bones together. No joint capsule exists, but the joint is supported by the anterior and posterior tibiofibular ligaments as well as by an extension of the interosseous membrane, the crural interosseous ligament. This structural arrangement allows some rotation and slight abduction (spreading) while still maintaining joint integrity. The strength of the crural interosseous ligament is such that strong lateral stresses often fracture the fibula rather than tear the membrane, although excessive eversion or dorsiflexion can result in sufficient widening of the ankle mortise to injure the ligaments supporting the syndesmosis.

Plantar Arches

The bones and supporting ligamentous structures in the tarsal and metatarsal regions of the foot form interdependent longitudinal and transverse arches (**Fig. 14.4**). They function to support and distribute body weight from the talus through the foot, through changing weight-bearing conditions, and over varying terrain. The longitudinal arch runs from the anteroinferior calcaneus to the metatarsal heads. Because the arch is higher medially than laterally, the medial side usually is the point of reference, with the navicular bone serving as the point of reference between the anterior and posterior ascending spans.

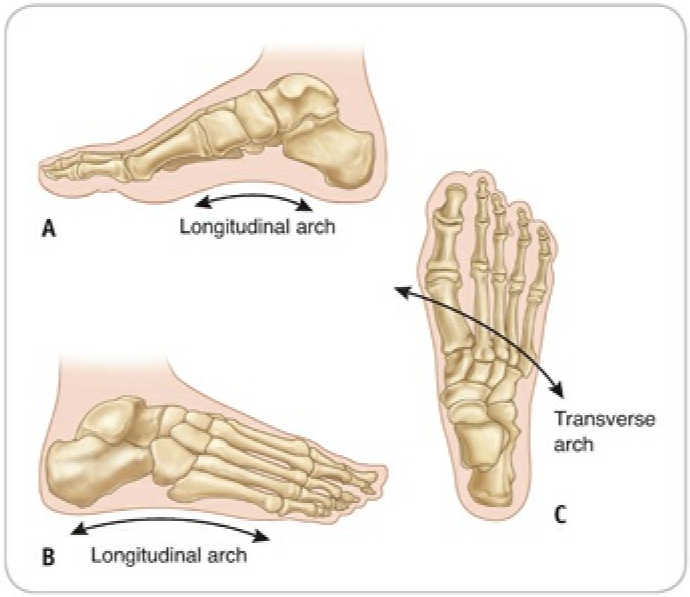


Figure 14.4. Arches of the foot. A, Medial view. **B,** Lateral view. **C,** Dorsal view.

The transverse arch runs across the anterior tarsals and metatarsals. The foundation of the arch is the medial cuneiform, with the apex of the arch formed by the 2nd metatarsal. The arch is reduced at the level of the metatarsal heads, with all metatarsals aligned parallel to the weight-bearing surface for even distribution of body weight. Structural support is derived from the intermetatarsal ligaments and the transverse head of the adductor hallucis muscle.

The primary supporting structures of the plantar arches, in order of importance, are the calcaneonavicular (i.e., spring) ligament, long plantar ligament, plantar fascia (i.e., plantar aponeurosis), and short plantar (i.e., plantar calcaneocuboid) ligament (Fig. 14.5). When muscle tension is present, the muscles of the foot, particularly the tibialis posterior, contribute support to the arches and joints as they cross them.

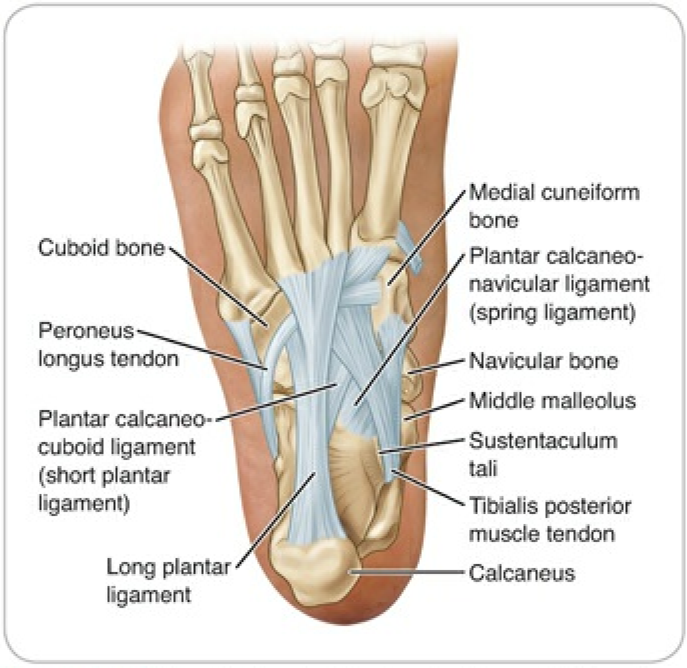


Figure 14.5. Medial longitudinal arch. The medial longitudinal arch is supported by the calcaneonavicular (spring) ligament, short plantar ligament, long plantar ligament, plantar aponeurosis, and tibialis posterior muscle tendon.

The plantar fascia, or plantar aponeurosis, is a specialized, thick, interconnected band of fascia that covers the plantar surface of the foot, providing support for the longitudinal arch (Fig. 14.6). It has three distinct slips. The central slip extends from the posteromedial calcaneal tubercle and inserts into the distal plantar aspects of the proximal phalanges of each toe, where it attaches with deep transverse metatarsal ligaments. As the central slip courses down the length of the foot, it gives off two other slips, one deviating medially and the other laterally. The plantar fascia is the single greatest contributor to the stability of the arch of the foot, providing approximately 80% of arch stiffness.[9] During the weight-bearing phase of the gait cycle, the plantar fascia stretches on the order of 9% to 12% of resting length, functioning like a spring to store mechanical energy that is released to help the foot push off from the surface.[10] Stretching the Achilles tendon may elongate the plantar fascia, because both structures attach to the calcaneus.

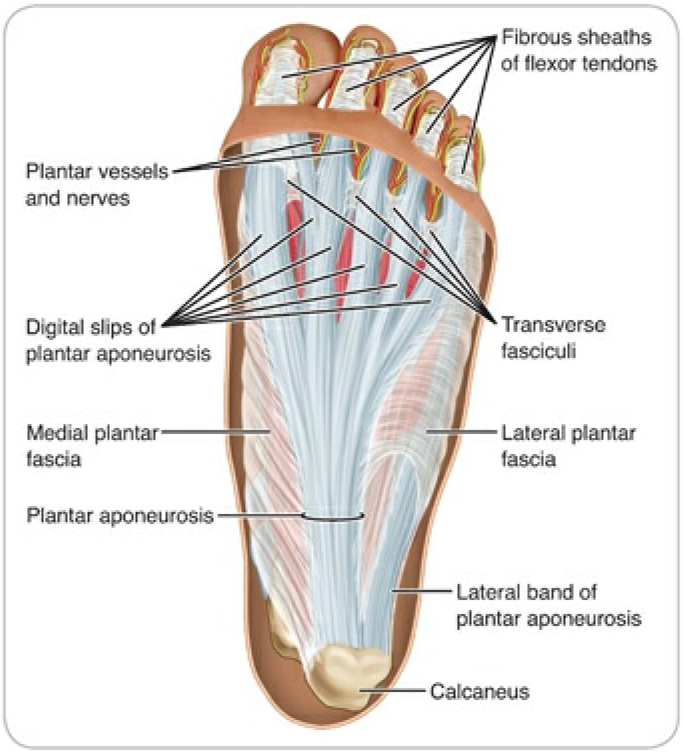


Figure 14.6. Plantar fascia. The plantar fascia stores mechanical energy each time the foot deforms during the weight-bearing phase of the gait cycle.

Muscles of the Lower Leg and Foot

A large number of muscles cross the ankle (Figs. 14.7 and 14.8). Identifying the actions of these muscles is complicated by the fact that several muscles are two-joint muscles.

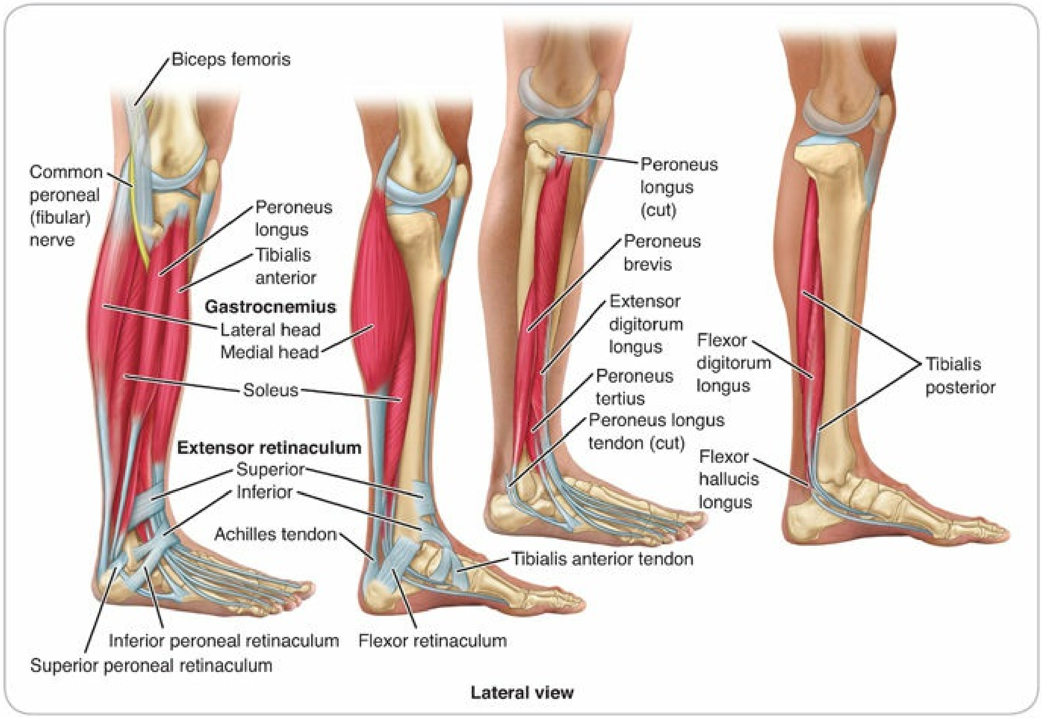


Figure 14.7. Muscles of the lower leg and foot. Lateral and medial views.

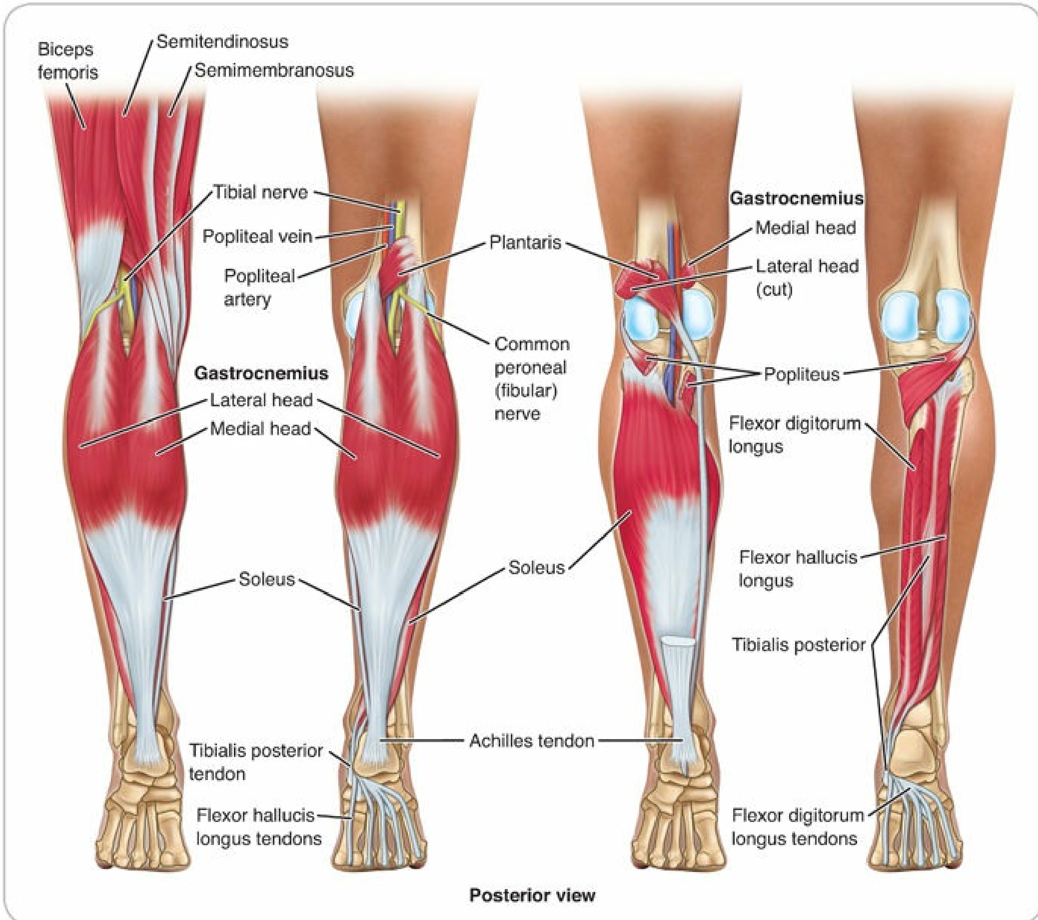


Figure 14.8. Muscles of the lower leg and foot. Posterior view.

Thick sheaths of fascia divide the muscles of the leg into four compartments—namely, the anterior, deep posterior, superficial posterior, and lateral compartments. The anterior compartment contains the tibialis anterior, extensor digitorum longus, extensor hallucis longus, and peroneus tertius. Muscles in the deep posterior compartment include the tibialis posterior, flexor digitorum longus, tibialis posterior artery, tibial nerve, and flexor hallucis longus. The superficial posterior compartment contains the gastrocnemius, soleus, and plantaris, and the lateral compartment contains the peroneus longus and peroneus brevis.

The foot contains both intrinsic and extrinsic muscles. An intrinsic muscle has both attachments contained within the foot (Figs. 14.9 and 14.10), whereas an extrinsic muscle has one attachment outside the foot.

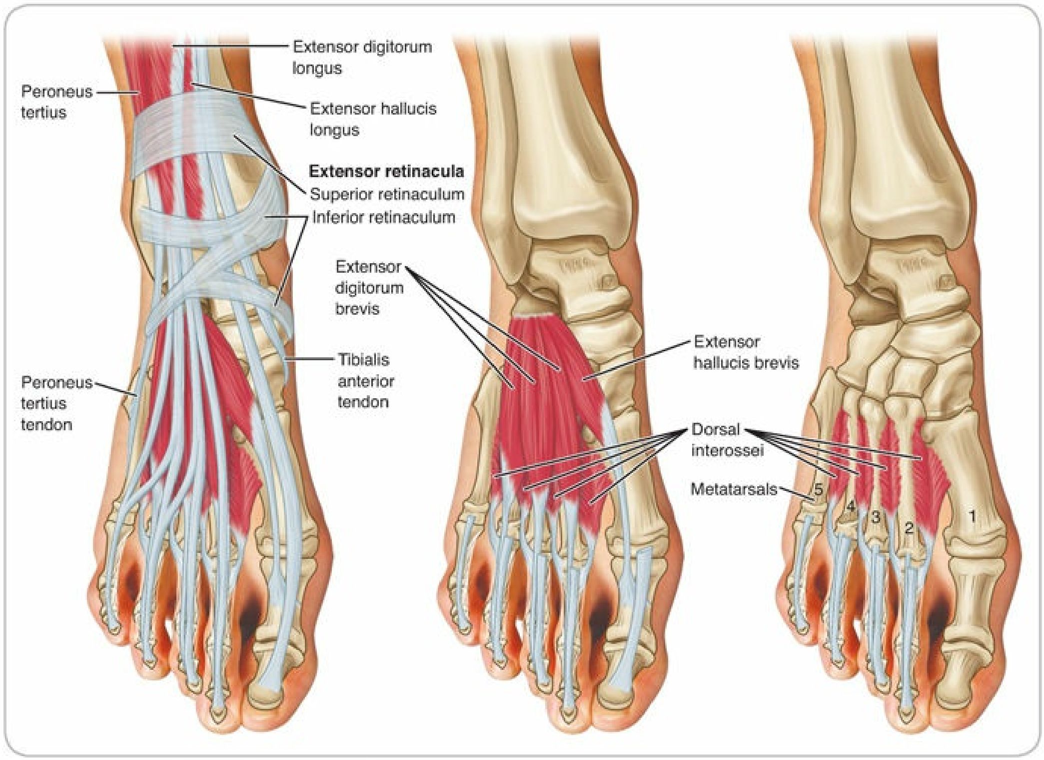


Figure 14.9. Intrinsic muscles of the foot. Dorsal view.

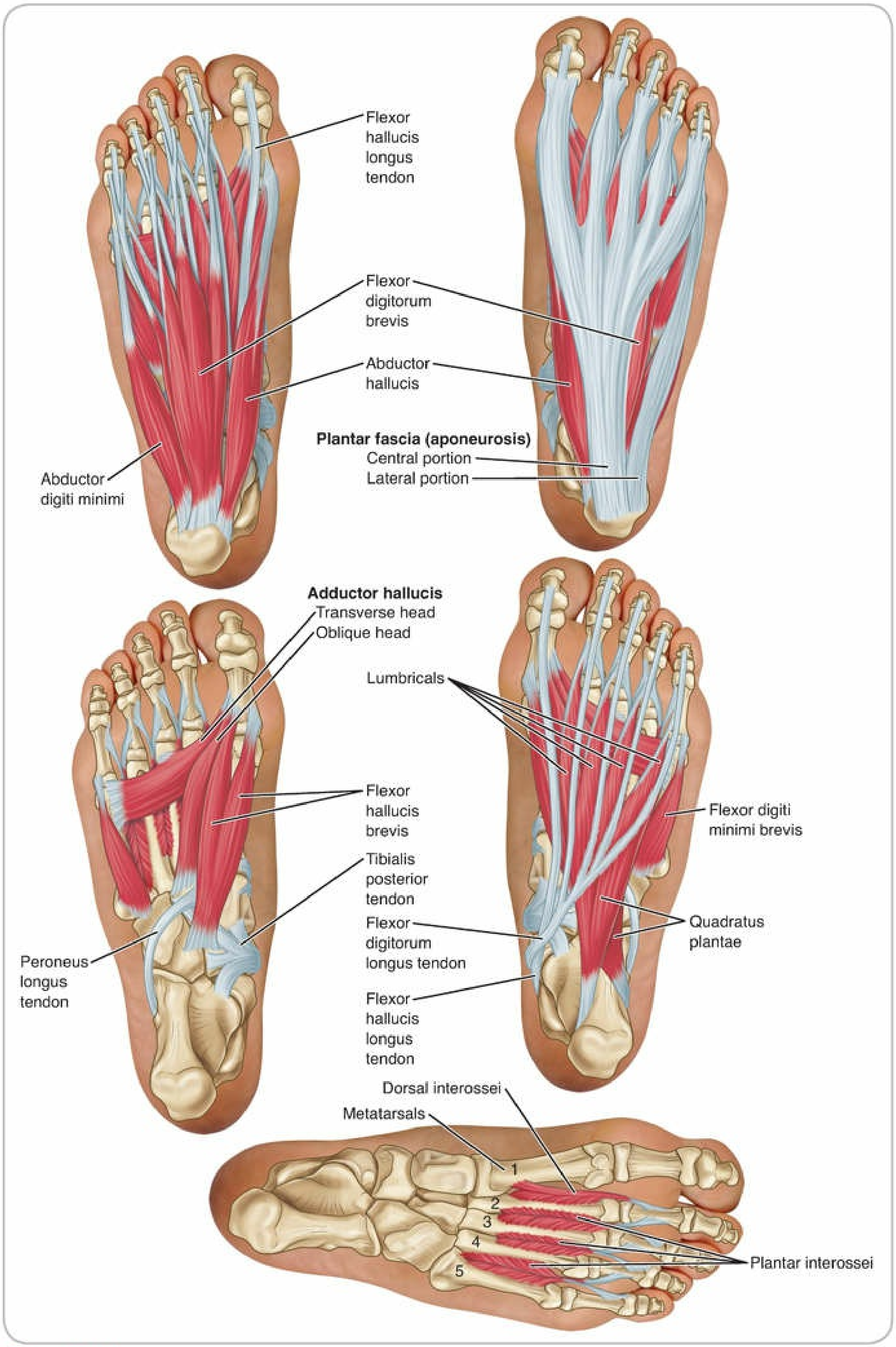


Figure 14.10. Intrinsic muscles of the foot. Plantar view.

See **Major Muscles of the Foot and Leg**, available on the companion Web site at thePoint, for a summary of the attachments and primary actions of the major extrinsic muscles of the lower leg, ankle, and foot.

Nerves of the Lower Leg, Ankle, and Foot

The sciatic nerve and its branches provide primary innervation for the lower leg, ankle, and foot. Traveling down the posterior aspect of the leg from the lumbosacral spine, the sciatic nerve branches into smaller nerves just proximal to the popliteal fossa. The major branches are the tibial nerve, which innervates the posterior aspect of the leg, and the common peroneal nerve, which spawns the deep and superficial peroneal nerves.

The tibial nerve (L4 through S3) passes through the popliteal fossa and down the leg between the superficial and deep muscles in the posterior compartment of the leg (see **Fig. 15.4**). It continues medially behind the medial malleolus with the posterior tibial artery to become the medial and lateral plantar nerves. The saphenous nerve (L2 through L4), which branches from the femoral nerve, supplies cutaneous innervation to the medial aspect of the ankle.

The common peroneal nerve passes laterally around the neck of the fibula to the anterolateral leg, where it splits into the deep and superficial peroneal nerves (see **Fig. 15.4**). The deep peroneal nerve (L4 through S1) innervates the anterior compartment, which contains the ankle dorsiflexors and toe extensors and then courses over the dorsum of the foot to innervate the skin between the first and second toes. The superficial peroneal nerve (L5 through S2) innervates the lateral compartment, which contains the primary evertor muscles, and provides cutaneous innervation to the second through fourth toes. The sural nerve (L4 through S2), a branch from both the common peroneal and tibial nerves, supplies cutaneous innervation to the lateral aspect of the ankle, heel, and foot. Given the extensiveness of the sciatic nerve supply to the lower extremity, it is no surprise that impingement of the sciatic nerve by a herniated disk in the lumbosacral region often results in pain, numbness, and/or impaired function in the foot and ankle region.

Blood Vessels of the Lower Leg, Ankle, and Foot

The blood supply to the lower leg, ankle, and foot enters the lower extremity as the femoral artery (Fig. 14.11). The femoral artery becomes the popliteal artery proximal and posterior to the knee and then branches into the anterior and posterior tibial arteries just distal to the knee. The anterior tibial artery becomes the dorsalis pedis artery to supply the dorsum of the foot. The posterior tibial artery gives off several branches that supply the posterior and lateral compartments and the plantar region of the foot.

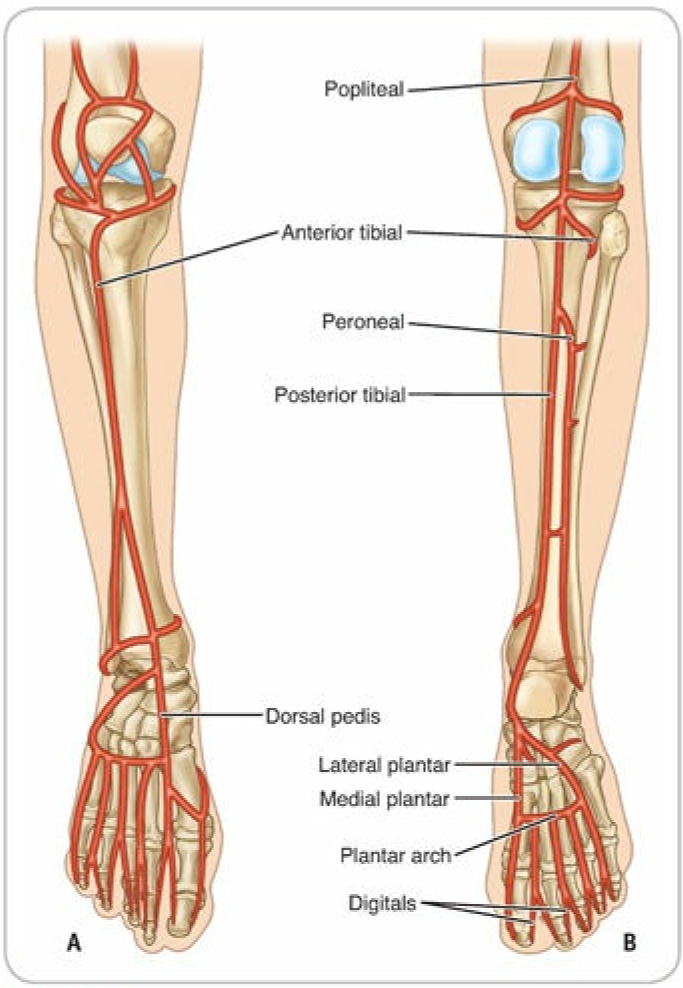


Figure 14.11. Blood supply to the leg, ankle, and foot region. **A,** The dorsalis pedis artery is easily palpated in the midfoot region between the second and third tendons of the extensor digitorum longus. **B,** The posterior tibial artery can be palpated just posterior to the medial malleolus.

KINEMATICS OF THE LOWER LEG, ANKLE, AND FOOT

As discussed in *Chapter 8: Assessment of Body Alignment, Posture, and Gait*, evaluation of the kinematics of gait during walking and running can provide important clues for the likelihood of injuries. Understanding the kinematics of the lower leg, ankle, and foot is imperative to accurately diagnose pathology and create appropriate prevention strategies and therapeutic exercise programs. If needed, please review the gait assessment information shared in Chapter 8.

PREVENTION OF LOWER LEG, ANKLE, AND FOOT CONDITIONS

Several steps can reduce the incidence or severity of injury. These include the use of appropriate protective equipment, footwear, and physical conditioning.

Protective Equipment

The use of protective braces and equipment for the lower leg, ankle, and foot is discussed in Chapter 3. Shin pads can protect the anterior tibial area from a direct impact by a ball, bat, stick, or kick from a foot. Taping and commercial ankle braces are commonly used ankle injury prevention strategies; however, the literature supports that players with prior ankle injury derive the greatest benefit from taping or bracing over players with no existing ankle pathology.[11] Commercial ankle braces come in three categories: lace-up brace, semirigid orthosis, or air-bladder brace (see **Fig. 3.9**). A lace-up brace can limit all ankle motions, whereas semirigid orthoses and air-bladder braces limit only inversion and eversion. In general, ankle braces are more effective than taping the ankle to reduce injuries, are easier for the wearer to apply independently, do not produce some of the skin irritation associated with adhesive tape, provide better comfort and fit, and are more cost-effective and comfortable to wear. Specific foot conditions can be padded and supported with a variety of products, including inner soles, semirigid orthotics, rigid orthotics, antishock heel lifts, heel cups, or commercially available pads and devices. Adhesive felt (e.g., moleskin), felt, and foam also can be cut to construct similar pads to protect specific areas.

Physical Conditioning

Physical conditioning is one of the strongest defenses against injury. It is recommended that the injury prevention program be implemented 3 months prior to the start of the season and take a multi-intervention strategy approach focusing on balance, neuromuscular control, leg muscle strength, hip muscle strength, and ankle ROM. Examples of exercises for improving balance and neuromuscular control include incorporating aspects of the Balance Error Scoring System, the Star Excursion Balance Test, the Biodex Balance System, and other balance activities on hard and soft surfaces, stable and unstable surfaces, and in single, double, and tandem stance positions. The use of **functional** exercises to stimulate activation and strength of muscles controlling ankle eversion, inversion, plantar flexion, and dorsiflexion as well as muscles responsible for hip extensors and abductors should be incorporated into the injury prevention program. Exercises should target both concentric and eccentric activation. Before initiating strategies to target increasing ROM, it is important to assess if motion is limited. The motion of specific interest is dorsiflexion. If dorsiflexion is limited, joint mobilization techniques should be included as part of the injury prevention strategy to help improve ankle arthrokinematics and osteokinematics.[11]

Application Strategy 14.1 demonstrates several exercises that can be used to prevent injuries to the lower leg, ankle, and foot.

APPLICATION STRATEGY 14.1

Exercises to Prevent Injury to the Lower Leg

Intrinsic Muscle Exercises of the Foot

1. **Plantar fascia stretch.** Place a towel around the toes and slowly overextend the toes. Dorsiflex the ankle to stretch the Achilles tendon.
2. **Towel crunches.** Place a towel between the plantar surfaces of the toes and feet. Push the toes and feet together, crunching the towel between the toes.

3. **Toe curls.** With the foot resting on a towel, slowly curl the toes under, bunching the towel beneath the foot. (Variation: Use two feet or a book or small weight on the towel for added resistance.)
4. **Picking up objects.** Pick up small objects, such as marbles or dice, with the toes and place them in a nearby container, or use therapeutic putty to work the toe flexors.
5. **Shin curls.** Slide the plantar surface of the foot up the opposite shin, moving distal to proximal.
6. **Unilateral balance activities.** Stand on uneven surfaces with the eyes first open and then closed.
7. **BAPS board.** In a seated position, roll the board slowly clockwise and then counterclockwise 20 times.

Ankle/Lower Leg Muscle Exercises

1. **Ankle alphabet.** Using only the ankle and foot, trace the letters of the alphabet from A to Z three times with capital letters and three times with lowercase letters.

2. **Triceps surae stretch.** Keeping the leg straight and the heel on the floor, lean against a wall or stand on a slant board until tension is felt in the calf muscles. To isolate the soleus, bend both knees. Point the toes outward, straight ahead, and inward to stretch the various fibers of the Achilles tendon.

3. **Thera-Band or surgical tubing exercises.** Secure the Thera-Band or tubing around a table leg and do resisted dorsiflexion, plantar flexion, inversion, and eversion.

4. **Unilateral balance exercises.** Balance on the opposite leg while doing Thera-Band exercises.
5. **BAPS board.** In a standing position, balance on the involved foot; repeat several times. Additional challenges, such as using no support or dribbling with a basketball while balancing, can be added.

Footwear

The demands of a particular activity require adaptations in shoe design and selection. In field sports, shoes may have a flat-sole, long-cleat, short-cleat, or multicleated design. Cleats should be positioned under the major weight-bearing joints of the foot and should not be felt through the sole of the shoe. Shoe models with flat cleats or screw-in cleats, or pivot-disk models, have been shown to reduce the incidence of anterior cruciate ligament injuries when compared to shoes with the longer, irregular cleats. In individuals with arch problems, the shoe should include adequate forefoot, arch, and heel support. In all cases, individuals should select shoes based on the demands of the activity.

Shoe selection and guidelines for fitting shoes are discussed in detail in Chapter 3.

ASSESSMENT OF THE LOWER LEG, ANKLE, AND FOOT CONDITIONS

? A cross-country runner reports to the athletic training room complaining of pain along the plantar surface of the left foot. How should the assessment of this injury progress to determine the extent and severity of injury?

Initial assessment of the lower leg, ankle, and foot is usually conducted in three different situations. The first is the on-field (or sideline) evaluation of the acutely injured patient. In the acute setting, it is important to first assess for and treat any life-threatening conditions that may be present before focusing on the orthopedic injury. Next, assess for and treat obvious fractures, dislocations, and severe bleeding if present. Finally, assess for and treat other soft-tissue damage. When conducting an on-field evaluation of the acutely injured patient, the goals are to determine (1) the type and severity of damage the patient has sustained; (2) immediate first aid and care needed; (3) if referral is needed, the urgency of the referral, and to whom the patient should be referred; (4) the manner in which the patient will be removed from the playing field; and (5) the patient's participation status.

The second situation is the nonacute evaluation of the patient who has had ongoing pain or disability. When conducting an evaluation of a nonacutely injured patient, the goals are to determine (1) which structures have been injured, (2) the severity of the injury, (3) the cause of the injury, (4) strategies to address the patient's pain and dysfunction and restore normal function, and (5) participation status.

The third situation is with patients who will need longer and more complex therapeutic intervention due to the complexity, seriousness, or severity of injury. When conducting an evaluation of a patient in the clinic setting, the goals are to determine the patient's (1) baseline function, disability, and pain; (2) goals for recovery; (3) strategies to address function, disability, and pain that incorporate the patient's goals; and (4) return to participation.

The following information describes the assessment process for evaluating the lower leg, foot, and ankle. The exact content, sequence, and tools utilized will vary depending on the situation in which the evaluation is conducted.

See **Application Strategy: Lower Leg, Ankle, and Foot Evaluation**, available on the companion Web site at thePoint.

HISTORY

? The injury assessment of the cross-country runner should begin with a history. What questions need to be asked to identify the cause and extent of this injury?

Many conditions in the lower leg, ankle, and foot are related to family history; congenital deformities; poor technique; and recent changes in the training program, surface, or foot attire. The assessment begins by asking questions related to the mechanism of injury, associated symptoms, progression of the symptoms, any disabilities that may have resulted from the injury, and related medical history. For example, an acute onset should lead one to suspect bony trauma or an acute ankle sprain until ruled out. A gradual onset of pain may signal inflammation from overuse of a muscle or the plantar fascia or the development of a stress fracture. Particular attention should be given to recent changes in the distance, duration, or intensity of training; each component can lead to overuse injuries. Medial heel pain may indicate plantar fasciitis or, if in the middle of the plantar heel area, a heel spur. Pain in the medial arch can be a sign of a fallen medial longitudinal arch or tarsal tunnel syndrome. Pain around either malleolus may indicate an ankle sprain. Pain posterior to the lateral malleolus can signify peroneal tendinitis, subluxation, or dislocation or even sural nerve entrapment. Pain posterior to the medial malleolus may reflect tendinitis or rupture of the tibialis posterior.

See **Application Strategy: Developing a History of the Injury**, available on the companion Web site at thePoint, for specific questions related to the lower leg, ankle, and foot.

The cross-country runner should be asked questions that address when, where, and how the injury occurred; intensity, location, and type of pain; when the pain begins (e.g., when getting out of bed, while sitting, while walking, during exercise, or at night); how long the condition has been present; how long the pain lasts; if the pain has changed or stayed the same; if the pain is worse before, during, or after activity; activities that aggravate or alleviate the symptoms; changes in training; changes in footwear; and previous injury, treatment, and medication. This is an example of a history that is appropriate for a patient with a nonacute injury.

OBSERVATION AND INSPECTION

?

The cross-country runner reports pain on the plantar, medial heel that has been present for the past 5 days. The pain is worse after rest but is particularly severe with the first few steps in the morning. The runner indicates that he has increased both the intensity and distance of his daily runs over the past 7 days. Explain the observation component in the ongoing assessment of the cross-country runner.

Both lower legs should be clearly visible to denote symmetry, any congenital deformity, swelling, discoloration, hypertrophy, muscular atrophy, or previous surgical incisions. The individual should wear running shorts to allow full view of the lower extremity. In addition, the individual should bring the shoes that normally are worn when pain is present so that they can be inspected for unusual wear, which could be indicative of a biomechanical abnormality that may be affecting the knee.

In an ambulatory patient, observation begins with the completion of a postural examination. Any bilateral gross deformity, swelling, or redness in the toes, foot, or ankle should be noted. The foot should be observed for the presence or absence of an arch on weight bearing and non–weight bearing. A supple, or flexible, flatfoot appears to be flattened when weight bearing but produces an obvious arch when non–weight bearing. In contrast, a rigid flatfoot appears to be flattened on weight bearing and non–weight bearing. It is important to note if the foot is in a pronated, neutral, or supinated position (Box 14.1).

BOX 14.1 Common Injuries Associated with Foot Deformities

Pes Cavus

Plantar fasciitis

Metatarsalgia

Stress fractures of the tarsals and metatarsals

Peroneal tendinitis

Sesamoid disorders

Iliotibial band friction syndrome

Pes Planus

Tibialis posterior tendinitis

Achilles tendinitis

Plantar fasciitis

Sesamoid disorders

Medial tibial stress syndrome

Patellofemoral pain

See **Application Strategy: Postural Assessment of the Lower Leg, Ankle, and Foot**, found on the companion Web site at thePoint, for specific areas to focus on in the lower extremity.

Next, the clinician should instruct the individual to lie prone on a table with the feet and ankles extended over the end of the table to determine the talar neutral position. In assessing the left foot, the clinician places the right thumb and index finger on the anterior aspect of the foot spanning the talar dome. Using the left hand, the clinician grasps the foot from the lateral side and then inverts and everts the ankle and foot until the neutral position of the foot is determined (**Fig. 14.12**). The neutral position is identified when the talus is aligned symmetrically between the thumb and index finger. When talar neutral is determined, the relationship of the forefoot and rearfoot alignment should be noted. This may be done in the non–weight-bearing position, the weight-bearing position, or both. The following conditions may be present with the calcaneus and talus in neutral position:

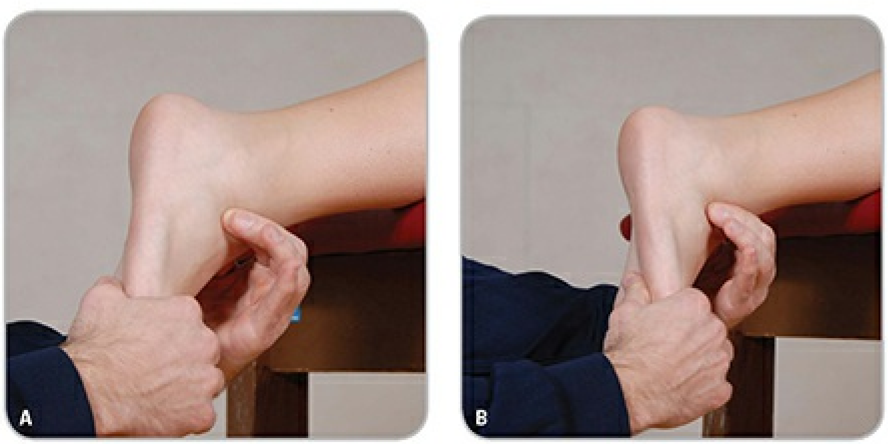


Figure 14.12. Assessing the neutral talar position. A and B, The clinician places the thumb and index fingers on the anterior aspect of the foot spanning the talar dome. Using the other hand, the clinician grasps the foot from the lateral side and then inverts and everts the ankle and foot until the neutral position of the foot is determined.

- **Forefoot varus.** The 1st metatarsal is elevated relative to the 5th metatarsal.
- **Forefoot valgus.** The 5th metatarsal is elevated relative to the 1st metatarsal.

- **Rearfoot varus.** The calcaneus is inverted relative to the long axis of the tibia, which may result from a varus tibial alignment.
- **Rearfoot valgus.** The calcaneus is everted relative to the long axis of the tibia, which may result from a valgus tibial alignment.

The mobility of the first ray (i.e., the first tarsometatarsal joint extending into the first MTP joint) should be assessed. If the first ray is slightly plantar flexed at the tarsometatarsal joint, this causes the ray to be situated inferior to the remaining four rays. This often is associated with a cavus foot, as is a rigid ray. In contrast, hypermobility of the first ray is associated with pes planus.

The clinician should then instruct the individual to walk barefoot and observe the individual from an anterior, posterior, and lateral view. It is important to note any abnormalities in gait, favoring of one limb, heel–toe floor contact, and heel alignment. The gait analysis should be repeated with the individual wearing shoes and any orthoses.

Finally, the injury site should be inspected for obvious deformities, discoloration, edema, scars that might indicate previous surgery, and general condition of the skin. A bilateral comparison should be performed. In contrast, the observation and inspection for a patient with an acute injury consists of inspecting for bleeding, deformity, swelling, discoloration, antalgic gait, and reaction to pain.

Observation of the cross-country runner should include a full postural assessment and gait analysis. The specific injury site should be inspected for obvious deformities, discoloration, edema, scars that might indicate previous surgery, and general condition of the skin.

PALPATION

The observation of the cross-country runner reveals no abnormal findings. Explain palpation specific to the injury sustained by the cross-country runner.

The individual should be seated on an examination table, with the foot and ankle extended beyond the table's edge. Bilateral palpation should be performed to determine temperature, swelling, point tenderness, crepitus, deformity, muscle spasm, and cutaneous sensation. Pulses can be taken at the posterior tibial artery behind the medial malleolus and at the dorsalis pedis artery on the dorsum of the foot.

Palpation should proceed proximal to distal, but the area anticipated to be most painful should be left to last. The following structures should be palpated:

Anterior and Medial Palpation

1. Shaft of the tibia
2. Medial malleolus
3. Posterior tibial artery
4. Tibialis posterior, flexor digitorum longus, and flexor hallucis longus muscles and tendons
5. Deltoid ligament
6. Sustentaculum tali (one finger width inferior to the medial malleolus)
7. Talar dome and neck (plantar flexion exposes this area)
8. Joint capsule
9. Tibialis anterior, extensor hallucis longus, extensor digitorum longus muscles and tendons, and dorsalis pedis artery
10. Navicular bone and tubercle of the navicular
11. Medial, middle, and lateral cuneiforms
12. Calcaneonavicular ligament (i.e., spring ligament)
13. Medial calcaneus
14. Plantar fascia

15. Head of 1st metatarsal, sesamoid bones, and great toe
16. Second metatarsal and second toe

Anterior and Lateral Palpation

1. Head of the fibula as well as peroneal longus and brevis
2. Distal tibiofibular joint and ligament
3. Lateral malleolus
4. ATFL, PTFL, CFL, peroneal tubercle, and peroneal tendons
5. Sinus tarsi (indentation over the talus next to the muscle belly of the extensor digitorum brevis)
6. Joint capsule and dome of the talus (plantar flex the foot)
7. Cuboid bone
8. Styloid process of the 5th metatarsal as well as shafts of the 3rd, 4th, and 5th metatarsals
9. Third through fifth toes

Posterior Palpation

1. Triceps surae and Achilles tendon
2. Calcaneus, calcaneal bursa, and retrocalcaneal bursa
3. Posterior aspect of the heel pad and calcaneus

When evaluating the acutely injured patient, only the structures in the painful area and those adjacent to the area are palpated. Findings such as extreme point tenderness, deformity, and crepitus suggest a more significant injury and warrant conducting specific special tests to confirm or rule out potential pathologies. For example, if a fracture is suspected, percussion and compression tests should be administered before moving the limb. Examples of these techniques are provided in **Application Strategy 14.2**.

APPLICATION STRATEGY 14.2

Determining a Fracture in the Lower Leg and Foot

- **Percussion.** Tapping on the head of the fibula or tibial shaft can be used to detect a fracture of the malleolus. Tapping on the ends of the toes along the long axis of the bone may detect a phalangeal fracture.
- **Bump test.** Strike the bottom of the heel with the palm to drive the talus into the mortise. Increased pain may indicate an osteochondral fracture, malleolar fracture, or increased mortise spread.
- **Squeeze test.** Compress the tibia and fibula together just distal to the knee. This causes the distal malleoli to distract. Increased pain distally may indicate a fracture.
- **Circumferential squeeze test.** Encircle the midfoot with the hand and slowly squeeze the metatarsal heads. Increased pain may indicate a tarsal or metatarsal fracture.
- **Vibration.** Place a vibrating tuning fork near the suspected fracture site. Increased localized pain is a positive sign.
- **Compression/distraction.** Compress the ends of the toes and metatarsals along the long axis of the bone. Follow this with distraction along the long axis. If a fracture is present, compression should increase pain, but distraction should decrease pain. If distraction increases pain, the injury may be a joint sprain.

The clinician should also make use of specific clinical prediction rules to help guide decision making regarding treatment options. The Ottawa ankle rules (OARs) have been found to be useful in the clinical setting.[11] The OARs are clinical prediction rules designed to assist the clinician in determining the need to refer the patient for radiographic imaging to detect potential fractures of the ankle and midfoot. The OARs are presented in Figure 14.13.

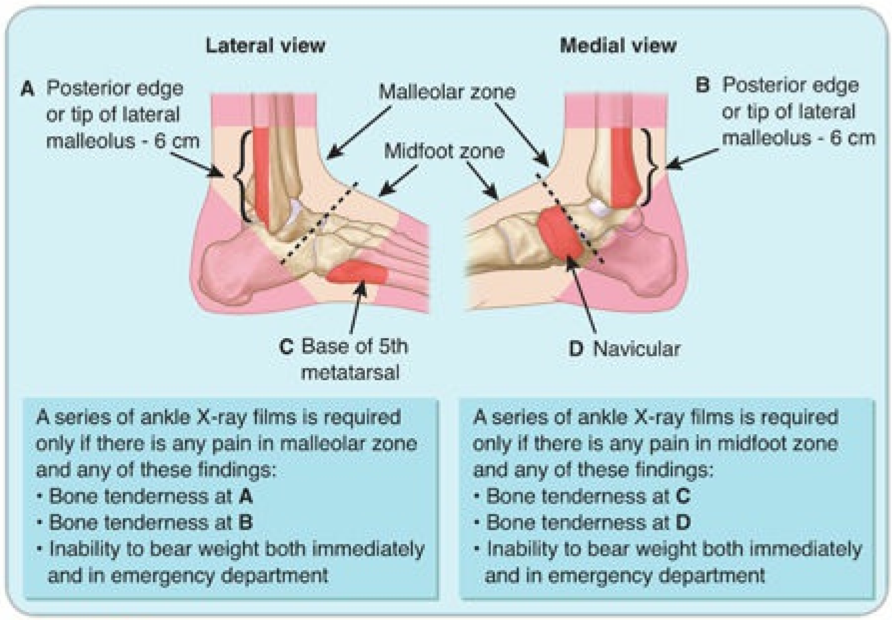


Figure 14.13. Clinical predictions rules: Ottawa ankle rules.

In the continued assessment of the cross-country runner, the bony and soft-tissue structures on the plantar aspect of the foot should be palpated for point tenderness, swelling, deformity, sensation, or other signs of trauma.

PHYSICAL EXAMINATION TESTS

The cross-country runner has point tenderness over the medial calcaneal tubercle. Explain the physical examination of the cross-country runner.

Physical examination testing should be performed in a comfortable position, with the individual lying on a table with feet hanging over the end or with the individual sitting. Bilateral comparison is used to assess normal level of function. When evaluating the acutely injured patient, the physical examination is usually conducted in the position the patient is found. It is important not to move an acutely injured patient until serious injury has been ruled out.

Functional Tests

The clinician should determine the available ROM in ankle dorsiflexion–plantar flexion, supination–pronation, toe flexion–extension, and toe abduction–adduction. Remember that in the acute setting, testing ROM may be contraindicated, based on findings obtained in the history, inspection, and palpation portions of the examination process.

Active Movements

Active movements, depicted in **Figure 8.8**, are best performed with the individual sitting on a table, with the leg flexed over the end of the table. The thigh and knee must be stabilized. Actions that may cause pain should be performed last to prevent any painful symptoms from overflowing into the next movement. The motions that should be assessed, and the normal ROM for each, are as follows:

- Dorsiflexion of the ankle (20°)
- Plantar flexion of the ankle (30° to 50°)
- Pronation (15° to 30°)
- Supination (45° to 60°)
- Toe extension
- Toe flexion
- Toe abduction and adduction

Passive Range of Motion

If the individual is able to perform full ROM during active movements, gentle pressure is applied at the extremes of motion to determine end feel. The end feel for dorsiflexion, plantar flexion, pronation, supination, and toe flexion and extension is tissue stretch. If the individual is unable to perform full active movements, passive movement should be performed to determine available ROM and end feel. ROM is measured most often when evaluating patients in nonacute situations. Obtaining baseline ROM measurements through the use of a goniometer provides a benchmark that the clinician can use to assess if the patient is improving. After the initial measurements are taken, measures taken throughout the rehabilitation process can be compared with the initial baseline numbers. Figure 14.14 demonstrates proper positioning for goniometry measurement at the ankle.

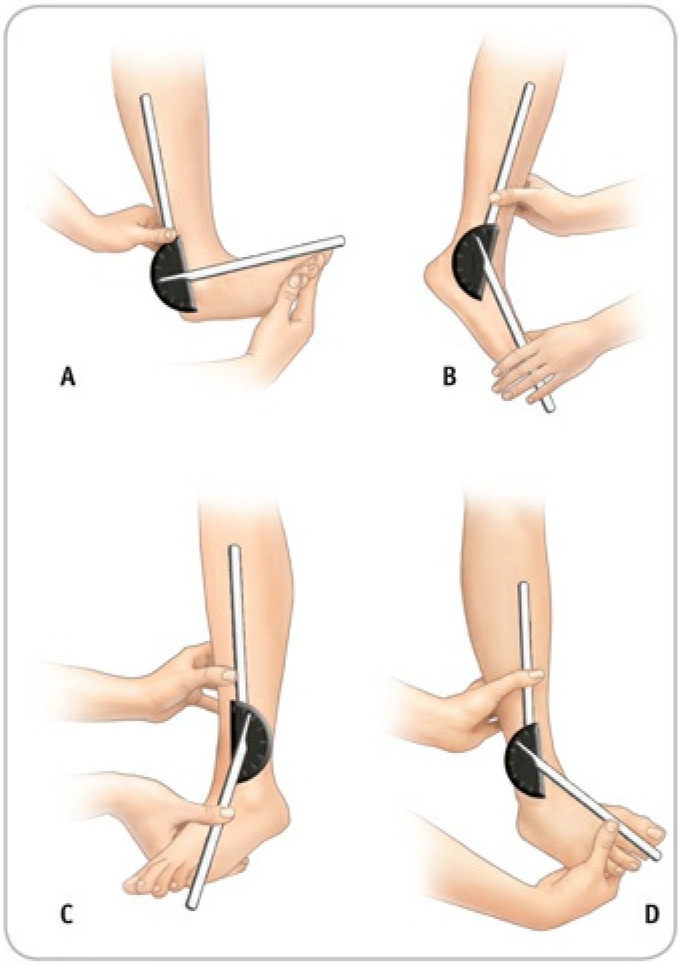


Figure 14.14. Goniometry measurement. Ankle dorsiflexion **(A)** and plantar flexion **(B)**. Center the fulcrum over the lateral malleolus. Align the proximal arm along the fibula using the head of the fibula for reference. Align the distal arm parallel to the midline of the 5th metatarsal. Pronation **(C)** and supination **(D)**. Center the fulcrum over the anterior ankle midway between the malleoli. Align the proximal arm with the midline of the crest of the tibia. Align the distal arm with the midline of the 2nd metatarsal.

Resisted Range of Motion

The thigh must be stabilized and resisted muscle testing performed throughout the full ROM. The assessment begins with the muscle on stretch, and resistance is applied throughout the full ROM. The clinician should note any muscle weakness when compared with the uninvolved limb. Potentially painful motions should be delayed until last. **Figure 14.15** demonstrates the motions that should be tested.

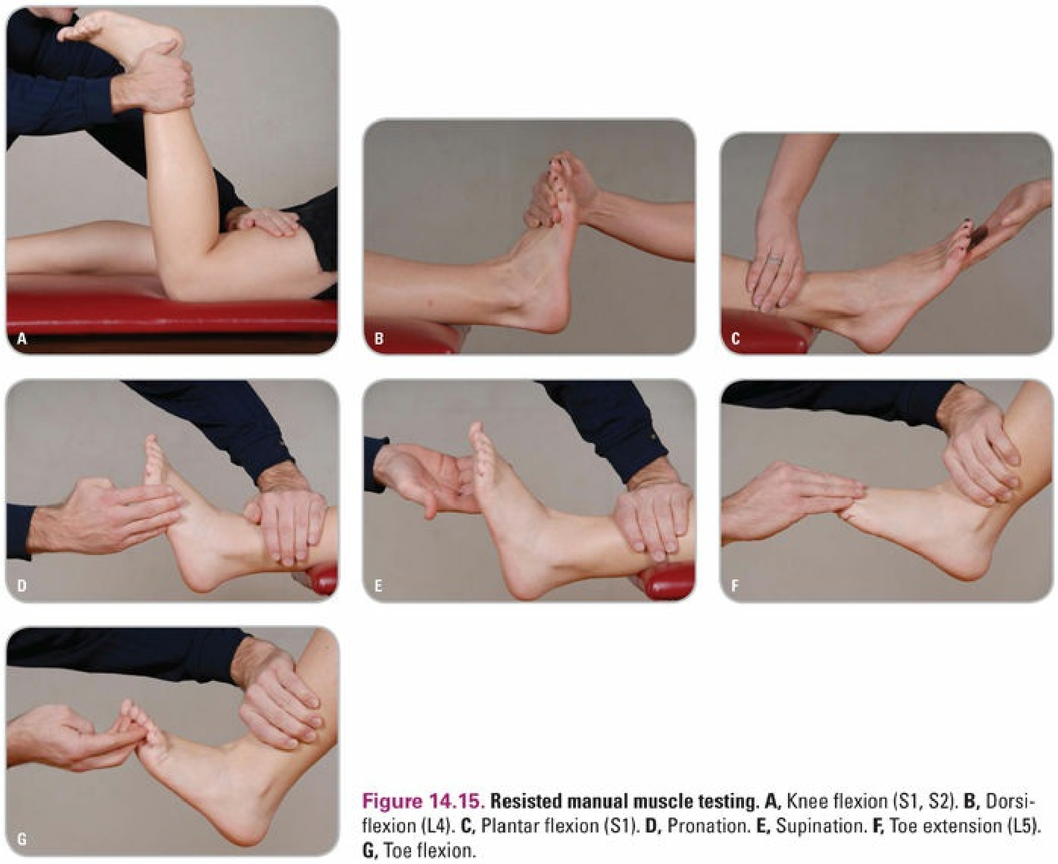


Figure 14.15. **Resisted manual muscle testing. A,** Knee flexion (S1, S2). **B,** Dorsiflexion (L4). **C,** Plantar flexion (S1). **D,** Pronation. **E,** Supination. **F,** Toe extension (L5). **G,** Toe flexion.

Manual Muscle Testing

If pain or weakness is found during resisted ROM, the clinician may decide to perform a manual muscle test to determine which muscle is damaged. When performing manual muscle testing, class I and II muscles should be tested at end range with maximal shortening of the muscle.[12] One-joint muscles that concentrically contract through the ROM are considered class I muscles. Class I muscles are short and strong. In contrast, class II muscles are two-joint and multijoint muscles that actively shorten all joints crossed and are also strong at the end range. Several class I and II muscles are involved with lower leg, ankle, and foot motion. See Table 14.2 for MMT positioning.

TABLE 14.2 Manual Muscle Testing of Lower Leg and Ankle Muscles

MUSCLE	JOINT POSITIONING	APPLY PRESSURE
Extensor hallucis longus	Ankle is in slight plantar flexion. MTP and IP joints of great toe are extended.	To dorsal aspect of the distal and proximal phalanges of the great toe in the direction of flexion
Extensor digitorum longus	Ankle is in slight plantar flexion, either everted or inverted, with the 2nd–5th digits in full extension.	To the dorsal aspect of the 2nd–5th digits in the direction of flexion
Tibialis anterior	Knee is flexed with ankle in dorsiflexion and inversion. Great toe should not be extended.	To the medial and dorsal aspect of the foot, along the 1st metatarsal, in the direction of eversion and plantar flexion
Flexor hallucis longus	Ankle is midway between dorsiflexion and plantar flexion with first IP joint flexed.	To the plantar surface of the distal phalanx of the 2nd–5th digits, in the direction of flexion
Flexor digitorum longus	Knee is flexed with ankle in neutral position. The distal IP joints of 2nd–5th digits are flexed.	To the plantar surface of the distal phalanges, in the direction of flexion
Tibialis posterior	Ankle is plantar flexed with foot inverted.	To the medial and plantar aspect of the foot in the direction of DF and EV

IP, interphalangeal; *DF*, dorsiflexion; *EV*, eversion.

From Kendall FP, McCreary EK, Provance PG, et al. *Muscles: Testing and Function with Posture and Pain.* 5th ed. Baltimore, MD: Lippincott Williams & Wilkins; 2005.

Stress Tests for Ligament Laxity

From information gathered during the history, observation, inspection, and palpation, the clinician determines which tests will assess the condition most effectively. Special tests are used to confirm clinical impressions formulated during the history and early portion of the physical examination.[13] Although several tests are described in this text, only those tests that are deemed to be absolutely necessary should be performed. Important to note is that the clinical accuracy of joint stability tests increases when performed prior to onset of swelling.[11] Therefore, performing joint stability prior to onset of joint effusion is imperative to formulating an early accurate diagnosis.

Anterior Drawer Test

This test assesses collateral ligament integrity of the ankle. While the individual is supine and the foot is extended beyond the table, the clinician stabilizes the tibia and fibula in one hand and cups the individual's heel in the other hand. Testing of both the anterior talofibular and deltoid ligaments involves applying a straight anterior movement with slight dorsiflexion (Fig. 14.16A). If the entire dome of the talus shifts equally forward, it indicates both medial and lateral ligament damage. The ATFL and anterolateral capsule can be isolated by applying a straight anterior movement with slight plantar flexion and inversion. A positive test results in the lateral side of the talus shifting forward, indicating anterolateral rotary instability. The clinician should correlate mechanism of injury, pain, and areas of tenderness with the results of the anterior drawer test to determine involved structures. The diagnostic accuracy of the anterior drawer test increases when performed 5 days postinjury as compared to performing the test after 48 hours of injury.[11]

Figure 14.16. Stress tests for the ankle collateral ligaments. A, Anterior drawer test. **B,** Talar tilt test.

Talar Tilt

The calcaneofibular and deltoid ligaments are tested with the patient's foot and ankle in the same position described for the anterior drawer test. Maintaining the calcaneus in normal anatomical position (90° of flexion), the clinician slowly rocks the talus between inversion and eversion (**Fig. 14.16B**). Inversion tests the CFL, and eversion tests the deltoid ligament. The diagnostic accuracy of the talar tilt test increases when performed 5 days postinjury as compared to performing the test after 48 hours of injury.[11]

External Rotation (Kleiger) Test

A variation of the talar tilt test for deltoid ligament instability is the external rotation, or Kleiger, test. Being careful not to compress the joint, the lower leg is stabilized proximal to the distal tibiofibular syndesmosis. While the foot is in a neutral position, the clinician grasps the medial side of the foot and then rotates the foot laterally (i.e., external rotation) (Fig. 14.17). If this motion elicits pain over the medial joint line, it indicates damage to the deltoid ligament, whereas pain in the area above the talus over the anterior tibiofibular ligament indicates injury to the syndesmosis. Syndesmosis sprains are also referred to as a high ankle sprain.

Figure 14.17. Kleiger test (external rotation test). The clinician passively dorsiflexes the ankle and rotates the foot laterally. Pain in the area of the lateral malleolus indicates injury to the syndesmosis.

Glide Tests

Ligaments in the metatarsal and tarsal region of the foot are assessed through the use of glide tests to determine the amount of "play" or motion within the joint. Joints that have excessive joint play as compared to the noninvolved joint are said to be hypermobile. Joints that have restricted joint play as compared to the noninvolved joint are said to be hypomobile. When assessing for the presence of a sprain in the acutely injured patient, increased joint play and pain are positive findings.

Intermetatarsal glide test assesses the integrity of the ligaments between the metatarsals. The test is performed by stabilizing one metatarsal while gliding the adjacent metatarsal from dorsal to ventral and ventral to dorsal.

Tarsometatarsal glide test is used to assess the integrity of the ligaments of the tarsometatarsal joints. The test is performed by stabilizing a tarsal bone while gliding the adjacent metatarsal from dorsal to ventral and ventral for dorsal. For example, the clinician stabilizes the medial or first cuneiform while gliding the 1st metatarsal.

Intertarsal glide test is used to assess the integrity of the ligaments between the tarsals. To perform the test, the clinician stabilizes one tarsal (e.g., the cuboid) while gliding the adjacent tarsal (the navicular).

Varus and Valgus Stress Test

Varus and valgus stress tests are used to examine the integrity of the lateral stabilizing structures of the MTP joints and the interphalangeal (IP) joints. The varus stress test stresses the lateral collateral ligament (or fibular collateral ligament), whereas the valgus stress test stresses the medial collateral ligament (or tibial collateral ligament). It is difficult to perform these tests on the second to fourth MTP joints and is more easily applied to all IP joints. To perform the test, the joint should first be in full extension, and the clinician should stabilize the bone just proximal and distal to the joint being assessed. Then, either a valgus (for the valgus stress test) or a varus (for the varus stress test) stress is placed on the joint. Degree of joint laxity is used to determine degree of sprain. If no pain or joint opening is noted in full extension, the joint should be flexed slightly and the test repeated.

Special Tests

A variety of special tests can be used for detecting injury or related pathology involving the lower leg, ankle, and foot.

Thompson Test for Achilles Tendon Rupture

While the individual is prone on a table, the clinician squeezes the calf muscles. A normal response is slight plantar flexion. A positive test, indicating a rupture of the gastrocnemius–soleus complex or Achilles tendon, is indicated by the absence of plantar flexion (**Fig. 14.18**). The amount of motion should always be compared with the uninjured side, because some plantar flexion may occur if the plantaris muscle is intact. The magnitude of contraction, however, is significantly reduced compared with that of the uninvolved leg.

Figure 14.18. Thompson test. The clinician performs passive compression of the calf muscles. This should produce slight plantar flexion at the ankle. If no plantar flexion occurs, a possible rupture of the gastrocnemius–soleus complex or the Achilles tendon should be suspected.

Homans Sign

To test for deep venous thrombosis (DVT), the individual must be supine on a table. The clinician dorsiflexes the foot of the involved leg with the knee in extension. Pain in the calf indicates a positive Homans sign. Tenderness also may be elicited with palpation of the calf. In addition, pallor or swelling in the leg may be accompanied by an absence of the dorsalis pedis pulse.

Tinel Sign

To determine the presence of tarsal tunnel syndrome, the clinician should tap the posterior tibial nerve as it courses posterior to the medial malleolus (Fig. 14.19). The test is positive if numbness, tingling, and paresthesia occur.

Figure 14.19. Tinel sign. The clinician taps the posterior tibial nerve, which may produce numbing, tingling, and paresthesia, indicating the presence of a possible tarsal tunnel syndrome.

Thumb Index Squeeze Test

With a sensitivity of 96% and 96% accuracy, the thumb index squeeze test is the most clinically useful test for detecting the presence of Morton neuroma.[14] To perform the test, locate the sensitive area on the foot and place your thumb on the plantar surface of the foot and the index finger on the dorsal aspect and squeeze. Pain is a positive finding for the presence of Morton neuroma.[14]

Neurological Tests

Neurological integrity is assessed with isometric muscle testing of the myotomes, reflex testing, and sensation in the segmental dermatomes and peripheral nerve cutaneous patterns.

Myotomes

Isometric muscle testing should be performed in the following motions to test specific segmental myotomes:

- Knee extension (L3)
- Ankle dorsiflexion (L4)
- Toe extension (L5)
- Ankle plantar flexion, foot eversion, or hip extension (S1)

Reflexes

Reflexes in the lower leg region include the patella (L3, L4) and Achilles tendon reflex (S1). These are discussed in Chapter 15 and demonstrated in **Figure 15.22**.

Cutaneous Patterns

The segmental nerve dermatome patterns for the pelvis, hip, and thigh are demonstrated in **Figure 14.20**. The peripheral nerve cutaneous patterns are demonstrated in **Figure 14.21**.

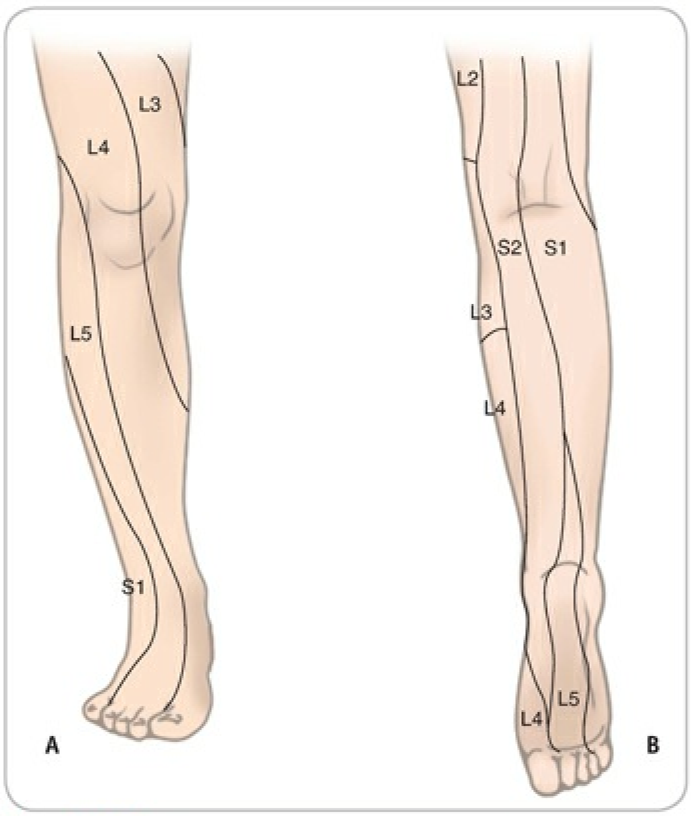


Figure 14.20. Dermatomes for the lower leg, ankle, and foot. **A,** Anterior. **B,** Posterior.

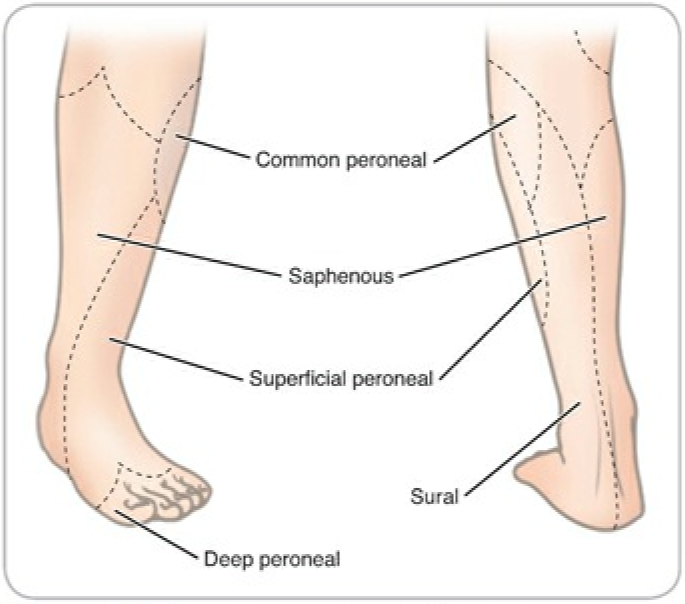


Figure 14.21. **Peripheral nerve distribution in the lower leg, ankle, and foot.**

Activity-Specific Functional Tests

Once the patient has achieved his or her rehabilitation goals, the patient should be assessed on his or her readiness to return to participation. Functional tests should be performed pain-free before clearing any individual for return to activity. Functional tests may sometimes be referred to as return to play guidelines. These may include any or all of the following:

- Squatting with both heels maintained on the floor
- Going up on the toes at least 20 times without pain
- Walking on the toes for 20 to 30 ft
- Balancing on one foot at a time
- Running straight ahead, stopping, and running backward
- Running figure eights with large circles that slowly decrease in size
- Running at an angle sideways and making V-cuts
- Jumping rope for at least 1 minute
- Jumping straight up and then going to a 90° squat

The physical examination of the cross-country runner should include active, passive, and restricted ROM of the foot and ankle; stretching the plantar aspect of the foot by having the athlete extend the toes while passively dorsiflexing the foot; fracture assessment; and performance of functional activities (e.g., walking and running).

TOE AND FOOT CONDITIONS

A defensive back reports throbbing pain on the plantar side of the great toe of the right foot that has been present for the last 2 days. The athlete does not recall a specific mechanism or time of onset. The pain increases significantly when the athlete pushes off the right foot to block an opponent. For the past 3 days, the team was forced to practice indoors on a composite-type floor. What injury should be suspected, and why?

Many individuals are at risk for toe and foot problems because of a leg length discrepancy, postural deviation, muscle dysfunction (e.g., muscle imbalance), or malalignment syndrome (e.g., pes cavus, pes planus, pes equinus, and hammer or claw toes) (**Fig. 14.22**). In particular, pes cavus (e.g., high arch and rigid foot) and pes planus (e.g., flatfoot and mobile foot) are associated with several common injuries (**Box 14.1**). Typically, when compared to a man's foot, a woman's foot has a narrower hindfoot, a relatively increased forefoot-to-hindfoot width, and increased pronation, and, because of fashion trends and societal pressures, women tend to wear shoes that have narrow toe boxes and narrow midfoot design. High heels shift the forefoot forward into the toe box, causing crowding of the toes and a tight heel cord. Consequently, women tend to be more prone to hallux valgus deformities, bunionettes, hammer toes, and neuromas.[15] Other skin conditions commonly seen at the foot include calluses, corns, athlete's foot, and plantar warts, all of which are discussed in Chapter 32.

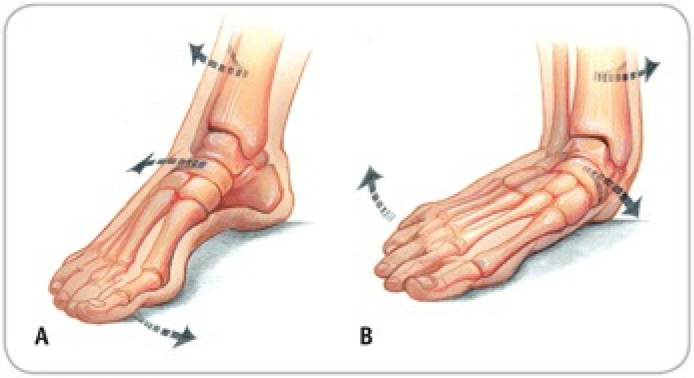


Figure 14.22. **Common foot deformities. A,** Pes cavus. **B,** Pes planus.

Toe Deformities

Most toe deformities are minor and can be treated conservatively. A few deformities require surgical intervention to correct serious structural malalignment.

Hallux Rigidus

Etiology

Degenerative arthritis in the first MTP joint, associated with pain and limited motion, is known as hallux rigidus. Activities that involve running and jumping may predispose an individual to this condition as a result of degenerative changes resulting from direct injury, hyperextension injury, or varus/valgus stress.[16]

Signs and Symptoms

The individual presents with a tender and enlarged first MTP joint, loss of motion, and difficulty wearing shoes with an elevated heel. A hallmark sign is restricted toe extension (dorsiflexion), usually less than 60°, because of a ridge of osteophytes that can be palpated easily along the dorsal aspect of the metatarsal head.

Management

Conservative management includes ice, wearing low-heeled shoes with adequate width and depth to accommodate the increased bulk of the joint, nonsteroidal anti-inflammatory drugs (NSAIDs), and therapeutic mobilization. Individuals can add a Morton extension to their orthosis or use a rigid insole or shoe to reduce stress across the joint. Steroid injections may help if chronic inflammation is present. If conservative measures fail to resolve the symptoms within 6 months, surgery is indicated. Spurs may be removed through a cheilectomy, which can improve motion and reduce, but not eliminate, pain. An arthrodesis procedure may be suggested to fuse or resect the proximal portion of the proximal phalanx. Both techniques have a good or excellent outcome.[17]

Hallux Valgus

Etiology

Prolonged pressure against the medial aspect of the first MTP joint can lead to thickening of the medial capsule and bursa (i.e., bunion), resulting in a severe valgus deformity of the great toe (**Fig. 14.23**). The most common cause is wearing poorly fitted shoes with a narrow toe box, but it also can be caused by heredity, metatarsus primus varus, pes planus, rheumatoid arthritis, and neurological disorders.

Figure 14.23. Hallux valgus. Hallux valgus is an abnormality in which the great toe is deviated laterally and may overlap the second toe. An enlarged, painful, inflamed bursa (bunion) may form on the medial side.

Signs and Symptoms

Many individuals with the deformity are asymptomatic. Those with symptoms complain of pain over the MTP joint and have difficulty wearing shoes because of the medial prominence and associated overlapping toe deformity. The condition may also cause the 2nd metatarsal to bear more weight, leading to a callus under the second metatarsal head.

Management

Treatment varies depending on the degree of deformity and the severity of symptoms. Wide, soft shoes with a broad toe box and sufficient insole padding are critical for comfort. Orthoses that support the longitudinal arch and redistribute the pressure areas also may provide some relief. If conservative measures fail, surgery may correct the deformity, but this does not necessarily improve activity performance. Rehabilitation can take from 4 to 6 months.[17]

Claw, Hammer, and Mallet Toe

Etiology

Other lesser toe deformities may be congenital but more often develop because of improperly fitted shoes, neuromuscular disease, arthritis, or trauma. A **hammer toe** is extended at the MTP joint, flexed at the PIP joint, and hyperextended at the DIP joint (Fig. 14.24). **Claw toe** involves hyperextension of the MTP joint and flexion of the DIP and PIP joints. A **mallet toe** is in neutral position at the MTP and PIP joints but flexed at the DIP joint.

Figure 14.24. Toe deformities. A, Hammer toe. **B,** Claw toe. **C,** Mallet toe.

Signs and Symptoms

Each condition can lead to painful callus formation on the dorsum of the IP joints. Pressure against the shoe and under the metatarsal head, particularly the second toe, is caused by the retrograde pressure on the long toe.

Management

These conditions are difficult to treat conservatively. A metatarsal pad may help control symptoms, but surgery may be necessary to rectify tendon lengthening, capsulotomy, and/or ligament release. For more significant deformities, resection of the head of the proximal phalanx may be necessary to treat the condition.

Ingrown Toenail

Etiology

Although ingrown toenails are common, they are preventable with proper hygiene and nail care. Toenails should be long enough to extend beyond the underlying skin but short enough so as not to push into the toe box of the shoe. Toenails should be trimmed straight across to prevent the edges from growing under the skin on the side of the nail. In addition, properly fitted shoes and socks should be worn.

Signs and Symptoms

Improper cutting of the nail, improper shoe size, and constant sliding of the foot inside the shoe can traumatize the nail, causing its edge to grow into the lateral nail fold and surrounding skin. The nail margin reddens and becomes painful. If a fungal or bacterial infection is present, the condition is called **paronychia**.

Management

Two methods to treat this condition are discussed in Application Strategy 14.3.

APPLICATION STRATEGY 14.3

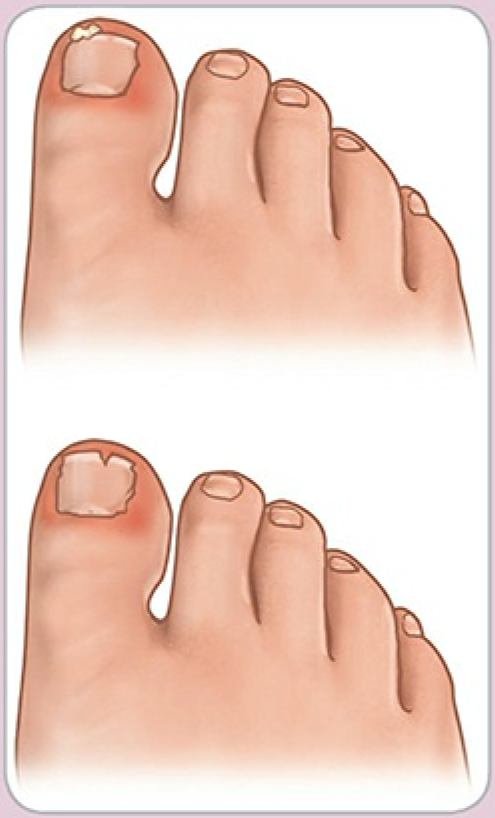
Management of an Ingrown Toenail

Method 1

- Soak the involved toe in hot water (108°–116°F) until the nail bed is soft (usually 10–15 minutes).
- Lift the edge of the nail and place a small piece of cotton or tissue under the nail to elevate the nail out of the skinfold.
- Apply antiseptic to the area and cover with a sterile dressing.
- Repeat the procedure daily, keeping the area clean and dry.
- *If a purulent infection is present, the individual should be referred to a physician for antibiotics and drainage of the infection.*

Method 2

- Soak the toe as in the preceding and cut a "V" in the center of the nail.
- As the nail grows, its edges pull toward the center, drawing the nail edges from under the skin.
- Apply an antiseptic, cover with a sterile dressing, and keep the area clean and dry.
- *If a purulent infection is present, the individual should be referred to a physician for antibiotics and drainage of the infection.*



Metatarsalgia

Etiology

General discomfort around the metatarsal heads is called **metatarsalgia**, or Morton metatarsalgia. Although often related to participation in sport and physical activity, other factors, such as age, arthritic disease, gout, and diabetes, can predispose an individual to metatarsal pain (Box 14.2).

BOX 14.2 Factors Leading to Metatarsalgia

Intrinsic Factors

- Excessive body weight
- Limited extensibility of the triceps surae complex
- Fallen metatarsal arch
- Valgus heel
- Hammer toes

- Pes planus or pes cavus

Extrinsic Factors

- Narrow toe box
- Improperly placed shoe cleats
- Improper technique (e.g., in a cyclist, poor foot position or rigid high gears at low cadence)
- Landing incorrectly from a height
- Repetitive jumping or excessive running
- Running style that puts undue pressure on the forefoot

Signs and Symptoms

Constant overloading of the transverse ligaments leads to flattening of the transverse arch, resulting in callus formation over the middle three metatarsal heads, particularly the second. The patient will complain of pain generalized in the metatarsal region and will have a gradual onset in intensity and duration.

Management

Treatment involves reducing the load on the metatarsal heads through activity modification, footwear examination, metatarsal pads or bars, and strengthening the intrinsic muscles of the foot.

Bunions

Etiology

Bunions generally are found on the medial aspect of the MTP joint of the great toe but also can occur on the lateral aspect of the fifth toe (i.e., a bunionette or tailor's bunion). Pronation of the foot, prolonged pronation during gait, contractures of the Achilles tendon, arthritis, and generalized ligamentous laxity between the first and second metatarsal heads can produce a thickening on the medial side of the first metatarsal head as it constantly rubs against the inside of the shoe.

Signs and Symptoms

As the condition worsens, the great toe may shift laterally and overlap the second toe, leading to a rigid, nonfunctional hallux valgus deformity (**Fig. 14.23**). This condition is exacerbated by high heels and pointed toe boxes in shoes, factors that account for a higher incidence of the condition in women compared to men.

Management

Once the deformity occurs, little can be done to correct the condition. Strapping the great toe as closely to proper anatomical position as possible and wearing wider shoes can provide some relief, but surgical correction is indicated in severe cases.

Retrocalcaneal Bursitis

Etiology

External pressure from a constrictive heel cup, coupled with excessive pronation or a varus hindfoot, can lead to swelling, erythema, and irritation of the retrocalcaneal bursa located between the Achilles tendon and calcaneus (**Fig. 14.25**). The posterior calcaneal bursa also can be irritated.

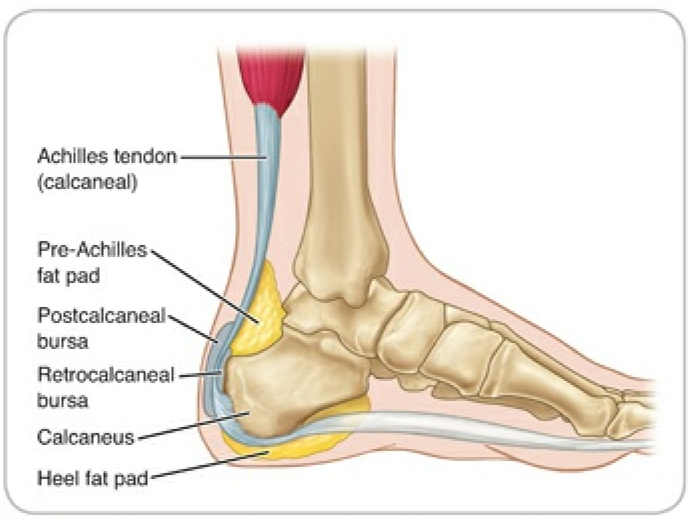


Figure 14.25. Retrocalcaneal bursa. The retrocalcaneal bursa commonly is inflamed when it is pinched between the Achilles tendon and calcaneus during plantar flexion.

Signs and Symptoms

Pain is elicited on palpation of the soft tissue just anterior to the Achilles tendon, and the skin may be thickened, especially on the lateral side. Active plantar flexion during push-off compresses the bursa between the tendon and bone, leading to increased pain.

Management

Standard acute care, NSAIDs, stretching exercises for the Achilles tendon, shoe modification, or a heel lift may provide some relief. Radiographs may show calcification in the bursa. If so, excision of the bursa may be indicated if conservative treatment fails. Injection with steroids is not recommended.[16]

Occasionally, an inflamed bursa can lead to a dramatic, large mass referred to as a "pump bump," which is common among female figure skaters and runners (i.e., runner's bump). The condition also may be called **os calcis exostosis**. This bump may be related to an underlying bony spur caused by frequent microtrauma or microavulsions surrounding the distal attachment of the Achilles tendon. An additional Achilles tendinopathy above the insertion may be present when the symptoms have been present for more than 3 months. Conservative treatment is similar to that of retrocalcaneal bursitis. Open (preferably with tendinopathy) or endoscopic excision is recommended. Steroid injections should not be used because of the risk of Achilles tendon rupture.[16]

The defensive back may have a turf toe. The injury could be the result of repeated hyperextension. The change in surface to a more rigid and less giving surface as well as use of inappropriate footwear could have contributed to this injury.

CONTUSIONS

A soccer player was kicked in the anterolateral aspect of the lower leg. The athlete continued to play the remaining 10 minutes of the game.

> Twenty minutes after the game ended, however, the athlete reported severe pain to the area. Inspection revealed a firm mass and tight skin over the injured site. What condition should be suspected, and what further assessment should be performed?

Contusions of the foot and leg result from direct trauma, such as dropping a weight on the foot or being stepped on, kicked, or hit by a speeding ball or implement. Many of these injuries are minor and easily treated with standard acute care. A few injuries, however, can result in complications, such as excessive hemorrhage, periosteal irritation, nerve damage, or damage to tendon sheaths, leading to tenosynovitis.

Foot Contusions

Etiology

Compression on the midfoot can be painful and may damage the extensor tendons or lead to a fracture of the metatarsals or phalanges. During weight bearing, contusions of the plantar aspect of the forefoot may result from a cleat or spike irritating the ball of the foot. A contusion to the hindfoot, called a **heel bruise**, can be more serious. Elastic adipose tissue lies between the thick skin and the plantar aspect of the calcaneus to cushion and protect the inferior portion of the calcaneus from trauma. It is constantly subjected to extreme stress in running, jumping, and changing directions. Excessive body weight, age, poorly cushioned or worn-out running shoes, increases in training, and hard, uneven training surfaces can predispose an individual to this condition.

Signs and Symptoms

Pain, swelling, and ecchymosis may be present at the site of the contusion. Walking barefoot is particularly painful. Underlying skeletal structures should be assessed for presence of crepitus, which may suggest a fracture.

Management

Application of cold to minimize pain and inflammation, followed by regular use of a heel cup or doughnut pad, can minimize the condition. Despite excellent care, the condition may persist for months. Repairing or replacing the object, along with ice therapy to reduce immediate hemorrhage and discomfort, usually is sufficient to remedy the situation.

Lower Leg Contusions

Etiology

A contusion to the tibia, commonly called a **shin bruise**, may occur in soccer, field hockey, baseball, softball, football, or activities in which the lower leg is subjected to high-impact forces. The shin is particularly void of natural subcutaneous fat and is vulnerable to direct blows that irritate the periosteal tissue around the tibia. Participants should always wear appropriate shin guards to protect this highly vulnerable area.

Signs and Symptoms

Contusions of the anterior shin can be extremely painful. Localized swelling may be evident and dorsiflexion will be painful. Contusions to the gastrocnemius result in immediate pain, weakness, and partial loss of motion. Hemorrhage and muscle spasm quickly lead to a tender, firm, easily palpable mass.

Management

Although painful, the condition can be managed effectively with ice, compression, elevation, and rest. A doughnut pad or additional shin protection can allow the individual to participate within pain tolerance levels. For a gastrocnemius contusion, it is important when applying ice to keep the muscle on stretch to decrease muscle spasm. If the condition does not improve in 2 to 3 days, ultrasound may be used, to assist in breaking up the hematoma.

Acute Compartment Syndrome

Etiology

An acute compartment syndrome occurs when increased pressure within a limited or nonyielding space compromises the local venous pressure and obstructs the neurovascular network. In the lower leg, it tends to be caused by a direct blow to the anterolateral aspect of the tibia or by a tibial fracture. The anterior compartment is particularly at risk, because it is bounded by the tibia medially, the interosseous membrane posteriorly, the fibula laterally, and a tough fascial sheath anteriorly. Although an acute compartment syndrome occurs less frequently than the more common chronic exertional compartment syndrome, the acute syndrome is considered to be a medical and surgical emergency because of the compromised neurovascular functions. Compartment syndrome should be considered if there is a recent history of trauma, excessive exercise, vascular injury, or prolonged, externally applied pressure.

Signs and Symptoms

Signs and symptoms include increasing severe pain and swelling that appear to be out of proportion to the clinical situation. A firm mass, tight skin (because it has been stretched to its limits), loss of sensation on the dorsal aspect between the great and second toes, and diminished pulse at the dorsalis pedis are delayed and dangerous signs. A normal pulse, however, does not rule out the syndrome. Acute compartment syndrome can produce functional abnormalities within 30 minutes of the onset of hemorrhage. Immediate action is necessary, because irreversible damage can occur within 12 to 24 hours.

Management

Immediate care involves ice and total rest. Compression is not recommended, because the compartment already is unduly compressed and additional external compression only hastens the deterioration. In addition, the limb must not be elevated, because this decreases arterial pressure and further compromises capillary filling. Referral to a physician for immediate care is absolutely necessary.

If numbness in the foot is present, intercompartmental pressure is measured using either a slit catheter or a solid-state intracompartmental catheter. If the pressure ranges between 30 and 40 mm Hg (normal range, 0 to 10 mm Hg), the individual is watched carefully, and repeated measurements are taken until symptoms subside. If the pressure ranges from 40 to 60 mm Hg, a surgical release of the fascia (i.e., fasciotomy) is required to prevent permanent tissue damage.

The soccer player may have an acute compartment syndrome. In the continued assessment of the athlete, the following should be examined: sensation between the first and second toes on the dorsum of the foot, circulation at the dorsalis pedis pulse, and active ROM, particularly the motions of dorsiflexion and eversion.

FOOT AND ANKLE SPRAINS

? A 30-year-old recreational basketball player has sustained a grade II lateral ankle sprain. What is the immediate management for this condition?

Sprains to the foot and ankle region are common in sports, particularly among those individuals who play on badly maintained fields. In many sports, cleated shoes become fixed to the ground while the limb continues to rotate around it. In addition, the very nature of changing directions places an inordinate amount of strain on the ankle region. Other methods of injury include stepping in a hole, stepping off a curb, stepping on an opponent’s foot, or rolling the foot off the surface.

Toe Sprains and Dislocations

Turf Toe

Etiology

A sprain of the plantar capsular ligament of the first MTP joint, called turf toe, results from forced hyperextension or hyperflexion of the great toe (i.e., jamming the toe into the end of the shoe). Hyperextension causes the sesamoid bones to be drawn forward to bear weight under the first metatarsal head.

Repetitive overload also can lead to injury, particularly when associated with a valgus stress. Because of forced hyperflexion of the MTP joint while kicking an instep ball strike, soccer players often irritate the dorsal capsular structures of the first MTP joint; the condition is then called reverse turf toe.

Signs and Symptoms

With regular turf toe, the individual has pain, tenderness, and swelling on the plantar aspect of the MTP joint of the great toe. Great toe extension is extremely painful. Because the sesamoid bones are located in the tendons of the flexor hallucis brevis, this condition sometimes is associated with tearing of the flexor tendons, fracture of the sesamoid bones, bone bruises, and osteochondral fractures in the metatarsal head. With reverse turf toe, symptoms are similar, except pain is noted dorsally over the joint and passive flexion of the toe is painful.

Management

Initial treatment for mild sprains involves standard acute care (i.e., ice, compression, elevation, and rest), NSAIDs, and protection from excessive motion. Taping to limit motion at the MTP joint, use of a metatarsal pad to lower stress on the 1st metatarsal, or use of a rigid shoe or forefoot plate may be helpful. In moderate-to-severe cases, the individual may need to be restricted from activity until symptoms disappear (i.e., usually 3 to 6 weeks).

Metatarsophalangeal and Interphalangeal Joint Injury

Etiology

Sprains and dislocations to the MTP and IP joints of the toes may occur by tripping or stubbing the toe. Varus and valgus forces more commonly affect the first and fifth toes rather than the middle three.

Signs and Symptoms

Pain, immediate swelling, dysfunction, and, if dislocated, gross deformity will be evident. Tenderness over the lateral aspects of the joint suggests damage to the collateral ligament, whereas tenderness on the volar or dorsal surfaces may be indicative of joint capsule, extensor hood mechanism, or volar plate damage.

Management

Depending on the location and severity of pain, adequate strapping, arch supports, and limited weight bearing are warranted during the acute stage. If the condition does not improve, the individual should be referred to a physician to rule out a possible avulsion fracture at the tarsal joints, but closed reduction and strapping to the next toe for 10 to 14 days usually are sufficient to remedy the problem. Reconditioning exercises should include ROM and strengthening for the intrinsic muscles of the foot.

Midfoot Sprains

Etiology

Midfoot sprains often result from severe dorsiflexion, plantar flexion, or pronation. Although the condition is seen in basketball and soccer players, it is more frequent among those who participate in activities where the foot is unsupported, such as in gymnastics or dance (in which slippers are typically worn) or in track athletes who wear running flats.

Signs and Symptoms

If the midfoot is sprained, pain and swelling will be deep on the medial aspect of the foot and weight bearing may be too painful.

Mechanisms of Injury for Ankle Sprains

Ankle sprains are the most common injury in recreational and competitive sports. They are classified as grade I (first degree), grade II (second degree), and grade III (third degree) based on the progression of the anatomical structures damaged and the subsequent disability (**Table 14.3**).[11] Ankle sprains generally are caused by severe medial (i.e., supination or inversion) and lateral (i.e., pronation or eversion) rotation motions. Excessive supination of the foot (i.e., adduction, inversion, and plantar flexion) results when the plantar aspect of the foot is turned inward, toward the midline of the body, which commonly is referred to as an inversion sprain. Excessive pronation (i.e., abduction, eversion, and dorsiflexion) results when the plantar aspect of the foot is turned laterally, which is referred to as an eversion sprain.

TABLE 14.3 Mechanisms of Common Ankle Sprains and Resulting Ligament Damage

MECHANISM	FIRST (MILD)	SECOND (MODERATE)	THIRD (SEVERE)
Inversion and plantar flexion	Anterior talofibular stretched	Partial tear of anterior talofibular, with calcaneofibular stretched	Rupture of anterior talofibular and calcaneofibular, with posterior talofibular and tibiofibular torn
Inversion	Calcaneofibular stretched	Calcaneofibular torn, and anterior talofibular stretched	Rupture of calcaneofibular, and anterior talofibular with posterior talofibular stretched
Dorsiflexion eversion	Tibiofibular stretched, deltoid stretched, or an avulsion fracture of medial malleolus	Partial tear of tibiofibular, partial tear of deltoid and tibiofibular	Rupture of tibiofibular, rupture of deltoid, and interosseous membrane with possible fibular fracture above syndesmosis

Inversion Ankle Sprains

Etiology

Acute inversion (i.e., lateral) sprains often occur while changing directions rapidly. Interestingly, injury typically involves the unloaded foot and ankle (or, more accurately, just at the moment of loading) with a plantar flexion and inversion force. In plantar flexion, the ATFL is taut and the CFL is relatively loose, whereas in dorsiflexion, the opposite is true. The medial and lateral malleoli project downward over the talus to form a mortise–tenon joint. The lateral malleolus projects farther downward than the medial, thus limiting lateral talar shifts. As stress is initially applied to the ankle during plantar flexion and inversion, the ATFL first stretches. If the strain continues, the ankle loses ligamentous stability in its neutral position. The medial malleolus acts as a fulcrum to further the inversion and stretches or ruptures the CFL (Fig. 14.26). The overlying inner wall of the peroneal tendon sheath lies adjacent to the CFL and can absorb some strain to prevent injury to this ligament. If the peroneal muscles are weak, however, they are unable to stabilize the joint, leading to tearing of the CFL. In severe injuries, the PTFL also is involved. As the ankle joint becomes unstable, the talus can pinch the deltoid ligament against the medial malleolus, which leads to injury on both sides of the ankle joint.

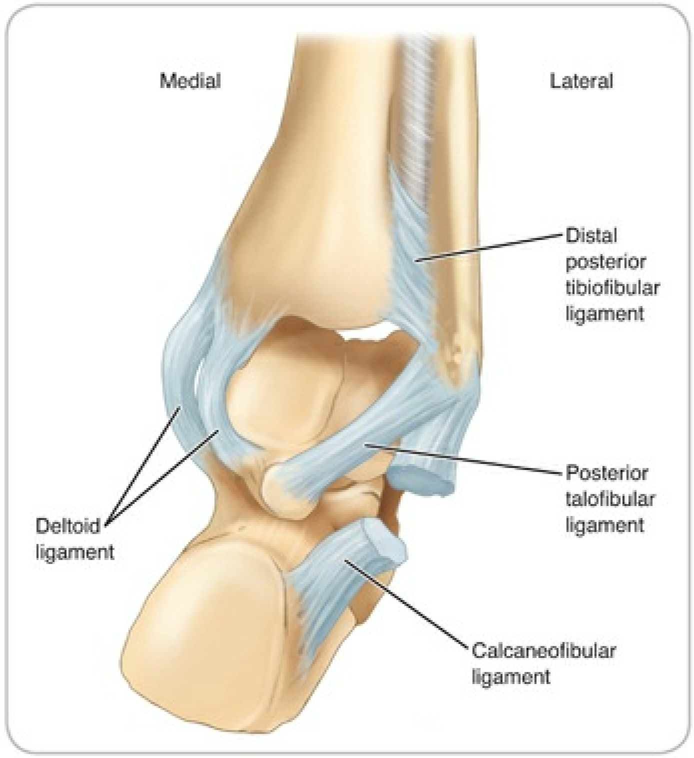


Figure 14.26. Inversion ankle sprain. During inversion, the medial malleolus acts as a fulcrum to further invert the talus, leading to stretching or tearing of the calcaneofibular ligament.

Signs and Symptoms

The individual usually describes experiencing a twisting, bending, or rolling action of the ankle. The individual may report hearing or feeling a cracking or tearing sound at the time of injury. In a grade I injury, the ligament has been stretched, resulting in slight or minimal tearing of fibers. An individual with a grade I ankle sprain may be able to bear weight immediately after injury and may even attempt to "walk it off" because the ankle feels stable. Initially, pain and swelling, if occurring at all, are mild. There is minimal point tenderness. In a grade II injury, the ligament has sustained greater damage with moderate tearing of the fibers. Swelling and tenderness are localized over the injured structure and may extend to surrounding tissue. Ecchymosis or bruising may occur, especially in the hours after the injury was sustained. The individual may be able to bear some weight and will definitely walk with an antalgic gait. The patient will be tender over the involved structures during palpation and the area may feel warm. A complete tear or rupture of a ligament is considered to be a grade III sprain. The ankle is unstable and swelling, and ecchymosis is rapid and diffuse. The individual demonstrates functional and clinical instability and will be unable to bear weight or walk with a normal gait. Table 14.4 summarizes the signs and symptoms of the various grades of sprains of ligaments on the lateral aspect of the ankle.

TABLE 14.4 Signs and Symptoms of a Lateral Ankle Sprain

DEGREE	SIGNS AND SYMPTOMS
First	Pain and swelling on anterolateral aspect of lateral malleolus Point tenderness over ATFL No laxity with stress tests
Second	Tearing or popping sensation felt on lateral aspect; pain and swelling on anterolateral and inferior aspect of lateral malleolus Painful palpation over ATFL and CFL; also may be tender over PTFL, deltoid ligament, and anterior capsule area Positive anterior drawer and talar tilt test
Third	Tearing or popping sensation felt on lateral aspect, with diffuse swelling over entire lateral aspect, with or without anterior swelling; can be very painful or absent pain Positive anterior drawer and talar tilt test

Immediate assessment should distinguish the severity of injury, because swelling may soon obscure the level of instability. The same mechanisms that result in ligamentous damage may also result in damage to other musculoskeletal structures such as muscles, bones, and cartilage and should be considered when assessing the acutely injured ankle. A more focused discussion of these additional injuries is discussed later within this chapter.

Management

Initial treatment should consist of standard acute care (i.e., cold, compression, elevation, and protected rest), nonsteroidal anti-inflammatory medication, and restricted activity. Crutches should be used if the individual is unable to bear weight. When treating grade I and II injuries, the use of functional exercise has been found to be more effective than prolonged immobilization.[11] Individuals with moderate-to-severe sprains should be referred immediately to a physician. Radiographs can determine damage to the syndesmosis or detect an osteochondral fracture to the dome of the talus. In individuals with a history of ankle sprains, the use of prophylactic taping or bracing in conjunction with a rehabilitation program that includes balance and coordination training for at least 6 weeks after injury can reduce the risk of recurrent sprains.[18] Mechanical stability may still be present for up to 1 year after injury.[19] The focus of rehabilitation should include strengthening the peroneals, stretching the heel cord, proprioceptive training, and establishing normal joint motion.[11] Application Strategy 14.4 summarizes the management of lateral ankle sprains.

APPLICATION STRATEGY 14.4

Management Algorithm for a Lateral Ankle Sprain

1. Use a compression wrap to secure crushed ice packs directly to the skin as quickly as possible following the injury; apply the ice for 30 minutes.
2. Do not place a towel or elastic wrap (dry or wet) between the crushed ice pack and skin (reduces effectiveness of treatment).
3. Elevate foot and ankle 6–10 in above the level of the heart.
4. After initial ice treatment,
   - Remove ice pack.
   - Replace compression wrap.
   - Continue elevation.
5. Apply a horseshoe pad and open basket weave with tape and/or elastic wrap to protect the area.
6. Instruct the individual to reapply a crushed ice pack regularly until going to bed:
   - Every 2 hours
   - Every hour if active between applications (crutch walking, showering)
7. If limping,
   - Fit with crutches.
   - Reassess in the morning.
   - Start rehabilitation.

If fracture is suspected, the individual should be referred to a physician.

Eversion Ankle Sprains

Etiology

Eversion (i.e., medial) ankle sprains involve injury to the medial, deltoid-shaped talocrural ligaments (i.e., deltoid ligament) and may result from forced dorsiflexion and eversion, such as landing from a long jump with the foot abducted or landing on another player's foot. Most injuries to the deltoid ligament are associated with a fibula fracture, syndesmotic injury, or severe lateral ankle sprain. Individuals with pronated or hypermobile feet tend to be at a greater risk for eversion injuries.

The talar dome is wider anteriorly than posteriorly. During dorsiflexion, the talus fits more firmly in the mortise supported by the distal anterior tibiofibular ligament. During excessive dorsiflexion and eversion, the talus is thrust laterally against the longer fibula, resulting in either a mild sprain to the deltoid ligament or, if the force is great enough, a lateral malleolar fracture. If the force continues after the fracture occurs, the deltoid ligament may be ruptured or may remain intact, avulsing a small bony fragment from the medial malleolus and leading to a bimalleolar fracture. In either case, the distal anterior tibiofibular ligament and interosseous membrane may be torn, producing total instability of the ankle joint and eventual degeneration (**Fig. 14.27**).

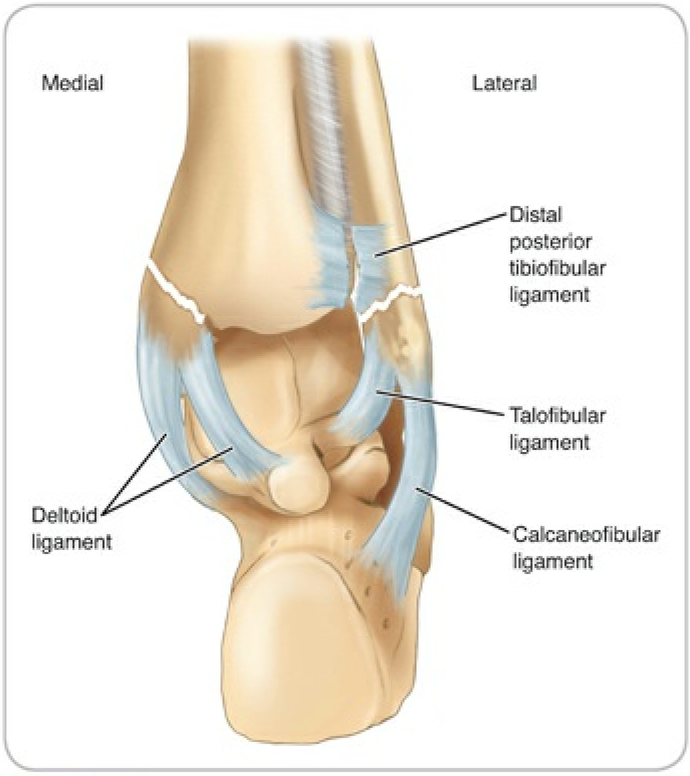


Figure 14.27. Eversion ankle sprain. During a severe eversion ankle sprain, the lateral malleolus can fracture, the deltoid ligament can avulse the medial malleolus, and the distal tibiofibular joint can be disrupted.

Signs and Symptoms

In mild to moderate injuries, the individual often is unable to recall the mechanism of injury. There may be some initial pain at the ankle when it was traumatized, but as the ankle returns to its normal anatomical position, pain often subsides and the individual continues to be active. In attempts to run or put pressure on the area, pain intensifies but the individual may not make the connection between the pain and the earlier injury. Swelling may not be as evident as a lateral sprain, because hemorrhage occurs deep in the leg and is not readily visible. Swelling may occur just posterior to the lateral malleolus, between it and the Achilles tendon. Point tenderness can be elicited over the deltoid ligament and distal anterior tibiofibular ligaments as well as the anterior and posterior joint lines. In severe injuries, passive motion may be pain-free in all motions except dorsiflexion. In a fracture of the malleoli, pain is evident over the fracture site and increases with any movement of the mortise. Percussion and heel strike produce increased pain.

Management

Initial management is the same as that of a lateral ankle sprain. Appropriate immobilization with a rigid posterior or vacuum splint is necessary. Referral to a physician is warranted. Surgical repair generally is indicated when a fracture or ligamentous disruption of the syndesmosis is involved.

Syndesmosis Sprain

Etiology

The most common mechanism involves an external rotation fracture mechanism. With this, the foot is planted fixed on the ground with internal rotation of the leg and body with respect to the foot, resulting in relative external rotation of the talus within the mortise and creating an external rotation force on the fibular with respect to the tibia.[20] As a result, the fibula separates from the tibia, disrupting the distal tibiofibular ligament, and potentially injuring the deltoid ligament. Injury to the distal tibiofibular syndesmosis (i.e., a “high” ankle sprain) often goes undetected, resulting in a longer recovery time and a greater disability than with the more frequent lateral ankle sprain.

Signs and Symptoms

The area of maximum point tenderness usually is over the anterolateral tibiofibular joint but may also be posteromedial at the level of the ankle joint. The degree of pain and swelling can be significant. The individual will have difficulty bearing weight and pushing off the ground on the injured ankle. The most commonly injured ligament (and a source of anterolateral ankle impingement) is the anterior inferior tibiofibular ligament, and the least injured ligament is the posterior inferior tibiofibular ligament, although the interosseous ligament may also be variably injured.[21] Assessment rests on six specific tests:

1. Syndesmosis ligament palpation

2. Passive dorsiflexion test
3. Anterior and posterior translation of the fibula (fibula translation test)
4. Medial and lateral translation of the talus (Cotton test)
5. Stabilizing the lower leg with one hand while applying an external rotation force to the ankle (external rotation test)
6. Compressing the proximal tibia and fibula while asking about pain at the ankle ("squeeze test")

Management

Treatment for syndesmotic sprains is more conservative than treatment provided for a lateral ankle sprain. In the acute stage, the patient should be non–weight-bearing and be fitted for an ankle boot in order to immobilize the joint to allow for healing and repair of tissues.[11] Referral to a physician is warranted for radiographic confirmation to assess for fractures, bony avulsions (10% to 50% occur off the tibia), and the mortise alignment of the tibia, talus, and fibula. A grade I high ankle sprain is treated with immobilization in a long, semirigid pneumatic stirrup brace that extends to just below the knee for up to 3 weeks. The individual may return to physical activity with protective taping and a heel lift.[21] A grade II injury involves 3 to 6 weeks of non–weight bearing, including stabilization with a fracture brace for 3 to 4 weeks, followed by a pneumatic stirrup brace for an additional 3 weeks. Application of cold should continue until swelling is reduced. Initially, weight bearing should be permitted with crutches, and weaning off of the crutches is done as tolerated. Participation in sports and physical activity may be delayed for up to 3 months after the initial treatment begins. If the injury involves no fracture but widening of the joint mortise is seen on stress radiographs, surgery is recommended.[22]

Subtalar Sprain

Etiology

The ligaments associated with the lateral subtalar joint are the CFL (spanning both the ankle and subtalar joints), the inferior extensor retinaculum, the lateral talocalcaneal ligament, the cervical ligament (just anterior to the tibiocalcaneal), and the interosseous ligament. The most common mechanism is believed to be dorsiflexion and supination. This position places the CFL in a position of maximal tightness. Further supination can lead to rupture of the CFL, followed by tearing of the cervical ligament and the interosseous tibiocalcaneal ligament.[22]

Signs and Symptoms

The individual often complains of a sensation of the ankle "turning inward" or "turning over." Individuals with this problem consistently watch the ground when they walk and are uncomfortable when running on uneven surfaces. Assessment of chronic subtalar instability varies only slightly from that of ankle instability; the conditions may coexist. The anterior drawer test should be negative in isolated subtalar instability but positive with ankle instability. A subtle finding with subtalar instability, however, is increased rotation of the calcaneus under the talus on the anterior drawer test. A definitive diagnosis can be established only with stress radiographs.

Management

Conservative treatment includes standard acute care, strengthening of the peroneals, stretching the heel cord, proprioceptive training, and use of a brace if needed. Functional exercises should be incorporated earlier into the rehabilitation process for grade I and II ankle sprains.[11] High-grade subtalar sprains (as determined by examination and imaging studies) are treated with 2 weeks of non–weight bearing in a below-knee cast, followed by 4 weeks in a commercial walker boot.[22] Chronic instability may necessitate surgical repair.

Subtalar Dislocation

Etiology

Another serious sprain that involves the subtalar joint results from a fall from a height (as in basketball or volleyball). The foot lands in inversion, disrupting the interosseous talocalcaneal and talonavicular ligaments. If the foot lands in dorsiflexion and inversion, the CFL also is ruptured. When the dislocation occurs, the injury is better known as "basketball foot."

The clinician should activate the emergency action plan, including summoning emergency medical services (EMS). While waiting for EMS to arrive, the clinician should monitor the patient for shock and treat as necessary. Neurovascular function should be monitored as well.

Signs and Symptoms

Extreme pain and total loss of function are present. Gross deformity at the subtalar joint may not be clearly visible. The foot may appear to be pale and feel cold to the touch if neurovascular damage is present. The individual may show signs of shock.

Management

Because of the potential for peroneal tendon entrapment and neurovascular damage, leading to reduced blood supply to the foot, this dislocation is considered to be a medical emergency.

The immediate management of the grade II ankle sprain sustained by the 30-year-old recreational basketball player should include standard acute care (i.e., ice, compression, elevation, and protected rest). Application of a horseshoe pad or open basket weave strapping and an elastic wrap can be used for compression. The patient should be fitted with crutches and referred to a physician.

TENDINOPATHIES OF THE FOOT AND LOWER LEG

? A 55-year-old woman preparing to compete in a recreational badminton tournament reports to a sports medicine clinic complaining of pain and swelling behind the medial malleolus and of pain in the arch when arising in the morning. Observation reveals pes planus. During resisted muscle testing, plantar flexion and inversion are weak. What muscle is involved in this injury, and how should this condition be managed?

Tendinopathies of the foot and lower leg are relatively common and encompass a wide spectrum of conditions ranging from tendinitis to tenosynovitis to partial and complete ruptures. The tendons most often involved in the foot and ankle include the Achilles, posterior tibialis, peroneal brevis, and peroneal longus tendons. In contrast to acute traumatic tendinous injury, these injuries most often involve repetitive submaximal loading of the tissues, resulting in repetitive microtraumas.

Strains and Tendinitis

Etiology

Muscle strains seldom occur in the lower extremity, except in the gastrocnemius–soleus complex. Instead, injury occurs to the musculotendinous junction or to the tendon itself. Most of the tendons in the lower leg have a synovial sheath surrounding the tendon; the Achilles tendon, which has a peritendon sheath that is not synovial, is an exception. Several factors can predispose an individual to tendinitis (**Box 14.3**). Common sites for tendon injuries include the following:

BOX 14.3 Predisposing Factors for Tendinitis in the Lower Leg

- Training errors that include the following:
  - Lack of flexibility in the gastrocnemius–soleus muscles
  - Poor training surface or sudden change from soft to hard surface, or vice versa
  - Sudden changes in training intensity or program (e.g., adding hills, sprints, or distance)
  - Inadequate work-to-rest ratio that may lead to early muscle fatigue

- Returning to participation too quickly following injury
- Direct trauma
- Infection from a penetrating wound into the tendon
- Abnormal foot mechanics producing friction among the shoe, tendon, and bony structure
- Poor footwear that is not properly fitted to foot

- The Achilles tendon just proximal to its insertion into the calcaneus
- The tibialis posterior just behind the medial malleolus
- The tibialis anterior on the dorsum of the foot just under the extensor retinaculum
- The peroneal tendons just behind the lateral malleolus and at the distal attachment on the base of the 5th metatarsal

Signs and Symptoms

Common signs and symptoms include a history of stiffness following a period of inactivity (e.g., morning stiffness), localized tenderness over the tendon, possible swelling or thickness in the tendon and peritendon tissues, pain with passive stretching, and pain with active and resisted motion.

Management

In the majority of cases, treatment of muscle strains, tendinitis, or peritendinitis is conservative. If mechanical problems are present, they should be addressed first so that recovery can occur. Early exercises should be within the levels of pain tolerance and should not be too strenuous. Ice massage, active ROM exercises with elastic tubing for resistance, stretching of the Achilles tendon, and eccentric calf exercises are recommended during the early phase of rehabilitation.

Foot Strains

Etiology

Foot strains, caused by a direct blow or chronic overuse, often affect the intrinsic and extrinsic muscles of the foot. The tibialis anterior and the toe extensor tendons may be injured as a result of having the feet repeatedly stepped on or by having the shoelaces tied too tightly.

Signs and Symptoms

Pain, localized edema, inflammation, and adhesions may be present. During assessment, the involved tendons have pain on passive stretching and with active and resisted motion. Palpation over the tendon during active motion may reveal a sound similar to that heard when crunching a snowball together; hence, the sound is called "snowball" crepitation.

Management

Treatment involves standard acute care, NSAIDs, and strapping to limit active motion of the tendon. ROM and strengthening exercises should be started after acute pain has subsided.

Peroneal Tendinopathies

Etiology

Peroneal tendon injuries are less common than injury to the Achilles and posterior tibial tendons. Mechanisms of injury may include forceful passive dorsiflexion, as occurs when a skier catches the tip of the ski and falls forward; exploding off a slightly pronated foot, as when a football player is in a three-point stance and makes a forward surge; or being kicked from behind in the vicinity of the lateral malleolus. Tendinitis of the peroneus longus causes pain as the tendon passes beneath the cuboid toward its insertion on the plantar aspect of the metatarsal. Another problem that may exist involves the retinaculum that holds the tendons in place on the posterior aspect of the lateral malleolus. If this retinaculum gives way, the tendons slip forward over the lateral malleolus but usually return spontaneously. This condition can be overlooked or confused with an ankle sprain because it gives a feeling of instability and pain over the lateral malleolus. Partial tears of both the peroneus longus and brevis tendons have been linked to persistent lateral ankle pain and chronic lateral ankle instability.[23]

Signs and Symptoms

During an acute injury in which the reticulum ruptures, a cracking sensation, followed by intense pain and an inability to walk, is reported. Swelling and tenderness is localized over the posterosuperior aspect of the lateral malleolus rather than the anteroinferior aspect, as in an inversion ankle sprain. A hallmark symptom is extreme discomfort or apprehension during attempted eversion of the foot against resistance. If done immediately after injury, the dislocated tendons may be palpated during resisted dorsiflexion and eversion; however, swelling may soon obscure the dislocation. In a chronic injury, the individual complains primarily of instability; a “giving way”; or a slippage around the ankle, with little discomfort.

Management

Treatment is symptomatic with standard acute care. Acute injuries may respond to cast immobilization. External padding and strapping may help to stabilize the tendons, but because of the high rate of recurrence in the active population, surgery often is required.

Posterior Tibialis Tendon Dysfunction

Etiology

Posterior tibialis tendon dysfunction (PTTD) reflects the loss of support from the spring, deltoid, and talocalcaneal interosseous ligaments as well as from the talonavicular capsule and the plantar fascia.[24] PTTD is a common cause of painful acquired flatfoot deformity and is associated with substantial functional problems leading to significant morbidity. Individuals with a planovalgus foot, or flatfoot with pronation and loss of arch, are predisposed to this common injury. These individuals frequently have a loss of hindfoot inversion and difficulty in negotiating uneven ground and in climbing and descending stairs. Unfortunately, the problem frequently is missed, because progressive pronation is insidious and relatively painless. Overuse occasionally superimposes an acute injury by producing longitudinal tears or tethering, leading to dysfunction.

Signs and Symptoms

Three levels of dysfunction have been identified in the posterior tibialis muscle. In stage I, the individual has pain and swelling along the course of the tendon. Pain, tenderness, and swelling also may be present behind the medial malleolus, and there may be an accompanying aching discomfort in the medial longitudinal arch. Because the length of the tendon is normal, a single heel raise can be performed. The flatfoot deformity is minimal, alignment of the hindfoot and forefoot is normal, and the subtalar joint remains flexible.

In stage II, the individual is unable to perform a single heel raise because of attenuation or disruption of the posterior tibial tendon. Weakness is evident in plantar flexion and inversion. The tendon is enlarged, elongated, and functionally incompetent. The foot adopts a pes planovalgus position (flatfoot) with collapse of the medial longitudinal arch, hindfoot valgus and subtalar eversion, and forefoot abduction through the talonavicular joint. The subtalar joint remains flexible, and with the ankle in plantar flexion, the talonavicular joint can be reduced.

Stage III presents with the individual being unable to perform a single heel raise and a more severe flatfoot deformity. The pes planovalgus deformity is fixed, and the laterally subluxed navicular cannot be reduced. If the tendon is ruptured, a painful pop is felt, resulting in an immediate flatfoot deformity (acquired pes planus).

Management

Early treatment of PTTD depends on the severity of injury and may include standard acute care, NSAIDs, restricted activity, and a corrective orthosis, such as the University of California Biomechanics Laboratory brace, molded ankle–foot orthosis, or articulated molded ankle–foot orthosis.[24] The goal of early treatment is to control the progressive valgus of the calcaneus. Modalities (e.g., phonophoresis and iontophoresis, icing, and heat), eccentric strengthening, and hands-on physical therapy also are necessary early in the rehabilitation process. If nonoperative or conservative treatment fails, surgery is indicated, because the progression of dysfunction may be rapid and disabling. In the early stages of dysfunction, soft-tissue surgical procedures, such as tendon debridement or tenosynovectomy, may halt the progression of deterioration. Surgical release with tenolysis and/or augmentation by another tendon may be necessary early on to prevent irreversible bony/joint changes. Surgical procedures involving osteotomies and arthrodesis are necessary once a flatfoot deformity develops.[24]

Gastrocnemius Muscle Strain

Etiology

Strains to the medial head of the gastrocnemius often are seen in tennis players older than 40 years, hence, the nickname "tennis leg." Common mechanisms are forced dorsiflexion while the knee is extended, forced knee extension while the foot is dorsiflexed, and muscular fatigue with fluid-electrolyte depletion and muscle cramping.

If related to muscle cramping, the strain commonly is attributed to dehydration (particularly in the heat), electrolyte imbalance, or prolonged muscle fatigue that stimulates cramping followed by an actual tear in the muscle fibers. Acute spasms may awaken an individual in the night following a day of strenuous exercise. Acute cramps are best treated with ice, pressure, and slow stretch of the muscle as it begins to relax. Prevention of this condition involves adequate water intake during strenuous activity and a regular stretching program for the gastrocnemius–soleus complex. When participation extends over 2 hours in hot weather, increased water intake with a weak electrolyte solution should be ensured during and after strenuous activity.

Signs and Symptoms

In an acute strain, the individual experiences a sudden, painful, tearing sensation in the calf muscles, primarily at the musculotendinous junction between the muscles and Achilles tendon or in the medial head of the gastrocnemius muscle (Fig. 14.28). Immediate pain, swelling, loss of function, and stiffness are common. Later, ecchymosis progresses down the leg into the foot and ankle.

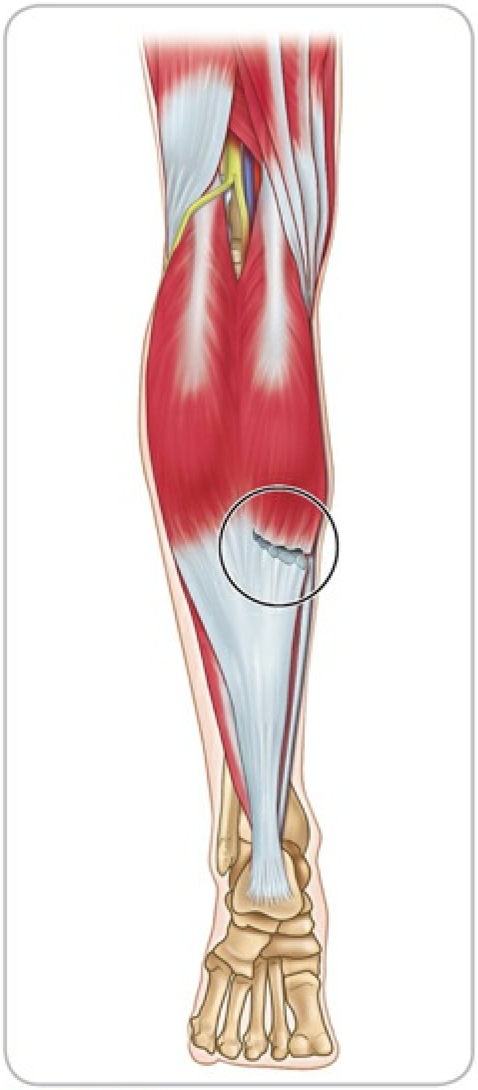


Figure 14.28. Gastrocnemius muscle strain. The medial head of the gastrocnemius muscle commonly is strained in individuals older than 40 years. A defect often can be palpated at the musculotendinous junction.

Management

Acute management consists of standard acute care to control inflammation, restricted activity, gentle stretching of the gastrocnemius, heel lifts, and a progressive strengthening program. In more severe cases, immobilization and non–weight bearing may be necessary to allow the muscle to heal fully.

Achilles Tendon Disorders

Etiology

Achilles tendon disorders occur most often in athletes and, of those, most often in individuals who are involved in running sports. Inappropriately generalized as "Achilles tendinitis," posterior heel pain resulting from an overuse injury of the foot and ankle actually encompasses a myriad of distinct and often coexisting pathological disorders with both inflammatory and degenerative etiologies. Common intrinsic risk factors that can predispose an individual to disorders of the Achilles tendon include several foot malalignment and biomechanical faults, such as hyperpronation of the foot; limited mobility of the subtalar joint and limited ROM of the ankle joint; leg length discrepancy; varus deformity of the forefoot and increased hindfoot inversion; decreased ankle dorsiflexion with the knee in extension; poor vascularity; genetic makeup; and gender, age, endocrine, or metabolic factors. Extrinsic factors that may lead to the disorder include changes in shoes or running surface; a sudden increase in workload (e.g., distance or intensity) or change in exercise environment (e.g., training on hard, slippery, or slanting surfaces); poor technique; and monotonous, asymmetric, and specialized training.[25]

When intrinsic and extrinsic factors are involved, microtraumatic changes occur in the Achilles tendon from different force contributions of the gastrocnemius and soleus, producing abnormal loading concentrations within the tendon and frictional forces between the fibrils leading to localized fiber damage. The tendon is relatively avascular at approximately 0.8 in (2 cm) above its distal insertion into the calcaneus, which is the site of the most torque on the tendon. This area is highly vulnerable to partial tears, with secondary nodule formation and degenerative cysts seen in **tendinosis**.

Signs and Symptoms

Acute signs and symptoms include an aching or burning pain in the posterior heel, which increases with passive dorsiflexion and resisted plantar flexion, such as going up onto the toes. Point tenderness and crepitus can be elicited at the bony insertion or 1 to 3 cm above the insertion. There also can be associated retrocalcaneal bursitis. Palpation may reveal local nodules either within the tendon, which moves during dorsiflexion and plantar flexion, or in the peritendon, which does not move during these motions.

Chronic signs and symptoms include pain that is worse after exercise within days of a change in activity levels or training techniques. The tendon often becomes thickened, and pain is localized on the posterolateral heel. The gastrocnemius–soleus complex is tight, which may result from tendon adhesions, muscle spasm, or inflexibility. Radiographs usually show a prominent posterosuperior calcaneus (Haglund deformity), and calcific spurring often occurs at the bone–tendon interface. Pathologically, the tendon demonstrates chronic degeneration rather than inflammation. Rest may relieve symptoms, but return to activity reactivates the pain, generally within a few training sessions.

A tendinopathy poses the risk of complete rupture of the tendon. Magnetic resonance imaging often is needed for accurate diagnosis.

Management

The goal of treatment is to minimize pain, prevent further degeneration, and allow the individual to return to baseline activity. Initial conservative treatment involves standard acute care, activity modification, and correcting factors that cause load imbalance and repetitive strain on the tendon and surrounding structures. Complete restriction of activity may be necessary for 3 weeks. Active stretching of the Achilles tendon before and after activity, along with a full strengthening program for the gastrocnemius–soleus complex, including eccentric loading, is initiated immediately after acute pain has subsided. Use of oral NSAIDs or steroidal pain relievers to control inflammation remains controversial. Recently, some success has been seen in ultrasound-guided injections of polidocanol, a sclerosing agent, to decrease the neovascularization and symptoms of chronic midportion Achilles tendinosis.[26]

Operative treatment is recommended for individuals who do not respond to a 3- to 6-month trial of appropriate conservative treatment. Surgery usually involves excision of fibrotic adhesions and degenerated nodules or decompression of the tendon by longitudinal tenotomies.[27]

Achilles Tendon Rupture

Etiology

Acute rupture of the Achilles tendon probably is the most severe acute muscular problem in the lower leg. It more commonly is seen in individuals from 30 to 50 years of age.[28] The usual mechanism is a push-off of the forefoot while the knee is extending, which is a common move in many propulsive activities. Tendinous ruptures usually occur 1 to 2 in proximal to the distal attachment of the tendon on the calcaneus.

Signs and Symptoms

The individual hears and feels a characteristic "pop" in the posterior ankle and reports a feeling of being shot or kicked in the heel. Clinical signs and symptoms include a visible defect in the tendon, inability to stand on tiptoes or even balance on the affected leg, swelling and bruising around the malleoli, excessive passive dorsiflexion, and a positive Thompson test (**Fig. 14.18**). Because the peroneal longus, peroneal brevis, and muscles in the deep posterior compartment are still intact, the individual may limp or walk with the foot and leg externally rotated, because this does not require push-off with the superficial calf muscles.

Management

A compression wrap should be applied from the toes to the knee. The leg and foot can be immobilized in a posterior splint. The individual should be referred immediately to a physician. Nonoperative treatment offers excellent functional results for partial tears in older, noncompetitive individuals. With delayed diagnosis or in highly competitive individuals, surgical repair provides better push-off strength and prevents over elongation of the tendon and, in doing so, lowers the risk for reinjury. The course of action depends on the supervising physician, but in either case, full ROM and strength may not be achieved until 6 months after the injury.

> The 55-year-old badminton player has tenosynovitis of the tibialis posterior. Pes planus, along with weakness in plantar flexion and inversion, provide evidence of the muscle involved. Management of the condition includes standard acute care. In addition, the patient should be advised to wear shoes with better arch support. If the condition does not improve, the patient should be referred to a physician.

OVERUSE CONDITIONS

> ? A slightly overweight, novice runner is in the third week of training for a 10K run. He reports the following symptoms: excruciating pain in the anteromedial hindfoot on arising in the morning, which disappears within 5 to 10 minutes; point tenderness just distal to the medial calcaneal tubercle; and pain that increases with weight bearing. What condition may be present, and how should this injury be managed?

Repetitive microscopic injury to tendinous structures can lead to chronic inflammation that overwhelms the tissue's ability to repair itself. Other factors, such as faulty biomechanics, poor cushioning or stiff-soled shoes, or excessive downhill running, also can inflame the tendons. Several overuse conditions are common in specific sports, such as plantar fasciitis in running; medial tibial stress syndrome in football, dance, or running; and exertional compartment syndrome in soccer or distance running. Many individuals complain of vague leg pain but have no history of a specific injury that caused the pain, differentiating these conditions from an acute muscle strain. A common complaint is pain caused by activity.

Plantar Fasciitis

Etiology

Plantar fasciitis is the most common hindfoot problem in runners and affects approximately 10% of the population during the course of a lifetime.[29] Extrinsic factors that increase the incidence of the condition include training errors, improper footwear, and participating on unyielding surfaces. Intrinsic factors include pes cavus or pes planus, decreased planar flexion strength, reduced flexibility of the plantar flexor muscles (e.g., Achilles tendon), excessive or prolonged pronation, and torsional malalignment. These factors can overload the plantar fascia's origin on the anteromedial aspect of the calcaneus during weight-bearing activities. In a chronic condition, entrapment of the first branch of the lateral plantar nerve can contribute to the pain syndrome. Entrapment of the posterior tibial or medial calcaneal nerve (i.e., tarsal tunnel syndrome) may mimic or complicate the condition.

Signs and Symptoms

The individual reports pain on the plantar, medial heel that is relieved with activity but that recurs after rest. Pain increases with weight bearing and may radiate up the medial side of the heel and, occasionally, across the lateral side of the foot. It is particularly severe with the first few steps in the morning, particularly in the proximal, plantar, medial heel, but diminishes within 5 to 10 minutes. Pain and stiffness are related to muscle spasm and splinting of the fascia secondary to inflammation. Point tenderness is elicited over or just distal to the medial tubercle of the calcaneus and increases with passive great toe extension and dorsiflexion of the ankle. If the lateral plantar nerve is involved, tenderness also is noted at the proximal, superior abductor hallucis muscle. A tight heel cord with decreased dorsiflexion of the ankle is seen in approximately 70% of patients who have unilateral symptoms.[30]

Management

Treatment involves standard acute care. Following completion of the inflammatory stage, therapeutic modalities used to alleviate symptoms may include ice, deep friction massage, ultrasound, and electrical muscle stimulation. Achilles tendon stretching exercises, stretching of the toe flexor tendons, strengthening of the peroneal and posterior tibial muscles, NSAIDs, and a soft heel lift may be helpful. A moleskin plantar fascia strap or figure eight arch strapping is an effective means of support. Circular strips of tape around the foot are contraindicated, however, because they may overstretch the fascia and prolong recovery. Use of a viscoelastic heel cushion and/or orthoses along with a corticosteroid injection may be needed. Night splinting to hold the heel cord under mild tension may be used as well. Surgery or noninvasive ultrasonic treatment should be considered after 6 to 12 months.[16] Application Strategy 14.5 highlights the management of plantar fasciitis.

APPLICATION STRATEGY 14.5

Management of Plantar Fasciitis

- Use immediate ice therapy and NSAIDs.
- Use a shock-absorbing soft heel pad or soft plantar arch pad.
- Figure eight arch strapping or night splints may relieve acute symptoms.
- Use aggressive Achilles tendon stretching for 2–4 minutes, three to four times a day, with the toes straight ahead, the toes in, and the toes out.
- Use gentle isometric contractions initially for intrinsic muscles of the foot.
- Progress to active ROM exercise within pain-free ranges: toe curls, marble pick-up, towel crunches, and towel curls.
- Strengthen the intrinsic and extrinsic leg muscles.
- Maintain body fitness and strength, as well as aerobic fitness, with non–weight-bearing activities.
- The physician may administer cortisone injections into the plantar fascia aponeurosis.

Medial Tibial Stress Syndrome

Etiology

Medial tibial stress syndrome (MTSS) is a **periostitis** along the posteromedial tibial border, usually in the distal third that is not associated with a stress fracture or compartment syndrome. MTSS is one of the most common causes of exercise-induced leg pain.[2] Although originally thought to be related to stress along the posterior tibialis muscle and tendon causing myositis, fasciitis, and periostitis, it is now believed to be related to periostitis of the soleus insertion along the posteromedial tibial border or the flexor digitorum longus. The soleus makes up the medial third of the heel cord as it inserts into the calcaneus. Excessive or prolonged pronation of the foot causes an eccentric contraction of the soleus, resulting in the periostitis that produces the pain. Other contributing factors include recent changes in running distance, speed, form, stretching, footwear, and running surface and being female.[31]

Signs and Symptoms

Typically seen in runners or jumpers, the pain can occur at any point in the workout and typically is characterized as a dull ache, although it occasionally can be sharp and penetrating. As activity continues, pain diminishes only to recur hours after activity has ceased. During later stages, pain is present before, during, and after activity and may restrict performance. Point tenderness is elicited in a 3- to 6-cm area along the distal posteromedial tibial border. Pain is aggravated by resisted plantar flexion or by standing on tiptoe. An associated varus alignment of the lower extremity, including a greater Achilles tendon angle, often is present. In experienced runners, the condition usually is secondary to mechanical abnormalities, such as the following:

- Increased Achilles tendon angle (during stance phase and while running)
- Greater Achilles tendon angle between heel strike and maximal pronation
- Greater passive subtalar motion in inversion and eversion

Management

To relieve acute symptoms, 5 to 7 days of rest are essential. Other modalities (e.g., cryotherapy, NSAIDs, cortisone injections, heel pads, casting, crutches, and activity modification) have not been shown to be as effective as rest alone.

Pain-free stretching of both the anterior and posterior musculature helps to improve joint mobility, increase muscle and tendon strength as well as coordination, and aid the musculoskeletal system in adapting to the physical demands of a specific sport. If the condition does not improve, possible stress fractures to the tibia should be ruled out through appropriate radiograph or scanning procedures. Analysis of the individual's running motion, foot alignment, running surface, and footwear may prevent recurrence. Application Strategy 14.6 summarizes the management of MTSS.

APPLICATION STRATEGY 14.6

Management of Medial Tibial Stress Syndrome

- Five to 7 days of rest is essential.
- Ice, compression, elevation, and NSAIDs may help to relieve acute symptoms.
- Determine if a stress fracture is present.
- Evaluate and correct any foot malalignment or problems in technique.
- Change the running surface and, possibly, shoes.
- Increase muscle flexibility in the anterior and posterior compartments.
- Increase strength in all muscles of the lower leg and foot.

Exertional Compartment Syndrome

Etiology

Exertional compartment syndrome (ECS) is characterized by exercise-induced pain and swelling that is relieved by rest. The two most frequently affected compartments are the anterior and deep posterior, but the lateral, superficial posterior, and "fifth" compartment around the tibialis posterior muscle may also be affected. Whereas acute ECS generally occurs in relatively sedentary people who undertake strenuous exercise, chronic ECS usually is seen in well-conditioned individuals younger than 40 years.

Signs and Symptoms

Chronic ECS is often described as a tight, cramp-like, or squeezing ache and sense of fullness, both of which are felt over the involved compartment. The condition often affects both legs. Symptoms are relieved with rest, usually within 20 minutes of exercise, only to recur if exercise is resumed. Activity-related pain begins at a predictable time after starting exercise or after reaching a certain level of intensity, and the pain increases if the training persists. Many individuals with anterior compartment involvement describe mild foot drop or paresthesia (or both) on the dorsum of the foot and demonstrate fascial defects or hernias, usually in the distal third of the leg over the intramuscular septum.

Evaluation should be performed after the individual has exercised strenuously enough to reproduce the symptoms. The exercise produces swelling and tenderness in the involved compartments and increased leg girth. Tenderness, if present, may be located in the middle third of the tibia, although many individuals have no focal pain. Vibration with a tuning fork produces no pain, as one typically sees in a stress fracture. Likewise, pain is not present in the distal leg, which corresponds with MTSS. To confirm the diagnosis, intracompartmental pressure must be measured (see "Acute Compartment Syndrome" section).

Management

Treatment involves assessing extrinsic factors (e.g., training patterns, technique, shoe design, and training surface) and intrinsic factors (e.g., foot alignment, especially hindfoot pronation, muscle imbalance, and flexibility). In minor conditions, ice massage, NSAIDs, and occasionally, diuretics may assist, along with stretching and strengthening of the involved compartment muscles, orthotics, and relative rest. If symptoms persist for 6 to 12 weeks of conservative care, or in cases with extreme pressure elevation, fasciotomy is recommended; unlike a fasciotomy for acute ECS, this may be limited to complete release of the involved compartments.

The runner may have plantar fasciitis. As part of the assessment, it is important to check foot alignment, gait, and shoes for problems that may have contributed to the condition. Stretching of the toe flexors and Achilles tendon should be a major part of the treatment plan.

VASCULAR AND NEURAL DISORDERS

A figure skater is complaining of bilateral numbness in the posterolateral aspect of the leg along the Achilles tendon that has been present for the past 2 to 3 weeks. No history of trauma to the ankle is noted. The skater reveals that she routinely spirals her laces tightly around the proximal portion of each boot and then applies several circular bands of white tape to hold them in place. Could this technique impair the vascular or neural function of the lower leg, and how should this situation be managed?

Vascular and neural disorders of the lower leg are rare in sports but can occur. Vascular disorders typically involve occlusion of venous blood in the calf region; neural involvement typically affects the distal ankle and foot region. In either case, any change in circulation, sensation, or function should signal referral to a physician.

Venous Disorders

Etiology

By way of contraction of smooth and skeletal muscles, blood within the superficial venous system, as well as the deep venous system, is pushed, or "milked," back to the heart and lungs for elimination or metabolism. In some cases, particularly with inactivity following fracture or surgery, prolonged bed rest, and increasing age, this system becomes inefficient, leading to a reduced blood flow. The accumulated blood products may form a clot that can grow in size, depending on the vessel in which it is contained, causing partial or complete blockage. When symptoms are present for 14 days or fewer or when imaging studies confirm the condition, it is called acute DVT.[32] The deep calf veins are most frequently involved, but involvement of the popliteal, superficial femoral, and iliofemoral vein segments also is common. An **embolism** occurs when a loosened thrombus circulates from a larger vessel to a smaller one, subsequently obstructing circulation. When the obstruction occurs in the veins of the lungs, it is called a pulmonary embolism. Because the risk factors for DVT include a sedentary lifestyle, smoking, obesity, and prolonged periods of inactivity, DVT rarely is seen in an active population.[33]

Signs and Symptoms

DVT typically is asymptomatic and may not become apparent until a pulmonary embolism occurs. The most reliable signs are paresthesia in the area, chronic swelling and edema in the involved extremity, engorged veins, ecchymosis formation with a blue hue, and a positive Homans sign.

Management

Immediate referral to a physician is warranted. Treatment involves anticoagulant therapy, leg elevation, compression stockings, and ambulation in individuals who are clinically stable and for whom it is medically indicated. Functional neuromuscular stimulation of the gastrocnemius and tibialis anterior may help to activate the physiologic muscle pump while moving venous blood back to the central circulation to prevent DVT.

Neurological Conditions

Impingement of nerves in the lower leg and foot is rare but does happen. Three such conditions involve the compression of the interdigital nerves as they bifurcate at the metatarsal heads (i.e., plantar interdigital neuroma), the posterior tibial nerve beneath the flexor retinaculum and behind the medial malleolus (i.e., tarsal tunnel syndrome), and the sural nerve as it courses behind the lateral malleolus and into the lateral aspect of the foot.

Plantar Interdigital Neuroma

Etiology

A plantar interdigital neuroma (i.e., Morton neuroma) is a common source of forefoot pain and is 10 times more common in women than in men; women in their 30s and 40s who wear high-fashion shoes are particularly vulnerable.[34] Trauma or repetitive stress caused by tight-fitting shoes or a pronated foot can lead to abnormal pressure on the plantar digital nerves as they are compressed between the metatarsal heads and transverse intermetatarsal ligament. It typically occurs at the web space between the 3rd and 4th metatarsals (i.e., second and third intermetatarsal spaces) and, to a lesser extent, between the 2nd and 3rd metatarsals (**Fig. 14.29**).

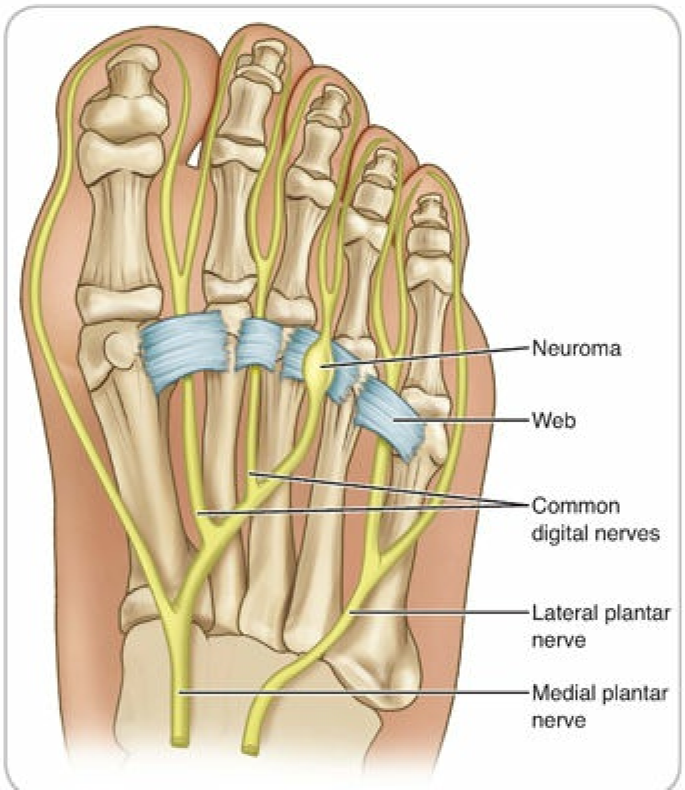


Figure 14.29. Plantar's neuroma. Plantar's neuroma (Morton neuroma) is caused by pinching of the interdigital nerve between the metatarsal heads. While weight bearing in shoes, the individual has an agonizing pain on the lateral side of the foot that is relieved when barefoot.

Signs and Symptoms

The individual may initially describe a sensation of having a stone or hot coal in the shoe that worsens when standing. Tingling or burning, radiating to the toes, along with intermittent symptoms of a sharp, shock-like sensation into the involved toes is commonly reported. Pain subsides when activity is stopped or when the shoe is removed. In fact, the desire to remove the shoe and massage the foot is a classic indicator of a neuroma. The clinician may be able to palpate a painful mass, elicit increased pain by squeezing the mass between the index finger and thumb.[14]

Management

Conservative management involves a metatarsal pad placed just proximal to the metatarsal heads and wearing a broad, soft-soled shoe with a low heel. The focus is to preserve and maximize flexion at the lesser toe MTP joints to prevent and treat the condition. NSAIDs and massage over the affected area once or twice a day may also help. Local corticosteroid injections or surgical excision of the nerve may be necessary to remedy persistent pain.[34]

Tarsal Tunnel Syndrome

Etiology

Tarsal tunnel syndrome occurs when the posterior tibial nerve, or one of its branches, becomes constricted beneath the fibrous roof of the flexor retinaculum of the foot (**Fig. 14.30**). Entrapment most often occurs at the anteroinferior aspect of the canal, where the nerve winds around the medial malleolus. Space-occupying lesions that have been identified as causes for tarsal tunnel syndrome include ganglions, varicosities, lipomas, tenosynovitis, fibrosis, and synovial hypertrophy.[35] The lateral plantar nerve branch tends to be affected more frequently than the medial branch. The condition often is linked to hyperpronation or an excessive heel varus or valgus deformity that leads to stress or traction on the nerve with impingement.

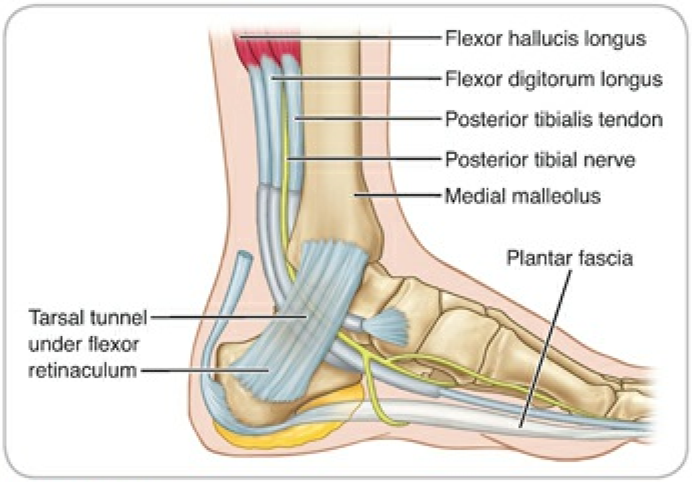


Figure 14.30. Tarsal tunnel syndrome. The posterior tibial nerve can become constricted beneath the tarsal tunnel roof formed by the flexor retinaculum.

Signs and Symptoms

Clinically, the individual complains of tingling and/or numbness around the medial malleolus radiating into the sole and heel (particularly with entrapment of the lateral plantar nerve) and hyperesthesia in the distribution of the posterior tibial nerve. The pain is often worse with activity, certain shoes that the patient may find aggravating, or standing, and the pain can be relieved by rest.[35] Hyperdorsiflexion, external rotation, and eversion may reproduce symptoms similar to those during provocative tests for carpal tunnel syndrome. One of the most reliable signs is a positive Tinel sign—namely, tingling elicited by tapping along the course of the nerve (**Fig. 14.19**).

Management

Conservative management involves rest, NSAIDs, orthoses (especially in individuals with hyperpronation), and gradual return to activity. A one-time injection of cortisone and lidocaine without epinephrine may be given into the tarsal tunnel, but if symptoms persist and other causes of heel pain are eliminated, surgical release may be necessary to relieve symptoms. Rehabilitation takes longer than with carpal tunnel syndrome because of the dependent weight-bearing requirements.[16]

Sural Nerve Entrapment

Etiology

The sural nerve, which is formed from branches of the tibial and peroneal nerves, provides cutaneous innervation to the lateral lower leg and foot. It passes distally along the lateral margin of the Achilles tendon to emerge from the fascia of the leg proximal to the lateral malleolus. After providing lateral calcaneal branches to the ankle and heel, the nerve passes behind the lateral malleolus and continues along the lateral border of the foot to extend to the fifth toe as the lateral dorsal cutaneous nerve. In addition to being vulnerable to compression from tight-fitting skates, boots, and shoes, the nerve can be irritated by fibrous adhesions that result from repetitive inversion ankle injuries or by ganglia that may form in the peroneal tendon sheath. Peripheral sural nerve neuropathy related to diabetes also may be a cause of paresthesia in this area.

Signs and Symptoms

Symptoms of sural nerve involvement include numbness in the affected area with decreased temperature sensation along the dorsolateral aspect of the foot, a burning sensation, local tenderness over the sural nerve, and reproduction of the symptoms by compression over the nerve (i.e., positive Tinel sign).

Management

Conservative treatment may be as simple as changing the lacing of the skates, boots, or shoes; however, surgical intervention may be necessary to correct the problem.

> The figure skater may have compressed the sural nerve with the tight laces and tape. The individual should be referred to a physician to determine the extent of injury to the nerve. The skater should be advised to change the way that she laces her boots.

FRACTURES

> **?** In addition to Sever disease, what conditions could lead to heel pain in young athletes?

Fractures in the foot and lower leg region seldom result from a single traumatic episode. Often, repetitive microtraumas lead to apophyseal or stress fractures. Tensile forces associated with severe ankle sprains can lead to avulsion fractures of the 5th metatarsal, or severe twisting can lead to displaced and undisplaced fractures in the foot, ankle, or lower leg. A combination of forces can lead to a traumatic fracture dislocation.

Freiberg Disease

Etiology

Freiberg disease is a painful avascular necrosis of the second or, rarely, third metatarsal head that often is seen in active adolescents aged 14 to 18 years before closure of the epiphysis.

Signs and Symptoms

The condition can lead to diffuse pain in the forefoot region.

Management

Early detection is best treated by a metatarsal pad or bar to unload the involved metatarsal head and activity modification to eliminate excessive running and jumping. If pain persists and deformity develops with degenerative osteophytes, surgical resection of the distal metatarsal head may be necessary.

Sever Disease

Etiology

Sever disease, or calcaneal apophysitis, frequently is seen in 7- to 10-year-old children. It is associated with growth spurts, decreased heel cord and hamstring flexibility, and other biomechanical abnormalities contributing to poor shock absorption (e.g., forefoot varus, hallux valgus, pes cavus, pes planus, and more commonly, forefoot pronation). Because the apophyseal plate is vertically oriented, it is particularly susceptible to shearing stresses from the gastrocnemius. Hard surfaces, poor-quality or worn-out athletic shoes, being kicked in the region, or landing off-balance also may precipitate the condition.

Signs and Symptoms

The individual complains of unilateral or bilateral, intermittent or continuous, posterior heel pain that occurs shortly after beginning a new sport or season. Pain tends to be worse during and after activity but improves with rest. Although gait may be normal, the child may walk with a limp or exhibit a forceful heel strike. Point tenderness can be elicited at or just anterior to the insertion of the Achilles tendon along the posterior border of the calcaneus. Mediolateral compression (i.e., squeeze test) of the calcaneus over the lower third of the posterior calcaneus elicits pain, as does standing on the tiptoes (i.e., positive Sever sign). Heel cord flexibility is tested by passive dorsiflexion of the foot with the knee extended. Other conditions that may lead to heel pain should be ruled out before determining the treatment plan (**Box 14.4**).

BOX 14.4 Differential Diagnosis of Heel Pain in Physically Active, Young Individuals

- Plantar fasciitis
- Calcaneal stress fracture
- Infection
- Heel fat pad syndrome
- Calcaneal exostosis
- Tarsal coalition
- Achilles tendinitis/strain

- Contusion
- Tarsal tunnel syndrome
- Retrocalcaneal bursitis

Management

Following standard acute care, the individual should be referred to a physician for further care. The condition usually resolves itself with closure of the apophysis. Until that time, rest, ice, NSAIDs, heel lifts, heel cups, strapping the foot in slight plantar flexion to relieve some strain on the Achilles tendon, and activity modification usually relieve symptoms. Heel cord flexibility and strengthening exercises of the dorsiflexors are recommended. Resistant cases may benefit from a nighttime dorsiflexion splint.

Stress Fractures

Stress fractures often are seen in running and jumping activities, particularly after a significant increase in training mileage or a change in surface, intensity, or shoe type. Women with **amenorrhea** of longer than 6 months' duration and **oligomenorrhea** have a higher incidence of stress fractures of the foot and leg; however, women who use oral contraceptives tend to have significantly fewer stress fractures compared with nonusers.[16]

Stress fractures can be generally classified as noncritical and critical. Noncritical stress fractures of the lower leg, foot, and ankle include the medial tibia; fibula; and the 2nd, 3rd, and 4th metatarsals. The neck of the 2nd metatarsal is the most common location for a stress fracture, although it also is seen on the 4th and 5th metatarsals. Critical stress fractures require special attention because of a higher rate of nonunion. Common sites include the anterior tibia, medial malleolus, talus, navicular, 5th metatarsal, and sesamoids.

Etiology

Stress fractures of the lower leg, ankle, and foot are commonly caused by repetitive stress that leads to a summation point in the bone accompanying muscle fatigue, a change in ground surfaces (moving from grass to pavement), or an overload caused by muscle contraction. The resulting loss in shock absorption increases stress on the bone and periosteum. In the tibia, most stress fractures occur at the junction of the middle and distal thirds (most common site), the posteromedial tibial plateau, or just distal to the tibial tuberosity. Fibular stress fractures usually occur in the distal metadiaphyseal region. Because the fibula has a minimal role in weight bearing, it is believed that fibular stress fractures result from muscle traction and torsional forces.[25]

Signs and Symptoms

Pain from a stress fracture begins insidiously, increasing with activity and decreasing with rest; pain usually is limited to the fracture site. A stress fracture of the talus, for example, commonly involves the lateral body near the junction of the body with the lateral process of the talus. The patient may present with prolonged pain (i.e., several months in duration) following an ankle sprain despite full rehabilitation. Excessive subtalar pronation is felt to predispose an individual to talar stress fractures by allowing impingement of the lateral process of the calcaneus on the concave posterolateral corner of the talus.[25] Stress fractures of the calcaneus produce significant pain on heel strike. The individual often has a history of a substantial increase in the individual's activity level, particularly in distance runners. Palpation reveals maximum pain on the medial and lateral aspects of the plantar-calcaneal tuberosity. The most common site is the upper posterior margin, just anterior to the apophyseal plate and at a right angle to the normal trabecular pattern.[25] Squeezing the calcaneus produces pain.

Stress fractures of the navicular are seen in jumpers, ballet dancers, and equestrians because of the nature of foot positions as well as the motions and inevitable stresses that are produced in the midfoot. Often seen in young men, this fracture is difficult to assess. A high degree of suspicion is required when an individual complains of generalized foot pain on the dorsomedial aspect of the midfoot brought on by activity and relieved with rest. During the advanced stages, overlying swelling and pain on walking become evident.

The two sesamoid bones of the great toe can carry threefold the body's weight with leg-based activity. These bones often are fractured as a result of constant weight bearing on a hyperextended great toe or because of prolonged pronation during running. Individuals with pes cavus or tight plantar fascia are predisposed to this injury because of the large tensile forces placed on the bones. Pain and swelling are present on the ball of the foot, and the individual is unable to roll through the foot to stand on the toes. Radiographs may be inconclusive, because it is common in the general population for sesamoid bones to be bipartite.

Management

Pain can be elicited with percussion, a tuning fork, or ultrasound over the fracture site. Encircling the forefoot or calcaneus with the hand and squeezing the fingers together produce added discomfort. Following standard acute care, the individual should be referred to a physician. Frequently, early radiographs are negative, but periosteal reaction or cortical thickening can be seen 2 to 4 weeks later (**Fig. 14.31**). Bone scans and magnetic resonance images are more sensitive and usually reveal the presence of a fracture long before it becomes evident on radiographs.

Figure 14.31. Stress fractures. Notice the sclerosis and widened cortices associated with bone healing.

Treatment usually requires relative rest, ice therapy, NSAIDs, stretching and strengthening exercises, and correcting any mechanical abnormalities that may have contributed to the condition. Protected weight bearing, a stiff shoe, a rigid orthosis, or a walking cast may be indicated in fractures of the metatarsals, calcaneus, or tibia. Wearing stiff-soled shoes or a heel cup may be helpful in cases with stress fractures of the sesamoid bones and calcaneus, respectively. The individual should be completely asymptomatic before returning to participation, which generally is seen in 6 to 8 weeks.

Avulsion Fractures

Etiology

Avulsion fractures may occur at the site of any ligamentous or tendinous attachment and as a result of a sudden, powerful twist or stretch of the body part. Severe eversion ankle sprains may cause the deltoid ligament to avulse a portion of the distal medial malleolus rather than tearing of the ligament.

Inversion ankle sprains can provide sufficient overload to cause the plantar aponeurosis or peroneus brevis tendon to be pulled from the bone, avulsing the base of the 5th metatarsal (i.e., the so-called dancer's fracture). If the styloid process is avulsed, it is called a type II fracture and has an excellent prognosis, with healing occurring within 4 to 6 weeks.

Signs and Symptoms

Avulsion fractures are painful directly over the fracture site. Pain increases with a traction force applied to the joint or bony attachment. A much more complicated avulsion fracture that is seen in sprinters and jumpers involves a type I transverse fracture into the proximal shaft of the 5th metatarsal at the junction of the diaphysis and metaphysis, called a **Jones fracture** (**Fig. 14.32**). It often is overlooked in conjunction with a severe ankle sprain that involves plantar flexion and a strong adduction force to the forefoot. Because of low vascularization and high stresses at this site, Jones fractures are associated with a poor outcome; nonunions and delayed unions are common.

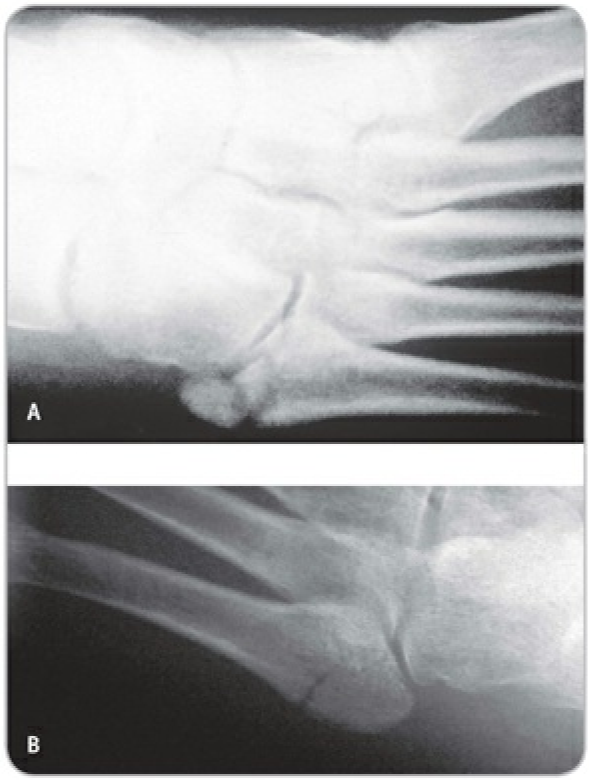


Figure 14.32. Avulsion fractures. A, A type I transverse fracture into the proximal shaft of the 5th metatarsal often is overlooked in cases of an inversion ankle sprain, resulting in a nonunion fracture. **B,** A type II fracture involves the styloid process of the 5th metatarsal.

Management

Following standard acute care, the individual should be referred to a physician. Treatment involves non–weight-bearing immobilization for 6 to 10 weeks, followed by use of a walking cast or orthosis for an additional 4 weeks. Physical activity should be avoided until clinical and radiographic evidence of union appears, typically by 8 to 12 weeks. Displaced fractures may require open reduction and internal fixation. After screw fixation, progressive weight bearing is initiated at 2 weeks, with return to running in 7 weeks. When bone grafting is used, running activities are delayed for 12 weeks to allow bony healing.[25]

Osteochondral Fracture of the Talus

Etiology

Severe ankle sprains can impinge the dome of the talus against the malleoli, leading to a fracture of the cartilaginous cover. Anterolateral fractures account for 43% of osteochondral lesions, are wafer-shaped, and result from forceful inversion and dorsiflexion. Posteromedial fractures account for 57% of osteochondral fractures and are cup-shaped. They result from forceful inversion and plantar flexion (**Fig. 14.33**). The fragment may remain nondisplaced or float freely in the joint. Osteochondritis dissecans of the talus can develop if the fragment, particularly one of the corners, floats freely in the ankle joint, thus losing its blood supply.

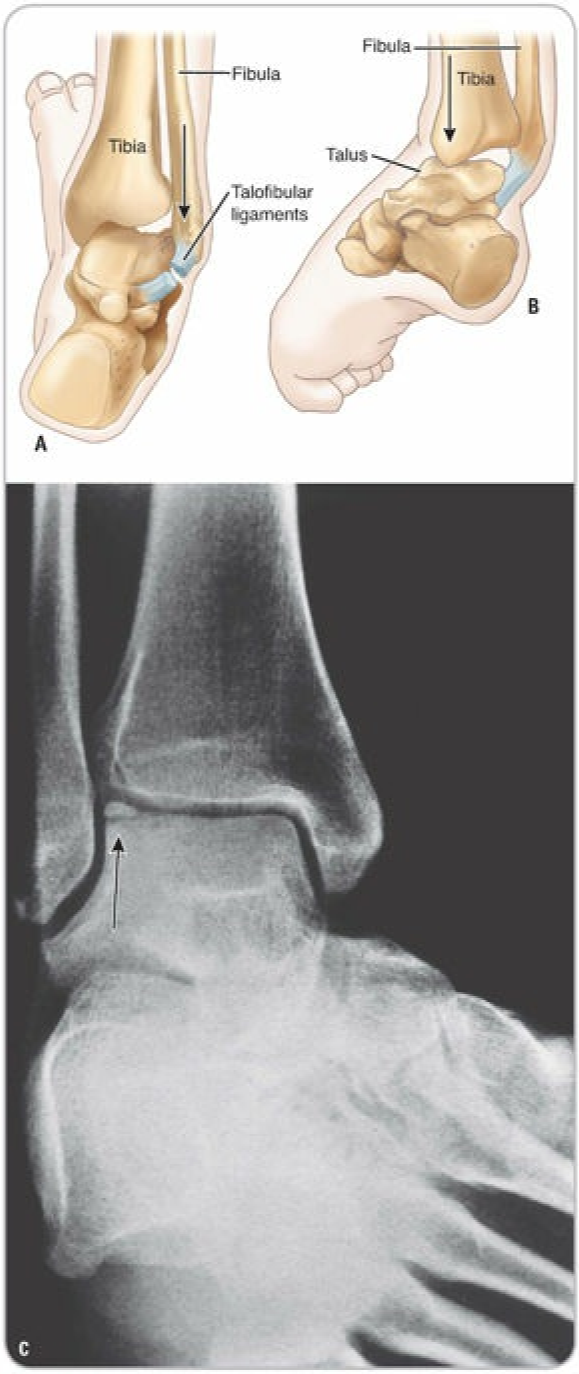


Figure 14.33. Osteochondral fractures. A, Forceful inversion of a dorsiflexed ankle can produce damage to the anterolateral talar dome. **B,** Forceful inversion of a plantar-flexed ankle can produce damage to the posteromedial aspect of the dome. **C,** Radiograph of an osteochondral lesion on the lateral aspect of the talus.

Signs and Symptoms

Symptoms may be nonspecific and include a deep, aching pain that is aggravated by activity, recurrent ankle swelling, ankle instability and stiffness, occasional crepitus, clicking, and locking (if displaced). Passive plantar flexion and palpation of the anterolateral and posteromedial corner of the talus elicit point tenderness. A palpable lesion or crepitus may be felt on the corners.

Management

If pain and joint effusion persist after an inversion ankle sprain or ankle fracture, or if symptoms return after an asymptomatic period, a more serious underlying condition should be suspected, and referral to a physician is warranted. Limited weight bearing (and/or immobilization) and NSAIDs are used to treat undisplaced fractures. Arthroscopic excision or repair usually is necessary in cases with displaced fractures.

Displaced Fractures and Fracture Dislocations

Severe fractures result from direct compression in acute trauma (e.g., falling from a height or being stepped on) or from combined compression and shearing forces (e.g., as occurs during a severe twisting action). Because of the proximity of major blood vessels and nerves, many displaced and undisplaced fractures necessitate immediate immobilization and referral to the nearest trauma center.

Forefoot Fractures

Etiology

Phalangeal fractures are caused by an axial load (e.g., jamming the toe into an immovable object) or direct trauma (e.g., crushing injury). Most are minor injuries, with the exception of a fracture to the great toe.

Signs and Symptoms

Metatarsal fractures are classified according to their anatomical location (i.e., neck, shaft, or base). A single fracture tends to be minimally displaced because of the restraining forces of the intermetatarsal ligaments. Swelling and pain are localized over the fracture site, and pain increases with weight bearing. Swelling, ecchymosis, and pain are present; the individual is able to walk but may have problems with footwear. Most tenderness resolves in 3 to 4 weeks.

Management

If the bony fragment is nondisplaced, buddy padding, splinting, and wearing a wooden shoe or a shoe with a wide toe box may help. If the great toe is fractured, a walking cast with a toe plate, or a wooden shoe and crutches, is helpful; if displaced, surgery may be necessary to prevent osteoarthritis. Metatarsal fractures are treated with a short slipper cast or wooden shoe for 6 weeks, with weight bearing as tolerated.

Tarsal Fractures

Lisfranc Injury

Etiology

A **Lisfranc injury** involves disruption of the tarsometatarsal joint, with or without an associated fracture, and is notorious for delayed diagnosis (**Fig. 14.34**). The typical mechanism is a severe twisting injury (e.g., a football player falls onto the heel of another player’s plantar-flexed foot) that causes an axial load along the metatarsals.

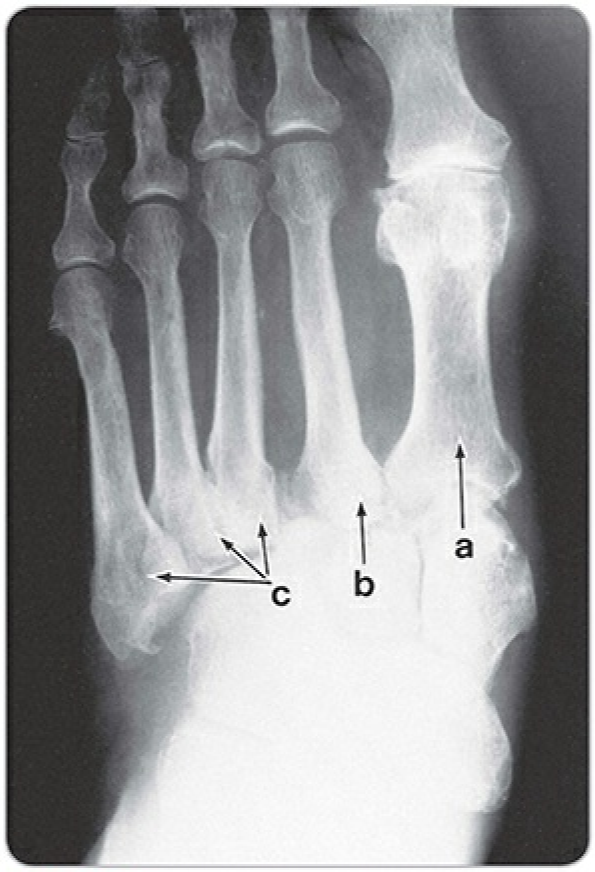


Figure 14.34. Lisfranc injury. Radiograph of a Lisfranc injury: *(a)* 1st metatarsal; *(b)* 2nd metatarsal; and *(c)* 3rd, 4th, and 5th metatarsals, which have been dislocated laterally.

Signs and Symptoms

The 1st metatarsal typically is dislocated from the first cuneiform, whereas the other four metatarsals are laterally displaced, usually in combination with a fracture at the base of the 2nd metatarsal. Because the supply of blood to the forefoot can be compromised by the dislocation and subsequent swelling, a compartment syndrome may develop and create a serious injury. If assessed soon after the injury, the fracture may appear to be unremarkable until massive swelling sets in. A history of severe midfoot pain, paresthesia, or swelling along the midfoot region with variable flattening of the arch or abduction of the forefoot should signal a serious condition.

Management

A nondisplaced Lisfranc injury can be treated in a short-leg, nonwalking cast for 6 weeks, followed by 6 weeks in a short-leg, walking cast. Most injuries require open reduction and internal fixation.

Talus Fracture

Etiology

A fracture of the lateral process of the talus and neck of the talus, which is rare, is caused by acute hyperdorsiflexion with inversion. Posterior fractures of the talus are seen in individuals aged 15 to 30 years, particularly in those activities requiring forced plantar flexion of the foot, such as ballet or soccer, and may be either acute or stress-related.

Signs and Symptoms

Severe posterior pain is present when jumping, running, or kicking with the instep of the foot, and this pain is increased on forced plantar flexion and resisted great toe flexion, stemming from the close proximity of the flexor hallucis longus tendon to the fractured process. Moderate to severe edema, tenderness, and ecchymosis may be present.

Management

Because of the potential devastating complication of avascular necrosis of the talus, talar neck fractures need immediate immobilization and referral to a physician.

Calcaneus Fractures

Etiology

Traumatic fractures of the calcaneus are rare, but when they do occur, such fractures commonly are caused by high-energy axial loads. Occasionally, fractures occur at the anterior process either by forceful plantar flexion and adduction or by compression. Nearly 75% of calcaneus fractures extend into the subtalar joint.

Signs and Symptoms

Symptoms include severe heel pain, an inability to walk, and palpable, intense pain directly over the process, located just distal to the sinus tarsi.

Management

Initial treatment of intra-articular fractures includes immobilization in a bulky dressing and splint, with ice and elevation to control edema. Nondisplaced extra-articular calcaneal fractures can be treated with a short-leg cast or walking boot for approximately 6 weeks. Most displaced fractures must be repaired surgically, but patients typically experience residual stiffness of their subtalar joint that can adversely affect future athletic performance.

Tibia–Fibula Fractures

Etiology

In an inversion sprain, the medial malleolus typically is fractured at the level of the talar dome, or the injury may occur as a spiral fracture at the distal tibial metaphysis. Eversion and dorsiflexion injuries lead to spiral or comminuted fractures of the lateral malleolus. In lateral malleolar fractures, the risks for a bimalleolar fracture are high when the deltoid ligament avulses the medial malleolus.

A **Maisonneuve fracture** is an eversion-type injury of the ankle, with an associated fracture of the proximal third of the fibula, commonly at the junction of the proximal and middle thirds of the shaft (**Fig. 14.35**). The tibiofibular syndesmosis is disrupted, and either a tear of the tibiofibular ligament or a fracture of the medial malleolus also is present. The more proximal the location of the fibular fracture, the more damage to the interosseous membrane between the tibia and fibula, because the membrane is always disrupted up to the fracture site. The typical mechanism is external rotation of the foot.

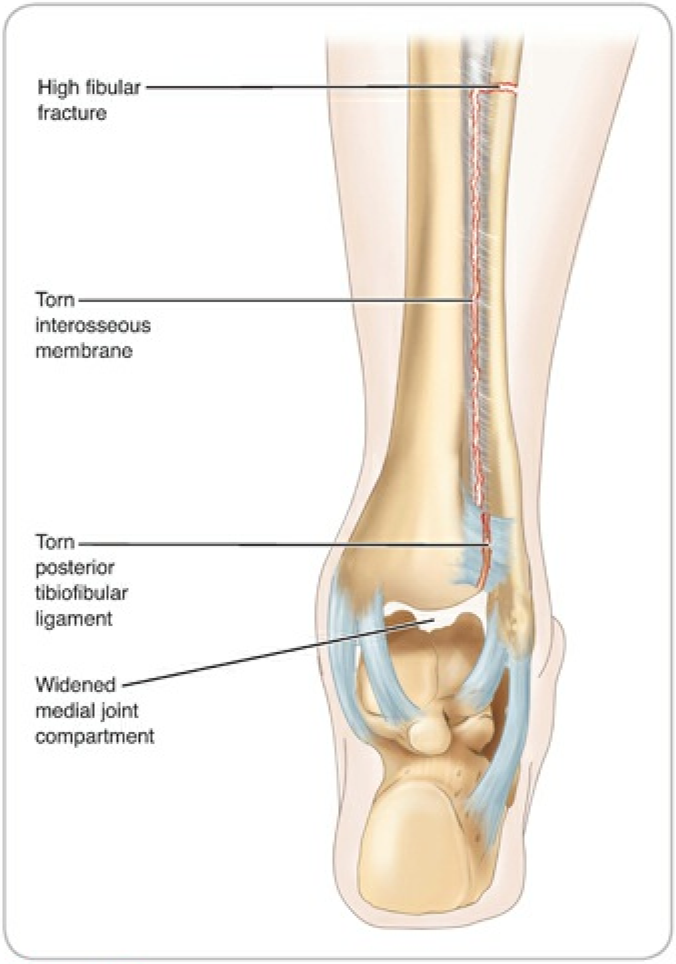


Figure 14.35. Maisonneuve fracture. The classic fracture occurs at the junction of the proximal and middle thirds of the fibula. The tibiofibular syndesmosis is disrupted, and the interosseous membrane is torn up the level of the fracture. The tibiotalar (medial) joint compartment is widened because of lateral subluxation of the talus.

Nearly 60% of tibial fractures involve the middle and lower thirds of the tibia. Whether open or closed, this fracture is associated with complications such as delayed union, nonunion, or malunion. The most common cause of an isolated tibial fracture is torsional force, resulting in a spiral or oblique fracture of the lower third of the tibia.

Fracture dislocations usually are caused by landing from a height with the foot in excessive eversion or inversion or by being kicked from behind while the foot is firmly planted on the ground. Typically, the foot is displaced laterally at a gross angle to the lower leg, and extreme pain is present. This position can compromise the posterior tibial artery and nerve.

Signs and Symptoms

In a simple tibial or fibular fracture, often a crack is heard, and the individual is unable to bear weight on the injured extremity because of intense pain. Gross deformity, gross bone motion at the suspected fracture site, crepitus, immediate swelling, extreme pain, or pain with motion should signal immediate action.

With a Maisonneuve fracture, deformity may or may not be present. The individual presents with tenderness over the deltoid ligament and the fracture site on the proximal fibula. Any proximal fibular tenderness after a twisting injury calls for radiographs of the ankle, the tibia, and the fibula. A high fibular fracture often requires open reduction and internal fixation between the distal fibula and tibia to maintain the normal relationship of the bones while ligament healing occurs. The screws generally are removed 8 to 12 weeks after surgery.

Management

Management of lower leg, ankle, and foot fractures involves removing the shoe and sock to expose the injured area. If a fracture is suspected, the clinician should perform percussion, compression, and distraction before any movement of the limb. Depending on the site, the techniques listed in **Application Strategy 14.2** may be helpful. The clinician also should assess the neurovascular integrity of the limb before and after immobilization by taking a distal pulse at the posterior tibial artery and/or dorsalis pedis artery or by blanching the toenails to determine capillary refill. The clinician should note the skin color of the foot and toes and should feel the toes for warmth. Sensation can be assessed by using the pulp of the fingers to stroke the top of the distal metatarsal heads and by asking the individual if the stroke was felt. The action is then repeated using the fingernail.

Nondisplaced malleoli fractures are treated conservatively, with cast immobilization for 4 to 6 weeks, followed by a functional brace until the fracture is completely healed. Displaced fractures involving joint stability require surgical intervention with open reduction and internal fixation. Healing after surgery usually takes 2 to 3 months or longer, followed by extensive rehabilitation. Internal fixation with plates and screws often is necessary to stabilize tibial fractures; however, some individuals may experience a high rate of infection as a complication of internal fixation.

Because shock is possible in serious traumatic fractures, the emergency action plan should be activated. In some settings, this will include summoning EMS to immobilize and transport the individual to the nearest medical facility. Suspected disruption of the tarsometatarsal joint (i.e., Lisfranc fracture) and fractures with suspected neurovascular compromise should be immobilized in a noncircumferential bulky splint to prevent complications from further compression.

In addition to Sever disease, the following conditions could lead to heel pain in young athletes: plantar fasciitis, heel fat pad syndrome, Achilles tendinitis/strain, retrocalcaneal bursitis, calcaneal stress fracture, calcaneal exostosis, contusion infection, tarsal coalition, and tarsal tunnel syndrome.

REHABILITATION

?

The cross-country runner has plantar fasciitis. What exercises should now be included in the rehabilitation program?

Rehabilitation exercises for the lower leg, ankle, and foot can be initiated during the acute inflammatory phase as long as the condition is not further irritated. For example, while icing an ankle, the gastrocnemius and soleus can be passively stretched, or strengthening exercises for the foot intrinsic muscles can be started. Pain and swelling dictate the amount of exercise that can be tolerated and may necessitate restricted weight bearing. The rehabilitation program should restore motion and proprioception, maintain cardiovascular fitness, and improve muscular strength, endurance, and power, predominantly through closed chain exercises.

Restoration of Motion

Application Strategy 14.1 provided several ROM exercises that can be performed non–weight bearing. For example, towel pulls stretching the Achilles tendon, writing the alphabet in large circles, picking up objects with the toes and combining the action with shin curls, and use of a biomechanical ankle platform system (BAPS) board can each be done in a seated position. As pain subsides and weight bearing is initiated, Achilles tendon stretches, toe raises, balance exercises, and use of a BAPS board can be completed in a standing position.

Restoration of Proprioception and Balance

Proprioception and balance must be regained to allow safe return to sport participation. Early exercises may include shifting one's weight while on crutches, performing bilateral minisquats, or using a BAPS board in a seated position. As balance improves, BAPS board exercises can progress to partial weight bearing while supported by a table and then to full weight-bearing exercises. Running in place on a minitramp and use of a slide board are closed chain exercises that also improve proprioception and balance.

Muscular Strength, Endurance, and Power

Early emphasis is placed on strengthening the foot's intrinsic muscles. Towel crunches are demonstrated in Application Strategy 14.1. As the condition allows, toe raises and Thera-Band or surgical tubing exercises are added. Use of a multiaxial ankle machine, toe raises with weights, squats and lunges, and isokinetic exercises continue to strengthen the lower leg musculature. During later stages, jogging, running side to side, and multiangle plyometrics can assist the individual in a gradual return to sport participation.

Cardiovascular Fitness

Maintenance of cardiovascular fitness can begin immediately after injury with use of an upper body ergometer or hydrotherapeutic exercise. Running in deep water and performing sport-specific exercises can provide mild resistance in a non–weight-bearing medium. When ROM is adequate, a stationary bicycle may be used. Light jogging, running backward, and running side to side should increase in both intensity and duration to facilitate return to activity. Application Strategy 14.7 lists several rehabilitation exercises that may be incorporated in a complete program for the lower leg.

APPLICATION STRATEGY 14.7

Rehabilitation Exercises for the Lower Leg

1. **Phase 1.** Control inflammation. Minimize inversion and eversion exercises to allow healing. Dorsiflexion and plantar flexion should be performed within the limits of pain. Exercises should be combined with ice therapy or electrical stimulation with elevation. Use those exercises listed in Application Strategy 14.1 as tolerated.
   - Plantar fascia stretch
   - Towel crunches
   - Toe curls
   - Picking up objects
   - BAPS board in seated position
   - Triceps surae stretch, non–weight bearing
   - Pool therapy or upper body ergometer (UBE) exercises for cardiovascular fitness
2. **Phase 2.** As pain and tenderness subside, initiate inversion and eversion ROM. Initiate strengthening exercises as tolerated. Include the following:
   - Shin curls
   - Ankle alphabet
   - Triceps surae stretch, standing position
   - Toe raises
   - Elastic tubing exercises in dorsiflexion, plantar flexion, inversion, and eversion
   - Unilateral balance BAPS board activities with support
   - Pool therapy, UBE, and stationary bike (if tolerated) for cardiovascular fitness
3. **Phase 3**

- Toe raises with weights
- Multiaxial ankle machine
- Squats and lunges
- Balance exercises with challenges, such as dribbling while balancing on one leg, performing elastic band exercises while balancing on one leg, or balancing on an uneven surface
- Straight-ahead jogging, if able to walk without a limp

4. **Phase 4.** (Use external support for the ankle as needed.)
   - Isokinetic exercises to work functional speeds
   - Multiangle plyometrics, including single- and double-limb jumping, front to front, side to side, and diagonals
   - Side-to-side running
   - Running backward
   - Jumping for height and distance (long jump)
   - Slide board
   - Gradual return to activity with protection

In addition to exercises, the individual should be assessed for biomechanical anomalies, and appropriate orthotics should be fabricated to correct any malalignment. Following an ankle injury, it may be necessary to provide external support to the ankle region. Following completion of the rehabilitation program and clearance for full participation, a proper maintenance program of stretching and strengthening exercises should be provided.

The rehabilitation program for the cross-country runner with plantar fasciitis should include aggressive Achilles tendon stretching for 2 to 4 minutes, three to four times a day, with toes straight ahead, toes in, and toes out; gentle isometric contractions for intrinsic muscles of the foot, progressing to active ROM exercises within pain-free ranges (e.g., toe curls, marble pick-up, towel crunches, and towel curls) to strengthen the intrinsic and extrinsic muscles of the leg; and general fitness (i.e., strength and aerobic conditioning) with non–weight-bearing activities.

SUMMARY

1. The true ankle (talocrural) joint is the mortise–tenon joint between the tibia, fibula, and talus. Plantar flexion and dorsiflexion occur at this joint. Motion at the subtalar joint occurs in an oblique direction. The combination of calcaneal inversion, foot adduction, and plantar flexion is known as supination; the combination of calcaneal eversion, foot abduction, and dorsiflexion is known as pronation.
2. The primary supporting structures of the plantar arches are the calcaneonavicular (i.e., spring) ligament, long plantar ligament, plantar fascia (plantar aponeurosis), and short plantar (plantar calcaneocuboid) ligament. In addition, the tibialis posterior provides some support.
3. Congenital abnormalities, leg length discrepancy, muscle dysfunction (e.g., muscle imbalance), or a malalignment syndrome (e.g., pes cavus, pes planus, pes equinus, and hammer or claw toes) can predispose an individual to several chronic injuries.
4. Generalized forefoot pain may result from intrinsic factors (e.g., excessive body weight, limited flexibility of the Achilles tendon, pronation, valgus heel, hammer toes, fallen metatarsal arch, pes planus, or pes cavus) or from extrinsic factors (e.g., narrow toe box, improperly placed shoe cleats, repetitive jumping or running, or landing poorly from a height).
5. An acute anterior compartment syndrome is a medical emergency. Signs and symptoms include a recent history of trauma; a palpable, firm mass in the anterior compartment; tight skin; and a diminished dorsalis pedis pulse.
6. Ankle sprains are classified as grade I, II, or III based on the progression of the anatomical structures that are damaged and the subsequent disability. In lateral ankle sprains involving plantar flexion and inversion,

the ATFL is torn first, followed by the calcaneal fibular ligament. In eversion ankle sprains, the deltoid ligament is injured, and an associated avulsion fracture of one or both malleoli also may be present.

7. Common sites for tendon injuries include the Achilles tendon just proximal to its insertion into the calcaneus, the tibialis posterior just behind the medial malleolus, the tibialis anterior just under the extensor retinaculum, and the peroneal tendons behind the lateral malleolus or at the distal attachment on the styloid process of the 5th metatarsal.
8. Injury to the tibialis posterior results in weakness in plantar flexion and inversion and may lead to acquired pes planus.
9. Risk factors for Achilles tendinitis include a tight heel cord, foot malalignment deformities, recent change in shoes or running surface, sudden increase in workload (e.g., distance or intensity), or changes in the exercise environment (e.g., changing footwear, or excessive hill climbing or impact-loading activities [e.g., jumping]).
10. MTSS is a periostitis along the posteromedial tibial border, usually in the distal third that is not associated with a stress fracture or compartment syndrome. Signs and symptoms include point tenderness in a 3- to 6-cm area along the distal posteromedial tibial border as well as pain and weakness with resisted plantar flexion or standing on tiptoe.
11. ECS is characterized by exercise-induced pain and swelling that are relieved by rest. The anterior compartment most frequently is affected, and in such cases, mild foot drop or paresthesia (or both) may be present. Fascial defects or hernias also may be present in the distal third of the leg over the anterior intramuscular septum.
12. Nerve impingement may involve the interdigital nerves as they bifurcate at the metatarsal heads (i.e., plantar interdigital neuroma), posterior tibial nerve beneath the flexor retinaculum and behind the medial malleolus, or sural nerve as it courses behind the lateral malleolus into the lateral foot.
13. Fractures of the lower leg, ankle, and foot may involve the following:

- Freiberg disease (i.e., avascular necrosis of the second metatarsal head)
- Sever disease (i.e., calcaneal apophysis)
- Stress fractures (most commonly the neck of the 2nd metatarsal)
- Avulsion fractures (e.g., styloid process of the 5th metatarsal and the medial and lateral malleoli)
- Osteochondral fractures (e.g., talar dome)
- Displaced fractures or fracture dislocations

14. Pain may be referred to the lower leg, ankle, and foot from the lumbar spine, hip, or knee.
15. Conditions that warrant special attention include the following:
    - Obvious deformity suggesting a dislocation, fracture, or ruptured Achilles tendon
    - Significant loss of motion or weakness in a myotome
    - Excessive joint swelling
    - Possible epiphyseal or apophyseal injuries
    - Abnormal reflexes or sensation or an absent or weak pulse
    - Gross joint instability
    - Any unexplained pain
16. Functional tests should be performed pain-free without limp or antalgic gait before clearing any individual for return to activity. In addition, the individual should have bilaterally equal ROM, strength, and proprioception as well as an appropriate cardiovascular fitness level before being allowed to return to activity. When necessary, protective equipment or braces should be used to prevent reinjury.

APPLICATION QUESTIONS

1. An 18-year-old cross-country runner comes to the athletic training room complaining of pain along the plantar surface of his left foot. Following the history and observation components of the exam, you learn that the runner has been increasing his distance and running more frequently on street-like surfaces. He has pain when he wakes in the morning, but the pain diminishes as he completes his morning routine (i.e., getting ready for classes). After he runs, the pain returns. His shoes are somewhat old and worn. He has some pes planus on the left foot when compared with the right foot. There is minor swelling along the longitudinal medial border but no discoloration. How should the testing components and palpations proceed with this history?
2. A 16-year-old soccer player has an aching pain on the posterior calcaneus just above the attachment of the Achilles tendon. When the tendon is palpated, it does not hurt, but when you reach around the tendon and squeeze into the soft-tissue area just anterior to the tendon, it is very painful. What condition might you suspect? What may have contributed to this condition? How should the injury be managed?
3. A middle-aged tennis player reports pain and swelling behind the medial malleolus and pain in the arch when arising in the morning. Observation reveals that the individual has pes planus. During resisted muscle testing, plantar flexion and inversion are weak. What muscles are involved in this injury? What exercises would you recommend to address this injury?
4. A 22-year-old ice hockey player is complaining of bilateral numbness in the posterolateral aspect of the leg along the Achilles tendon for the past 2 to 3 weeks. There is no history of trauma to the ankle, but he admits that, in order to provide better support for the ankles, he routinely spiraled his laces tightly around the proximal portion of each ice hockey boot and then applied several circular bands of white tape to hold them in place. Could this technique impair the vascular or neural function of the lower leg? What structures may be impacted by his actions? What recommendations

could be made to manage the injury?

5. A soccer athlete “rolled” her foot during the game and is now complaining of lateral ankle pain during the timeout. What special tests could you do to determine whether this ankle injury is a grade I or grade II sprain?
6. A high school lacrosse player accidentally stepped in a hole, inverting the ankle. Although she stayed off the ankle and iced it during the night, the ankle appeared swollen and discolored the next morning and continued to hurt on weight bearing. How would you manage this injury?
7. A softball player sprained the right ankle a week ago. Following standard acute care and partial weight bearing, the swelling and pain have significantly decreased around the lateral malleolus, but pain is still present on the styloid process of the 5th metatarsal. What additional injury may be present? What would you recommend for further management of the injury?
8. Prevention and rehabilitation for injuries to the foot, ankle, and lower leg typically include strengthening exercises. What exercises can be used to strengthen both the intrinsic and extrinsic muscles of the foot?
9. What factors that contribute to the development of metatarsalgia can be addressed in the prevention or management of this condition to alleviate pain?

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