Ankle and Foot Injuries in Pediatric and Adult Athletes

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As primary care physicians, foot and ankle injuries will likely fill our offices, emergency departments, and training rooms more often than any other athletic injury. The growing skeleton presents us with unique causes of foot and ankle pain, unlike the causes of injury in the mature athlete. For practitioners to be prepared to care for the injured pediatric or adult athlete, the authors provide a comprehensive discussion of the most common types of sport-related foot and ankle of injuries.

Ankle sprains

The ankle is the most commonly injured joint among athletes, accounting for up to 30\% of musculoskeletal injuries seen in sports medicine clinics, and is the most frequently seen musculoskeletal injury seen in the primary care setting [1]. There are an estimated 1 to 10 million ankle injuries in the United States each year, with 75\% to 85\% of these being ankle sprains [2,3]. Of all ankle sprains, 85\% are inversion injuries [3,4].
Anatomy

An understanding of the ankle anatomy will guide in the diagnosis and treatment of ankle sprains. The ankle is a simple hinge joint composed of the tibia, fibula, and talus. The tibia and fibula extend medially and laterally around the talus to form their respective malleoli. The tibia and fibula are stabilized by the anterior and posterior inferior tibiofibular ligaments (AITFL and PITFL), and the interosseous membrane (Fig. 1). Together, they make up the syndesmosis, in which the talus lies. Because of the bony relationships of the ankle, true ankle joint movement is limited to plantar flexion and dorsiflexion. Inversion and eversion actually occur at the subtalar or calcaneotalar joint.

The lateral stabilizing ligaments (see Fig. 1) are the most often injured with a typical sprain. They are comprised of the anterior talofibular ligament (ATFL), calcaneofibular ligament (CFL) and the posterior
talofibular ligament (PTFL). The ATFL, which extends from the anterior tip of the fibula to the lateral aspect of the talus, is the most commonly injured ligament and is considered the weakest [5]. The ATFL prevents inversion and anterior translation of the ankle during plantar flexion. The CFL is the next most commonly injured ligament. It extends from the central portion of the lateral fibula to the calcaneus. When the foot is in neutral alignment, the CFL resists inversion, especially during dorsiflexion and lateral subluxation. The CFL spans the ankle and subtalar joint, providing stability across both joints [6]. By extending from the posterior tip of the fibula to the posterolateral talus, the PTFL prevents inversion and posterior subluxation during dorsiflexion. The PTFL is the strongest of the three lateral ankle ligaments, and is rarely injured during inversion sprains [2]. Additional lateral support is provided by the musculotendinous aspects of the peroneus longus and brevis (Figs. 1, 2).

Medially, the ankle receives ligamentous support from the fan-shaped deltoid complex, which consists of a deep and superficial portion (see Figs. 1, 2) that resists eversion and subluxation. The musculotendinous units of the tibialis anterior and posterior, the flexor digitorum longus, the flexor hallucis longus, and the extensor hallucis longus provide additional medial support.

History and physical

Just as with any other musculoskeletal injury, obtaining an adequate history, especially with regard to the injury mechanism, can be invaluable in making an accurate diagnosis. Knowing the position of the foot and ankle (eg, inverted, everted, plantar, dorsiflexed) at the time of the injury is important. Other significant history includes whether the patient could bear weight after the injury, as well as the location, duration, and quality of pain. Significant swelling or bruising suggests at least a partial ligament tear, bony injury, or other extensive soft-tissue injury. A history of chronic ankle injuries, instability, or pain may suggest poor rehabilitation or other chronic, secondary injury.

The ankle examination begins with inspection for swelling, bruising, or any obvious deformity. Using the contralateral, uninjured ankle for comparison during the examination is recommended. Passive and active range of motion (ROM) and strength should be assessed, understanding that it will initially be abnormal in almost all cases of acute ankle sprains. Evaluation for tenderness to palpation over the ligamentous and tendonous structures described above will usually reveal a source of injury. It is also important to palpate specific bony structures, especially in children, understanding that in our younger athletes, the bony structures and growth plates are often weaker than the contiguous ligaments and tendons. Care should be taken to palpate both malleoli and their respective physes, the proximal fifth metatarsal—a site of peroneus brevis avulsion, and the tarsal navicular in
the skeletally immature athlete, because, as we will see, certain injuries can masquerade as ankle sprains and must be kept in mind.

**Lateral ankle sprains**

Lateral ankle stability can be tested using two common tests, the anterior drawer and talar tilt tests. (See the article elsewhere in this issue on the physical examination of the ankle). A comparison examination with the contralateral ankle is usually helpful. It should be noted that these tests can be difficult to interpret, and painful for the patient who has an acutely injured ankle.

The integrity of the ATFL can be tested with the anterior drawer test. With the ankle in slight plantar flexion, the examiner grasps the heel with one hand and holds the distal tibia and fibula just above the joint line with...
the other hand. While stabilizing the tibia and fibula, the examiner attempts to translate the foot forward with an anterior force placed on the heel. This test has been described as being performed while the patient is seated with the leg (knee) flexed over the end of the table [5,7], or with the patient supine on the examination table with only the heel lying slightly over the edge of the table [8]. The authors find the later method more comfortable for the examiner, without compromising accuracy.

The talar tilt test (also called inversion stress test) is traditionally performed with the foot in neutral position, and is used to demonstrate the integrity of the CFL. With the patient either seated or supine, the foot is placed in neutral position, and the tibia and fibula stabilized just superior to the ankle joint, usually by the inside hand, while the outside hand inverts the ankle, assessing the degree of talar tilt compared with the uninjured side [1,5,8]. Less commonly, the talar tilt test can also be performed with the foot in plantar flexion, thereby assessing the integrity of the ATFL [5,6], although the authors find the anterior drawer test to be a more reliable and better-tolerated test for assessing the ATFL. Grading the ankle sprains can be clinically useful in choosing treatment, guiding rehabilitation, and predicting prognosis. Box 1 lists ankle injuries graded by severity, and the phases of treatment for ankle injuries.

Imaging

Radiographic evaluation of ankle sprains should include an ankle series consisting of anterior-posterior (AP), lateral and mortise (oblique) views. Because less than 15% of ankle sprains are associated with fractures [9,10], use of the Ottawa ankle rules may be helpful in deciding when to obtain ankle radiographs in adults [11,12]. The Ottawa ankle rules have been shown to be 100% sensitive and 19% specific for detecting fractures, but were only used with patients who are at least 18 years of age by the investigators [9]. The same investigators [11,12] have also developed decision rules for obtaining foot radiographs as part of the evaluation of acute ankle injuries. Exclusions for the Ottawa ankle rules include patients younger than 18 years, intoxication, multiple painful injuries, pregnancy, head injury, or altered sensation due to a neurologic deficit [6]. Box 2 lists the Ottawa Ankle Rules.

When evaluating the pediatric athlete, bony tenderness, bruising, and the inability to bear weight are certainly indications to obtain radiographs. In addition, comparison views of the uninjured side can be helpful in distinguishing normal physis and secondary ossification centers from injuries more common in the children who have ankle sprains, such as bony avulsions and physeal fractures.

Treatment

The initial management of ankle sprains should include PRICE (protect, rest, ice, compression and elevation). Protection or immobilization of the
Box 1. Ankle rehabilitation in relation to severity of injury

Ankle injury severity

Grade I
- No tissue disruption (ligament stretched)
- Mild to moderate swelling/effusion
- Mild loss of function (0%–25%)
- Mild loss of ROM (0%–25%)
- No instability
- Minimal difficulty with weight bearing
- Time to return to play days to 2 weeks

Grade II
- Partial ligament tear
- Moderate to severe swelling/effusion/ecchymosis
- Moderate loss of function (25%–75%)
- Moderate to severe loss of ROM (25%–75%)
- Moderate instability
- Usually some difficulty with weight bearing
- Time to return to play 2 to 4 weeks

Grade III
- Severe swelling/effusion/ecchymosis
- Near complete loss of function (75%–100%)
- Severely limited ROM (75%–100%)
- Marked instability
- Time to return to play greater than 4 weeks

Rehabilitation phases

Phase I. Goals: control pain and swelling
- RICE (rest, ice, compression, elevation)
- Non- to partial weight bearing
- Nonsteroidal anti-inflammatory drugs (NSAIDS)
- ROM in safe planes (towel exercises)
- Isometrics (resistance against an immovable object) in all directions
- Rest-of-body conditioning
- Modalities as needed (prn) (ie, electrical stimulation, ice)

Phase II. Goal: increase ROM (active)
- Continue Phase I
- Strengthening exercises in all directions (elastic band, pick up objects with toes)
- Active ROM using pain as guide (eg, draw ABCs)
- Progress to full weight bearing
- Rest-of-body conditioning
- Modalities prn
joint can be achieved with the use of a semirigid orthosis, walking boot, or rigid cast, aided by crutch ambulation if pain indicates. Otherwise, weight bearing should be encouraged as soon as tolerated. For Grade III injuries specifically, a 7- to 14-day period of immobilization with crutches may be needed to control the initial pain and swelling. Ice should be applied for 15 to 20 minutes every 2 to 3 hours for the first 24 hours [1]. Additionally, avoidance of heat application during the first 48 to 72 hours may help to stabilize edema and inflammation [13]. Oral NSAIDs are useful for analgesia, and may help decrease inflammation. Compression can be achieved by use of an elastic wrap alone or by the use of a splinting device. When using a basic wrap, the authors recommend that placing a U-shaped, soft pad under the wrap and in place around the malleolus in order to enhance compression around the ankle. This can be accomplished with a piece of felt. Elevation at or just above the level of the heart will help facilitate lymphatic and venous drainage.

Early rehabilitation is recommended to speed recovery [14]. Investigators have shown that early mobilization may actually promote better healing, by producing a more favorable orientation of collagen fibers in the healed ligament in comparison with the healed ligament of an immobilized ankle [15,16].

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<tr>
<th>Phase III. Goals: increase strength and proprioception</th>
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<tr>
<td>Continue Phase II</td>
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<td>Full ROM in all planes</td>
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<tr>
<td>Strengthening exercises (increase resistance with elastic bands)</td>
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<tr>
<td>Proprioception exercises (balance on one foot with eyes open, closed, catch ball)</td>
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<td>Rest-of-body conditioning</td>
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<td>Modalities prn</td>
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<tr>
<th>Phase IV. Goals: full strength/proprioception, sport-specific training</th>
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<tr>
<td>Continue Phase III</td>
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<tr>
<td>Strengthening on weight equipment</td>
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<tr>
<td>Skill/sport-specific training (jogging, figure 8s, defensive slides, etc)</td>
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<tr>
<td>Limited practice/drills</td>
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<td>Proprioception on unstable surface (cushion, pillow)</td>
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<td>Modalities prn</td>
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<th>Phase V. Goal: gradual return to full activity</th>
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<td>Continue Phase IV as maintenance</td>
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<td>Gradual return to full practice/competition with bracing</td>
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<td>Modalities prn</td>
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There are five phases in ankle rehabilitation: I. control pain and swelling, II. restore ROM, III. begin muscle strengthening and proprioception, IV. start sport-specific functional rehabilitation, and V. gradual return to play. These five phases are further described in Box 1, above. The severity of injury will largely dictate how quickly the athlete progresses through rehabilitation.

In the United States, most ankle sprains are treated conservatively [1]. Acute operative repair of complete lateral ankle ligament ruptures offers no advantage in terms of subjective and objective laxity compared with nonoperative treatment at 2 years postinjury [17]. Therefore, conservative treatment for acute ankle sprains, even if complete ligament rupture is suspected, is a very acceptable treatment option [1,5,6,18].

Positive results have been reported after primary repair of acute ankle ligament tears [19,20], and some authors do advocate primary surgical repair for elite or high-demand athletes [21,22]. It should be noted, however, that delayed anatomic repair of complete ligament ruptures can be performed years after injury with results comparable to those of acute primary repair [23].

Persistent ankle pain beyond 6 to 8 weeks could indicate a complication or overlooked injury. Osteochondral injuries (see the article on osteochondral injuries elsewhere in this issue), missed fractures (see the article on ankle fractures masquerading as sprains), peroneal injury, chronic

**Box 2. Ottawa ankle rules for deciding to obtain ankle or foot radiographs in an acute ankle injury**

*Ankle series if pain in the malleolar zone*\(^a\) AND any one of the following:
- Bone tenderness at the posterior edge or tip of the medial malleolus
- Bone tenderness at the posterior edge or tip of the lateral malleolus
- Inability to bear weight immediately and in the emergency department or physician’s office

*Foot series if pain in the midfoot zone*\(^b\) AND any one of the following:
- Bone tenderness at the base of the fifth metatarsal
- Bone tenderness at the navicular
- Inability to bear weight immediately and in the emergency department or physician’s office

\(^{a}\) Malleolar zone is defined as the lower 6 cm (2.5 inches) of the fibula or fibula [11].

\(^{b}\) Midfoot zone is defined as the navicular, cuboid, cuneiforms, anterior process of the calcaneus, and base of the fifth metatarsal [11].
instability from recurrent sprains, and inadequate rehabilitation should top the list [1,3,5,6,24]. Repeat radiographs should be obtained to evaluate for bony injury, especially on the talar dome. MRI may be useful in identifying an osteochondral lesion, chronic ligament tear, or tendon injury. Box 3 lists causes of chronic pain after ankle sprains.

Prevention of ankle injuries is especially important during the several weeks after acute ankle injury, as well as with chronic ankle instability. Long-term ankle instability carries the risk of developing painful degenerative joint disease; therefore, proper rehabilitation of all ankle sprains is recommended.

Although taping remains popular, there is evidence of significant tape loosening within 20 minutes of application [25,26]. The use of a semirigid orthosis or brace was shown to be superior in controlling lateral stability and guarding against ankle sprains [27,28].

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**Box 3. Causes of chronic pain after ankle sprains**

**Fractures**
- Osteochondral (talar dome or tibial plafond)
- Lateral talar process
- Fifth metatarsal base
- Navicular
- Lateral malleolar
- Posterior distal tibial flake
- Anterior process calcaneal

**Peroneal nerve injury**

**Inadequate rehabilitation**

** Syndesmosis injury**

**Chronic instability (recurrent sprain)**

**Tendon injuries**
- Peroneal tendon tear (longitudinal)
- Peroneal tendon subluxation
- Anterior tibial tendon tear or tenosynovitis
- Posterior tibial tendon tear or tenosynovitis
- Achilles tear or tenosynovitis
- Flexor hallucis longus tear or tenosynovitis

**Impingement syndrome**

**Subtalar sprain**

**Subtalar coalition**

**Bifurcate ligament sprain**

**Complex regional pain syndrome**
**Chronic lateral ankle instability**

Chronic lateral ankle instability is defined as persistent mechanical instability at the subtalar joint, and is seen after an acute lateral ligament rupture in up to 20% of patients [5]; however, the most common factor related to chronic instability is inadequate rehabilitation after ankle sprains of any degree of severity [1,3,24]. The resultant condition is one of functional lateral ankle instability. Clinically, this is manifested as recurrent sprains, difficulty with running on uneven surfaces, jumping, or cutting, reliance on braces or taping, and loss of confidence in ankle support.

A trial of rehabilitation is usually worthwhile for most patients, focusing on motor strength (particularly the peroneal muscles), proprioception, and neuromuscular coordination [2,5,6]. Functional ankle bracing is also recommended during this treatment period to stabilize the ankle and to protect against further injury [5]. Recurrent ankle sprains and chronic instability have been associated with significant lost time away from work or sport and with degenerative joint disease [1,3,23]. Patients who remain symptomatic despite an adequate supervised rehabilitation program may be candidates for surgery. Various surgical procedures intended to restore subtalar stability have been described, but are beyond the scope of this article [5,19,20].

**Medial ankle and syndesmosis sprains**

Medial ankle sprains are usually eversion injuries, and only account for 15% or fewer of all ankle sprains [1]. In fact, some experts feel that isolated injury to the deltoid ligament complex is rare and is usually associated with a fracture [5,29].

The true prevalence of syndesmosis injuries associated with ankle sprains ranges between 1% and 10% [30]. The mechanism is eversion during an abrupt change in direction, forcing severe foot pronation and internal rotation of the leg. Bruising and swelling may be present.

Clinically, the same grading system for lateral ankle sprains can be applied to medial ankle sprains. On physical examination, pain will be localized medially. The high ankle can also be concomitantly injured, because the mechanism of injury may transmit this force proximally through the syndesmosis, and occasionally, the proximal fibula (Maisonneuve fracture). Pain may be elicited over the tibiofibular ligaments. External rotation of the ankle while in neutral position may cause pain. A positive squeeze test may be seen when the tibia and fibula are compressed or squeezed together at the mid lower leg level, causing pain distally in the ankle mortise. Deltoid instability can be appreciated by doing a valgus talar tilt test, in which the examiner applies a valgus stress to the talus from the hindfoot while in a neutral and plantar flexed position [5].

Standard ankle radiographs may show widening of the tibiofibular “clear space.” Widening greater than 6 mm or lateral displacement of the talus on the AP view or greater than 1 mm on the mortise view may indicate
a syndesmosis injury [30,31]. Stress radiographs are often useful to quantify valgus talar tilt. Chronic tearing of the syndesmosis may result in heterotopic ossification of the syndesmosis on radiographs. If radiographs are inconclusive or are nonreassuring, or if other injuries are suspected, MRI may also be useful [5].

Treatment for mild isolated medial ankle sprains should be similar to that outlined for lateral sprains (see Box 1). Higher-grade deltoid sprains often require 2 to 4 weeks of cast immobilization, followed by rehabilitation. Syndesmosis disruptions or injuries that demonstrate instability by examination or radiography may require reduction and screw fixation [5,32]. These are uncommon injuries that are difficult to evaluate, and they should be comanaged with an experienced orthopedic surgeon.

**Chronic ankle pain**

Chronic ankle pain lasting longer than 6 weeks after injury should be investigated. Complications such as osteochondral injuries may not become clinically evident until several weeks after injury. Therefore, even in the presence of previously normal radiographs, consideration for repeat radiographs should be given. If repeat radiographs remain normal, an MRI may be helpful to identify many of the causes of chronic ankle pain listed in Box 3.

**Lisfranc’s midfoot sprain**

The Lisfranc joint of the midfoot is the tarsometatarsal articulation between the bases of the first and second metatarsals and the first (medial) and second (middle) cuneiforms. Although Jacques Lisfranc, a field surgeon in Napoleon’s army, did not personally claim the name of this midfoot sprain, it was thus named because Lisfranc was the first to describe amputations through this joint, necessitated by gangrene caused when soldiers injured their midfoot as they fell of a horse while their foot was still in the stirrup [33,34]. Lisfranc joint fracture-dislocations are rare in the general population, constituting approximately 0.2% of all fractures, or fractures in 1 in 55,000 persons each year [33–35]; however, midfoot sprains may occur in as many as 4% of football players, of whom almost a third are offensive lineman [36]. This injury may be missed in up to 20% of emergency room visits; delayed or unrecognized diagnosis can lead to significant sequelae [34,35].

To understand the anatomy of the Lisfranc joint is to understand the most common mechanism of injury. Transverse ligaments connect the bases of the lateral four metatarsals; however, no transverse ligament exists between the first and second metatarsal bases, leaving only the joint capsule and dorsal ligaments to provide minimal support. Additionally, in considering the bony aspects of the joint, you will find a “keystone” wedging of the base of the second metatarsal, forming many small articulations with the cuneiforms. It is this precarious focal point that
supports the entire tarsometatarsal articulation [33,36,37]. This relatively complex anatomy renders many different injury patterns for this joint, with a sprain being the most common injury. The most consistently described mechanism is an axial loading through the joint as the foot is forcefully plantar flexed and slightly rotated [33–36]. This allows the proximal second metatarsal to dislocate dorsally. In one study, 60% of Lisfranc injuries in children occurred from falls from a height [37]. Fig. 3 demonstrates this best.

Patients usually present with dorsal foot swelling, pain at the midfoot, and inability to bear weight, especially when standing tiptoe [33]. Ecchymosis suggests a ligament tear or concomitant fracture. Plantar bruising should especially raise suspicion for a Lisfranc injury [35]. Although rarely injured, the dorsalis pedis artery courses over the second metatarsal base, and should be evaluated when a Lisfranc injury is suspected. Lisfranc injuries can be described like other sprains. Grade I (stretch injury causing pain and minimal swelling), and Grade II (partial tear causing increased pain and swelling with mild laxity) sprains are nondisplaced injuries with no clinical or radiographic evidence of instability. Grade III sprains (complete ligamentous disruptions of the capsule and supporting ligaments) vary from

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Fig. 3. Lisfranc injury. (A) A common mechanism of injury. (B) Anterior view of Lisfranc joint.
nondisplaced to frank fracture-dislocations, and demonstrate clinical and radiographic instability [5,33].

It is very important that weight-bearing views (AP, lateral, 30° oblique) be obtained if a Lisfranc injury is suspected, even in the presence of normal appearing non-weight bearing films. Loading the foot will allow the diagnostic deformities described below to become more apparent on radiograph, hopefully improving the almost 50% misdiagnosis rate observed at initial presentation [36]. Also, comparison views of the unaffected foot can be invaluable.

A Lisfranc injury should be suspected when weight-bearing AP radiographs show: (1) loss of in-line congruity between the lateral margin of the first metatarsal base with the lateral border of the first cuneiform; (2) loss of in-line congruity between the medial margin of the second metatarsal with the medial boarder of the second cuneiform—loss of these bony relationships will result in a diastasis between the first and second metatarsal; or (3) the presence of a small avulsion fracture (fleck sign) off of the second metatarsal base or first cuneiform, which may be present 90% of the time [33,35]. The weight-bearing lateral radiograph may show dorsal dislocation of the metatarsal base with respect to the cuneiform. Additionally, normal oblique foot radiographs should demonstrate alignment of the medial aspect of the fourth metatarsal base with the medial border of the cuboid [33].

A high index of suspicion combined with a careful history, physical examination, and adequate bilateral weight-bearing radiographs should suffice in most instances to make an accurate diagnosis; however, further imaging may be indicated when a significant Lisfranc injury is clinically suspected but cannot be proven by radiographs. This occurs when pain prohibits patients from full weight bearing during imaging, thereby falsely reassuring unsuspecting clinicians. Deciding which further imaging test to obtain is somewhat controversial, and seems to be guided by individual clinician experiences. Bone scanning can aid in diagnosing difficult cases [36]. In addition to identifying edema, MRI may also demonstrate hemorrhage associated with acute ligamentous injury, or may differentiate partial from complete tears [5,34]. Fine-cut CT scanning allows a more detailed analysis of alignment, can identify subtle osseous injury, and may have a role in surgical planning [5,33,34,35].

Although some controversy exists, Grade I and II sprains with normal radiographs or with metatarsal diastasis less than 2 mm can be treated conservatively with cast immobilization or walking boot for 4 to 6 weeks [33,36,38]. More severe sprains need anatomic reduction and fixation [5,35–38]. The optimal time for surgical intervention is also controversial. Recommendations range from immediate surgery (within 48 hours) to being able to successfully be repaired at 4 to 6 weeks postinjury; however, most authors agree that early intervention is essential to preserve the anatomic relationship of the joint, thereby preventing the long-term morbidity of pain, arthrosis, and disability.
Stress fractures in the foot

Stress fractures, also known as “insufficiency fractures,” “march fractures,” or “fatigue fractures,” represent the ultimate overuse injury [38]. Stress fractures occur when healthy bone is unable to withstand chronic, repetitive submaximal loads [39]. Stress fractures may account for up to 15% of all athletic injuries [40]. In the adult foot, the metatarsal and navicular bones are the most common sites for stress fractures. This is in contrast to the pediatric foot, in which stress fractures are generally much less common when compared with other sites in the skeleton (eg, spine, tibia, and fibula). Other possible sites for stress fracture in the foot include the calcaneus, tarsal bones, and sesamoids. Understandably, activities that involve repetitive stress to the lower extremity (running, jumping, or intense walking) are associated with stress fractures in the foot.

Multiple risk factors for developing a stress fracture have been discussed in the literature [39–45] and are listed in Table 1. In reality, it is more likely a combination of several risk factors rather than a single cause that leads to the development of a stress fracture; thus understanding the potential causes allows for an effective treatment and prevention plan.

Stress fractures present an atraumatic history of insidious, progressively worsening pain, aggravated by activity and relieved with rest. In the foot, pain is often localized to the involved bone. Plain radiographs should be the initial diagnostic tool of choice, though it is important to realize that the typical radiographic changes may not be obvious for 2 to 12 weeks, and more importantly, that 50% of stress fractures will never become apparent on plain films [46]. When present, abnormal findings on plain radiographs of diaphyseal (cortical-dominated) bone include periostial reaction, callous formation, or a fracture line, whereas epiphyseal injury (cancellous bone) typically demonstrates sclerosis [47,48]. Therefore, in the presence of normal radiographs, obvious risk factors, and a compatible history and physical examination, it is reasonable to establish the diagnosis of stress fracture and to treat low-risk fractures (eg, metatarsals) clinically [49]; however, because many of these athletes are in season when they present for evaluation, confirmatory diagnostic testing may be desirable to quickly establish a firm diagnosis. This often convinces the athlete (and coaches and parents) to adhere to an unpopular treatment plan that will temporarily interrupt the athlete’s season. Both the three-phase bone scan and MRI are very sensitive for identifying localized edema at the fracture site [47,48]. CT is sometimes used to further evaluate fractures that often elude findings on plain radiographs, and are also prone to complications such as nonunion or malunion if missed. An example is the navicular stress fracture seen in Fig. 4. Other stress fractures prone to chronic pain or poor healing include those involving the proximal fifth metatarsal and sesamoids.

Proper treatment mandates a period of relative rest. For most athletes, this means a temporary cessation of running or land-based training,
followed by a gradual return to activity. It is only then that the balance toward bone repair over bone destruction can be favorably tipped. During this 2- to 4-week period of modified rest, it is important for the athlete’s physical and psychological well-being to maintain some cardiovascular and muscular conditioning, in order to facilitate a gradual return to play and to prevent recurrent injury. This can be achieved by non land-based training (eg, swimming, deep pool running with a buoyant jogging belt, or cycling). Progression to more land-based activities is symptom-directed until the athlete is back to the preinjury level. This is an individualized process from one athlete to the next that is best developed in a cooperative fashion among athlete, physician, athletic trainer, coach, and parents.

Patients who have pain during nonathletic activity may require a short period of non-weight bearing (crutches) and immobilization (cast, boot, or

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<th>Risk factor</th>
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<td>Changes in training</td>
<td>Sudden increases in training volume or intensity and changing type of sports (eg, swimming to track); most stress fractures occur during the first 3–7 weeks after initiation of activity.</td>
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<tr>
<td>Activity type</td>
<td>Running and jumping activities most common; forces 2–5 times body weight generated during running.</td>
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<td>Footwear</td>
<td>Most running shoes loose 30% of their initial shock-absorption capacity after 500 miles, regardless of how much they cost. Shock-absorbing insoles shown to reduce stress fractures in the military.</td>
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<td>Effects of muscles on bone</td>
<td>Repeated, forceful muscle contractions can contribute to the development of stress fractures, especially in the upper body. Well-conditioned muscles are effective in absorbing shock and protecting bones. Contrary, fatigued, over-trained muscles loose their ability to dissipate tensile and bending forces on bone.</td>
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<td>Terrain</td>
<td>Uphill, downhill, zigzag, curbs, sloped surfaces place greater shock on the skeleton.</td>
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<tr>
<td>Age</td>
<td>Younger military recruits are more susceptible. The developing skeleton may also be at higher risk.</td>
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<td>Gender and race</td>
<td>More common in females and Caucasians</td>
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<td>Previous injury</td>
<td>60% of athletes diagnoses with stress fractures had one or more previous stress fractures.</td>
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<td>Nutrition</td>
<td>Athletes with stress fractures have been observed to consume less calcium than noninjured athletes.</td>
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<tr>
<td>Bone mineral density</td>
<td>Athletes with stress fractures have been shown to have lower bone densities than uninjured athletes.</td>
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<tr>
<td>Skeletal alignment and mass</td>
<td>Numerous reports in the literature, most of which are anecdotal or lack methodological rigor. Some of these include: genu valgus or varus, femoral anteversion, pes planus or cavus, overpronation, increased Q angle, narrow tibial width, abnormal hip rotation, tibia vara, Morton’s foot, metatarsus adductus, limited ankle dorsiflexion and subtalar motion, and tibia vara.</td>
</tr>
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pneumatic splint). This is common with historically difficult-to-heal or high-risk fractures such as those involving the sesamoids, navicular, or the proximal metaphaseal-diaphaseal junction of the fifth metatarsal (Jones fracture). It is unclear whether the application of electromagnetic fields is truly beneficial for the treatment of all stress fractures, as it has been suggested for nonunion fractures [50,51]. Surgical intervention is indicated for complications such as avascular necrosis, nonunion, malunion, or persistent pain despite appropriate treatment.

Prevention is directed toward correcting training errors, improving nutrition, ensuring the use of proper equipment, and addressing any medical issues. Additionally, the use of a shock-absorbing insole or orthotic device has been shown to be helpful in prevention [46,52,53], and should be considered if anatomic risk factors exist.

**Apophysitis**

Apophyses are the bony attachment sites of musculotendinous units that develop as accessory ossification centers and mimic the maturation of an epiphyseal plate [54]. The apophyses are constantly placed under stress from repeated muscle contraction, which can cause an irritation at the physis, referred to as apophysitis [54]. Subsequently, these injuries are unique to the growing athlete (see Fig. 5).
Sever’s disease

Calcaneal apophysitis (Sever’s disease) is a common overuse injury in the pediatric and adolescent population, accounting for approximately 8% of all overuse injuries in this group [55]. It is a traction apophysitis of the os calcis that most often occurs in athletes between the ages of 8 and 12, and can affect one or both feet [56,57].

Athletes typically complain of heel pain that increases with activity, particularly running and jumping. Physical examination reveals localized tenderness of the posterior heel at the insertion of the Achilles tendon, heel-cord tightness, and weakness of the ankle dorsiflexors [44,57]. When positive, radiographs reveal fragmentation and sclerosis of the calcaneal apophysis, but oftentimes radiographs appear normal [44,56,57].

Patients usually respond to conservative treatment consisting of relative rest from aggravating activity, ice, NSAIDs, stretching, strengthening, and shoe inserts. Heel cups, pads, lifts, or orthotics can provide significant relief from pain. A short course of supervised therapeutic exercise that addresses

![Common sites of apophysitis and osteochondrosis in the foot.](image)
gastrocnemius-soleus stretching and strengthening of dorsiflexors is recommended [44,54,56,57].

Iselin’s disease

The base of the fifth metatarsal is the site of a traction apophysitis termed Iselin’s disease. It appears as a small, shell-shaped bone fleck located on the lateral plantar aspect of the tuberosity of the fifth metatarsal [56]. It can best be identified on the oblique radiograph of the foot, although it is often helpful to obtain comparison views of the unaffected side to determine irregularity [58]. The apophysis appears in girls around age 10 and in boys around age 12, and fuses approximately 2 years later [56].

Patients will complain of pain along the lateral aspect of the foot with increased activity. Physical examination reveals pain with palpation and swelling about the tuberosity. Resisted eversion, extreme dorsiflexion, and plantar flexion of the foot increase pain [56].

Treatment consists of limiting activity, ice, NSAIDs, stretching, and strengthening exercises. A brief period of casting or immobilization may be indicated in more severe cases [56].

Osteochondroses

The term osteochondroses refers to a group of conditions of unknown origin. They are considered diseases of the ossification centers that present as an osteonecrosis followed by recalcification. The two most common of these conditions in the foot are Kohler’s disease and Freiberg’s infraction. Fig. 5 illustrates the types of osteochondroses described in this article.

Kohler’s disease

This condition refers to osteochondrosis of the tarsal navicular, which affects children between 5 and 9 years of age [57]. This is typically a unilateral condition, but may be bilateral in up to one fourth of all cases [59].

Patients complain of midfoot pain that worsens with weight bearing, and may cause a limp. Physical examination reveals localized tenderness over the navicular, swelling, and erythema [59].

Radiographs demonstrate increased sclerosis and narrowing of the tarsal navicular [57,59–61]. Figs. 6 and 7 demonstrate the contrast of the initial radiographic presentation of Kohler’s disease before and after treatment. Diagnosing Kohler’s disease may be difficult, however, because the navicular can have an irregular appearance in the normal, growing foot [56,57,59]. An estimated 20% of females and 30% of males exhibit irregular ossification of the tarsal navicular [60].

Patients usually respond well to rest, ice, and NSAIDs. Immobilization or casting for 4 to 6 weeks may be required for more severe and limiting cases [56,57,59,60].
**Freiberg’s infraction**

Freiberg’s Infraction is an osteonecrosis of the metatarsal head that seems to result from repetitive trauma [56,57,59,60]. It occurs most commonly in the second or third metatarsal, and is more prevalent in athletic adolescent females [56,59–61].

Patients experience a gradual onset of pain in the forefoot that worsens with weight bearing and activity. Physical examination reveals focal pain and tenderness over the affected metatarsal head. Initially, radiographs demonstrate widening of the metatarsophalangeal joint space, followed by collapse and sclerosis of the articular surface of the metatarsal head [59–61]. As the disease progresses, the metatarsal head reossifies within 2 to 3 years [60].

Initial treatment consists of rest and immobilization. Casting for 6 to 12 weeks may be indicated in the acute stage of more severe cases. Patients who fail conservative treatment may require surgical intervention [56].

**Tarsal coalition**

Tarsal coalition is the fusion of two or more of the tarsal bones, by way of either a bony or fibrocartilaginous bridge [60,62]. The most common types of coalitions are the calcaneonavicular and talocalcaneal, together accounting for nearly 90% of all cases, and the overall incidence of tarsal coalitions in the general population may be as high as 1% to 3% [59,60,62,63]. Patients may frequently have more than one coalition in the same foot [60,63]. Most coalitions seem to be congenital, and 50% are bilateral [59,60,63].

Fig. 6. AP and lateral foot radiographs demonstrating early presentation of Kohler’s disease of the navicular (white arrows).
Oftentimes, patients who have coalitions are asymptomatic until early adolescence, when activity levels increase and the coalition begins to ossify. Patients may complain of an insidious onset of pain that subsides with rest, and may report a history of recurrent ankle sprains, which can lead to a rigid, painful foot. The recurrent ankle sprains are thought to be caused by an increase in stress placed on the ankle secondary to the loss of subtalar motion [63].

Clinical examination reveals tenderness with palpation over the subtalar joint (lateral and anterior lateral ankle), rigid flatfoot, limited subtalar motion, absence of heel varus on tiptoes, peroneal tightness, and pain with foot inversion [60–63]. Plain radiographs, consisting of AP, lateral, and oblique views, reveal the calcaneonavicular coalition well. The talocalcaneal coalition is more difficult to identify on plain radiographs. A Harris view may be helpful in demonstrating this coalition [59].

When a coalition is suspected, CT or MRI can be employed to confirm the diagnosis. CT is considered the gold standard imaging technique for the diagnosis of tarsal coalitions. MRI can be useful in demonstrating a fibrous coalition [59–63].

Initial treatment is typically conservative and targets pain control. The use of orthotics or casting may prove useful. Stretching, strengthening, and proprioception exercises are also indicated, particularly if the patient is recovering from an ankle sprain. Patients who have talocalcaneal coalitions tend to respond with greater success to conservative treatment than those who have other coalitions [63].

Surgery may be indicated in cases that do not respond to conservative therapy. Surgical options include excision of the coalition, calcaneal osteotomy, and arthrodesis of the involved joints [60,63]. In patients younger than 18, resection of calcaneonavicular and non-bony coalitions tend to produce favorable outcomes [62]. Patients who undergo resection for talocalcaneal or calcaneonavicular coalitions may return to full activity in approximately 2 to 3 months [62].
Talar osteochondral lesions

Osteochondral lesions of the talar dome are a complication not uncommon after a seemingly ordinary ankle sprain. Also termed “osteocondritis dessecans,” these lesions make up .09% of all talar fractures and occur with approximately 6.5% of all ankle sprains [64]. The two areas of the talus most commonly affected are the posterior medial and anterior lateral aspects [56,60,65,66]. Posterior medial lesions are often asymptomatic and are less likely to become detached, whereas anterior lateral lesions tend to be more symptomatic and displace more frequently [65,66]. Talar osteochondral lesions are usually associated with trauma.

Ankle pain is the most common patient complaint. Patients may complain of persistent effusion, intermittent swelling, or delayed synovitis. Other symptoms may include ankle stiffness, instability or give-way episodes, or locking or catching in the joint [56,64,66]. Physical examination may reveal increased pain with ankle inversion or tibial talar compression, decreased ROM, weakness, and gastrocnemius atrophy.

It is important to consider osteochondral injury of the talus (osteocondritis dissecans) when ankle sprains do not respond to 6 to 8 weeks of conservative treatment [56]. Plain radiographs will not always identify the lesion. If plain radiographs are normal but suspicion remains clinically high, MRI is very sensitive in identifying and grading osteochondral lesions. Fig. 8 demonstrates an example of a large talar osteochondral lesion. CT scan can complement the MRI when additional staging and preoperative planning are needed to locate the exact position of the fracture [67]. A modified version of the Berndt and Harty classification used to stage osteochondral fractures of the talus [60] is as follows:

Stage I: Localized trabecular compression
Stage II: Incompletely separated fragment
Stage IIA: Formation of a subchondral cyst
Stage III: Undetached, undisplaced fragment
Stage IV: Displaced or inverted fragment

Treatment for talar osteochondral lesions is dependent upon the condition of the subchondral bone and overlying articular cartilage [63]. Nonoperative treatment consisting of immobilization and limited weight bearing for 6 weeks is recommended for all Stage I, II, and medial-sided Stage III lesions. Surgery is indicated for lateral-sided Stage III and all Stage IV lesions [60,64,65].

Peroneal tendon injuries

Peroneal tendon injuries include tendonitis, tears, and subluxation. The peroneus longus tendon (PLT) and peroneus brevis tendon (PBT) traverse
the ankle within a common sheath. The sheath travels posterior to the lateral malleolus and is anchored by the superior peroneal retinaculum at the lateral malleolus and the inferior retinaculum beneath the lateral malleolus. The PBT inserts on the lateral aspect of the fifth metatarsal, and the PLT traverses the cuboid to insert at the base of the first metatarsal. The peroneal tendons act to abduct, evert, and plantarflex the foot.

Peroneal tendonitis results from overuse. The peroneal tendons may be anatomically susceptible to chronic injury because of how they are tethered around the lateral malleolus. Symptoms include lateral ankle swelling, retrofibular pain, and subjective ankle instability [68]. Strength testing reproduces the described pain. Standard radiographs have limited value in routine evaluation, because they are often normal but can exclude other pathology. Treatment for peroneal tendonitis initially involves relative rest, ice, and anti-inflammatory medications; for severe symptoms, short-term immobilization may be necessary [69]. Tenosynovectomy is indicated for recalcitrant cases [68].

Peroneal tears, which are often longitudinal, can be difficult to detect because symptoms mimic other common causes of lateral ankle pain [69]. Patients report pain and swelling at the lateral ankle, with associated joint instability. The examiner should evaluate for tenderness over the peroneal tendons, increased hindfoot varus, and pain with active evasion to differentiate between peroneal injuries and more common ligamentous sprains [70]. If the diagnosis remains in question, MRI is indicated [68]. If peroneal tendon rupture is suspected or confirmed, conservative therapy may be attempted; however, surgical repair is often needed [70].

Peroneal tendon subluxation is uncommon, but can be a source of chronic lateral ankle pain. Often symptoms of acute peroneal subluxation are misdiagnosed, leading to recurrent subluxation, instability, and pain [71].

Fig. 8. MRI of the ankle demonstrating osteochondritis dissecans of the talus (white arrow).
Peroneal subluxation can be seen in various athletes, but most commonly in skiers [72]. The mechanism of subluxation injury has been proposed as peroneal contraction with the ankle in dorsiflexion and eversion [73]. Patients often report a popping sound or sensation at the posterior aspect of the ankle, with associated pain, swelling, and ecchymosis. Patients rarely present acutely because symptoms initially improve, but seek evaluation secondary to subsequent chronic subluxation and instability [68]. Peroneal subluxation can be elicited on examination by having the patient hold the foot in dorsiflexion and eversion while being manually resisted, observing the peroneal tendons as they sublux over the lateral malleolus. Obtain standard radiographs to evaluate for avulsion fracture of the lateral malleolar rim. Chronic subluxation is usually treated surgically. Surgical repair for acute dislocations is preferred especially in active patients; however, conservative management may be initially attempted [69].

**Plantar fasciitis**

Plantar fasciitis is the most common cause of inferior heel pain [74]. Plantar fasciitis was initially described as inflammation of the plantar aponeurosis, but recent histological studies indicate that this disorder is associated with degenerative changes in the fascia [75]. The plantar aponeurosis stretches from the calcaneal tuberosity, dividing to attach near the plantar aspect of the proximal phalanges, and acting as an important structure for dynamic arch support [76].

Plantar fasciitis results from microtrauma to the plantar aponeurosis from jumping or prolonged standing [77]. Individuals who have predominantly standing occupations and those whose body-mass index is greater than 30 kg/m² are at increased risk for development of plantar fasciitis; however, reduced ankle dorsiflexion appears to be the most important risk factor [78]. This condition is common in dance athletes, especially ballet and aerobic dancers. Plantar fasciitis is usually an isolated issue, but it can occasionally be associated with systemic rheumatologic diseases. Certain seronegative spondyloarthopathies, such as Reiter’s syndrome, anklyosing spondylitis, and psoriatic arthritis, can affect the entheses and periosteum, mimicking plantar fasciitis [79]. Studies have shown heel spurs in approximately half of patients who have plantar fasciitis; however, the presence of these spurs has not been proven to be causative in the development of symptoms, and is unrelated to treatment outcomes [80]. The authors approach the presence of spurs much like the chicken-versus-egg dilemma. Spurs only become clinically significant when they are felt to be a specific source of pain. Patients suffering from plantar fasciitis almost universally report plantar heel pain elicited with initiation of walking after rest, especially with the first steps in the morning after waking. On examination, localized tenderness is palpated at the anteromedial aspect of the heel with the foot in dorsiflexion. Laboratory testing is not helpful in the diagnosis, but is indicated when concern for
systemic rheumatic diseases exists. Radiograph investigation is used to rule out other suspected causes of heel pain or after conservative treatment has failed. MRI can be considered in refractory cases of plantar fasciitis to confirm the diagnosis. History and examination should differentiate between plantar fasciitis and other conditions, including tenosynovitis of the posterior tibialis or flexor hallucis longus [81].

Conservative treatment works best when started within 6 weeks after onset of symptoms [74]. Treatment includes relative rest, ice massage, arch supports, and fascial and heel-cord stretching and strengthening. The benefit of orthotics in the literature has been controversial; however, anecdotally this otherwise noninvasive treatment seems to have good clinical efficacy. NSAIDs are useful for short-term pain management. Night splints locking the ankle in dorsiflexion are helpful, but are often poorly tolerated by patients [82]. Stretching the Achilles tendon and strengthening intrinsic ankle and toe muscles should be encouraged. Footwear with adequate arch support and cushioning assists in limiting symptoms [83]. Localized points of tenderness may be amenable to corticosteroid injection, which has shown transient benefit. Corticosteroid injection can be complicated by fat-pad atrophy and even plantar fascia rupture; therefore, injection is considered a second-line therapy for experienced practitioners [76].

Extracorporeal shock-wave therapy for plantar fasciitis has been described with mixed results in the literature [84–89]. There is promise for this treatment as an additional option in our armamentarium, but it should probably be reserved for refractory cases. Finally, surgical intervention is rarely necessary, and only after aggressive and persistent conservative care has failed to alleviate patients’ symptoms. Surgery involves dividing the central portion of the plantar aponeurosis or partial fasciectomy, and neurolysis of the nerve to the abductor digiti quinti.

Turf toe

Turf toe is a hyperextension sprain of the first metatarsophalangeal joint. The term arose after the injury was linked with athletes competing on hard artificial surfaces. The classic mechanism of injury is a forced hyperextension injury of the first metatarsophalangeal (MTP) joint, with resulting subluxation and damage to the joint capsule [90]. Hyperflexion, valgus, and varus stress can also cause MTP injury [91]. Predisposing conditions to turf toe include a relatively firm artificial playing surface, wearing highly flexible footwear, and increased ankle dorsiflexion [92].

The diagnosis is clinically based on a history of hyperextension, allowing for predisposing factors. The differential diagnosis includes hallux rigidus, strain of the flexor hallucis, arthritis, gout, and fractures of the first metatarsal or sesamoids. Classic signs and symptoms include pain located over the plantar and medial aspect of the first MTP joint, with associated
swelling and ecchymosis [93]. Examine the joint for points of maximum tenderness and ligamentous stability. More severe injuries will exhibit marked swelling, limited ROM, and an antalgic gait [94]. Radiographs assist in narrowing the differential diagnosis and evaluate for avulsion fragments, sesamoid fractures, and possible degenerative arthritis [94]. If radiographs prove inconclusive or concerning, further imaging, including bone scan and MRI, may be considered. Bone scans will reveal stress fractures involving the sesamoid bones. MRI is definitive in diagnosing capsular disruption, and should be ordered if a severe injury is suspected [93].

Turf toe is often acutely disabling for athletes, and prompt treatment is recommended to prevent long-term sequelae of progressive hallux valgus, hallux rigidus, and arthrosis [94]. Treatment plans should be individualized, depending on the severity of the injury. Mild sprains respond to supportive care including ice, compression, and NSAIDs [93]. Further hyperextension can be limited with local taping and footwear modification creating stiffer soles [91]. Moderate sprains require augmentation of supportive care with partial immobilization and activity modification. Early ROM and strengthening exercises should be advanced as symptoms permit. Severe injuries, including dislocation, warrant immobilization with reduced weight bearing or crutches [94]. Long-term treatment involves shoe modification with a stiff forefoot insole or insert. Intra-articular fractures and dislocations require reduction and specialist consultation. Overall, surgery is rarely needed for turf toe, but it can be a chronically painful and frustrating problem for athletes to overcome.

Summary

Foot and ankle injuries are among the most common in athletes. Differential diagnosis, imaging decisions, and treatment plan should be influenced by the age of the athlete. A thorough history and physical examination, with an understanding of the anatomy of the foot and ankle anatomy and the mechanism of injury, will give the best opportunity to make the correct diagnosis. For most athletes, the prognosis for returning to play after a foot or ankle injury is very good. The recipe for keeping our athletes healthy includes early intervention, undergoing proper rehabilitation, applying braces or orthotics when indicated, and preventing injuries when appropriate.

References


