Acute soft-tissue injury to the foot has become an increasingly recognized problem in sports. Foot injuries rank third behind ankle and knee injuries as the most common time-loss injury among athletes according to the Weekly injury reports. This nemesis persists among the players in the National Football League. Of these injuries, a large proportion are sprains of the forefoot and the greatest proportion of these occur to the great toe metatarsophalangeal (MP) joint—an injury commonly referred to as turf toe.

The term turf toe was first established in the literature by Bowers and Martin in 1976. They correlated the increased incidence of traumatic injuries to the metatarsophalangeal joint of the great toe with participation on an artificial playing surface, and the use of more flexible shoe wear which became popular for use on the artificial surfaces.

Turf toe injuries can result in significant functional disability. Push-off is markedly impaired. Forward drive and running are compromised, initially believed to be a low morbidity injury, turf toe injuries have been found to have significant short term and long term morbidity and disability. It is for these reasons that a review of the relevant anatomy and biomechanics, causative factors, mechanism of injury, clinical assessment and treatment is important for the sports medicine specialist.

**ANATOMY AND BIOMECHANICS**

The capsuloligamentous complex is the essential stabilizing component of the first MP joint. Minor stability is provided by the shallow socket of the proximal phalanx articulating with the biconvex surface of the metatarsal head. Musculotendinous structures contribute to the capsuloligamentous complex, and provide dynamic support to the first MP joint (Fig. 1).

The first MP joint is unique in having medial and lateral sesamoids. The
Abductor hallucis

Flexor hallucis longus

Flexor hallucis brevis

Figure 1. Musculotendinous structures contributing to the capsuloligamentous complex. (Modified from Mann RA, Coughlin MJ: Hallux valgus and complications of hallux valgus. In Mann RA [ed]: Surgery of the Foot, ed 5. St. Louis, CV Mosby, 1986, p 66; with permission.)

The complex characteristics of the surrounding structures of the first MP joint reflect the demands placed upon this region. The great toe typically carries more than twice the load as compared to the lesser toes. The maximum force acting across the first MTP joint is equal to 40% to 60% of the body weight. During jogging and running, peak forces can be increased by two or three times and a running jump may increase these forces to almost eight times body weight.

The total of the first MP range of motion is quite variable, with the range of dorsiflexion greater than plantar flexion under normal circumstances. Joseph showed a range of passive plantar flexion from 3 deg to 43 deg and passive dorsiflexion from 40 deg to 100 deg. Total MP joint range of motion usually decreases with age: At least 60 deg of dorsiflexion is considered normal in barefoot walking on a level surface. Yet, restriction of MP joint dorsiflexion from 25 deg to 30 deg by stiff-soled footwear occurs without significantly affecting gait.

CAUSES OF TURF TOE INJURY

The causes of turf toe injury have primarily been related to artificial turf and shoewear characteristics. Other potentially responsible factors include restricted first MP motion, player sport and position, decreased ankle motion, foot shape, and a history of prior injury. The following discussion analyzes the contribution of these factors to turf toe injuries.

Artificial Turf

Artificial grass playing surfaces were introduced in the late 1960s. Although first MP joint sprains occurred in sports prior to the arrival of synthetic
grass, they were unworthy of mention in the literature. The incidence of first MP injuries appeared to increase as more athletes practiced and competed on artificial surfaces.

Hardness of the artificial turf has been alleged as a factor in the increased incidence of turf toe injuries. With age, synthetic surfaces lose resiliency and shock absorption capacity. Clanton and colleagues analyzed the relationship between turf injuries at Rice University occurring on the older, harder synthetic grass surface, compared with a more modern synthetic surface placed on the Rice stadium in 1980 and again in 1986. There was no significant change in the incidence of turf toe injuries documented on the different artificial surfaces during this period.

Nigh and Segesser showed an increased incidence of first MP injuries and correlated this to the enhanced surface friction inherent to artificial surfaces. With increased surface friction the forefoot becomes fixed on the turf. Externally applied forces on the athlete, push the foot into abnormal positions with respect to range of motion resulting in injury. Clanton and coworkers also believe that surface friction plays a significant role in the causes of turf toe injury. A high incidence of turf toe injuries have been observed in American football. Interestingly, soccer and lacrosse, which also practice and compete on artificial surfaces, have not observed a similar increase in incidence of turf toe injuries, according to published reports.

It seems evident that artificial surfaces do play a role in turf toe injury; however, the exact factor (hardness or friction or both) that is most responsible has not been conclusively determined. Furthermore, there must be other important contributing factors associated with this injury and affecting the injury rate seen in different sports.

Shoe Wear

The change from traditional grass to the artificial variety necessitated a change in shoe wear. The grass football shoe had seven cleats that attached to a metal plate in the sole. When this grass shoe was first used on the newly introduced "Astroturf," the players complained of poor traction whereas the team physician reported a lower injury rate. The importance of traction to performance led to a search for a more acceptable shoe for artificial turf and the subsequent usage of the multicleated but more flexible soccer shoe. This more flexible soccer-style turf shoe contributed to an increase in turf toe injuries because stress across the forefoot was more directly applied to the MP joints of the foot. As a result, more forefoot sprains were sustained. In a study of turf toe injury evaluating shoe type, football players wearing a flexible turf shoe were compared with players wearing a modern turf shoe with a stiffened forefoot. Results showed the players wearing more modern turf shoes with a stiffened forefoot were less likely to sustain a turf toe injury.

First MP Range of Motion

Beginning with the earliest reports of first MP joint injuries, the relationship with first MP joint range of motion was questioned. Coker and coworkers reported no relationship between first MP range of motion and turf toe injury. In their initial investigation of Rice University athletes, the authors concluded that range of motion was a significant factor and advised protection of those athletes who manifested a reduction in first MP dorsiflexion below 60°. Rodeo and colleagues found no such relationship in their study of professional football players, but noted the need for future research on this topic. Therefore, a more conclusive study was undertaken. Clanton and coworkers addressed the role of first MP motion and turf toe injuries. Football players were analyzed to determine whether or not limited first MP range of motion predisposed an athlete to a potential turf toe injury. The results showed no significant predictive merit in first MP compression, plantar flexion, or total range of motion values between injured and uninjured athletes. However, significant differences in dorsiflexion and total range of motion were observed between unjured and previously injured athletes. Dorsiflexion and total range of motion were lower in the previously injured athletes, whereas the mean age for the injured player to be 27.4 years as opposed to 24.7 years.

The study by Clanton and coworkers analyzed this and other causative factors. No statistical difference between positions was indicated, but offensive and defensive players were grouped by similar skills to provide statistically valid numbers in each group. Player weight had no bearing on injury risk. The study of professional football players showed the mean age for the injured player to be 27.4 years as compared to 24.7 years for controls. The mean number of playing years was 5.2 years for those injured compared to 3.0 years for controls. Mean range of ankle dorsiflexion was greater (13.3 deg) in injured players when compared to non-injured dorsiflexion in uninjured players (7.9 deg). A final predisposing factor that has been confirmed by subsequent reports is flattening of the first metatarsal head as noted by Coker and associates.

MECHANISM OF INJURY

Multiple mechanisms of injury have been associated with sprains of the first MP joint in athletes. The most common mechanism is a hyperextension injury to the MP joint. In this circumstance, the foot is typically in a dorsiflexed position with the forefoot fixed on the ground and the heel plantar flexed. Then, an external force drives the first MP joint into further dorsiflexion, and ultimately into exaggerated dorsiflexion. The joint capsule tears at the metatarsal neck because its attachment is weaker at this site than at the proximal phalanx. Compression injury to the dorsal articular surface of the metatarsal head also can result at the extremes of hyperextension. This type of hyperextension force is seen, for example, when a
player is caught in a pileup with his forefoot on the ground and the heel raised. Another player lands on the back of his leg and forces the MP joints into hyperextension (Fig. 3A and B).

Hyperflexion of the first MP joint can also produce a turf toe injury. A plantar flexed foot is forced into an exaggerated position with a resulting sprain of the dorsal capsule. This mechanism can be seen in a ball carrier who is tackled from behind and the knee is forced forward while the foot is plantar flexed.

A valgus mechanism of injury is less commonly observed in a pure form, but often is associated with the other injury patterns. Valgus stress is produced by the force of pushing off the foot from stance. Coker and coauthors felt that this mechanism was most responsible for the symptoms of a more chronic nature. Rodeo and coworkers have theorized that pes planus results in increased stress on the medial aspect of the foot and thereby predisposes individuals to a valgus mechanism of injury.

A final mechanism of injury that is rarely observed in turf-related injuries is pure varus stress. Mullis and Miller have reported this mechanism of injury in a basketball player who externally rotated on a fixed forefoot. Surgical exploration showed avulsion of both transverse and oblique heads of the adductor hallucis from the base of the proximal phalanx as well as capsule and collateral ligament tears. The flexor hallucis longus and brevis were intact.

Figure 3. Mechanism of Injury—hyperextension. A. Player falling towards the back of the leg and foot of an opponent player. B. Opponent's player foot dorsiflexed with forefoot fixed on ground and heel raised. Force of falling player drives the foot into further dorsiflexion and ultimately exaggerated dorsiflexion. (Photographs courtesy of Thomas O. Clanton.)

Clinical Assessment

Once a turf toe injury occurs, the clinician must determine the severity of the injury in order to institute appropriate treatment. In the player with chronic symptoms, the goals are to limit stress on the first MP joint, prevent further injury, and enable the athlete to complete the season at the highest level possible. In order to planning and allow some prediction for return to play, the authors created a classification system for these injuries that has since been modified slightly. It is important to recognize that turf toe injury with great variability in the extent of injury, as well as in athletes' responses to similar injuries.

Grade 1 Sprain

This is essentially a stretch injury or minor tearing of the capsuloligamentous complex of the first metatarsophalangeal joint. Clinical symptoms include localized plantar or medial tenderness, minimal swelling, and the absence of ecchymosis. There is minimal restriction of range of motion. The athlete is able to bear weight with minimal symptoms, and able to continue athletic participation with mild pain. This is also the typical clinical picture in the athlete with the chronic sprain.

Grade 2 Sprain

This is a partial tear of the capsuloligamentous complex of the first MP joint. Tenderness is more intense and diffuse than in the grade 1 sprain. Moderate swelling and ecchymosis are present (Fig. 4). There is usually mild to moderate restriction of range of motion. The athlete has moderate pain and a mild limp with weightbearing. Symptoms usually worsen during the first 24 hours. The player is unable to perform at his normal level.

Grade 3 Sprain

This is a more complete tear of the capsuloligamentous complex and often includes tearing of the plantar plate from its origin on the metatarsal head-neck.
juncture (in the hyperextension mechanism) and an impaction of the proximal phalanx into the metatarsal head dorsally. There may be a sesamoid fracture or separation of a bipartite sesamoid (Fig. 5). In rare circumstances, the tear of the capsuloligamentous complex is distal to the sesamoids and can result in their proximal migration. Clinical symptoms include severe pain and tenderness on both the plantar and dorsal aspects of the first MP joint. There is marked swelling and obvious ecchymosis. Severe restriction of first MP range of motion is present. The athlete is unable to bear weight normally on the medial aspect of the forefoot and is obviously unable to perform.

Diagnostic Studies

In grade 3 sprains routine anterior-posterior, lateral, and oblique radiographs are taken to rule out potential bony pathology such as capsular avulsions, sesamoid fractures, impaction injuries, separation of a bipartite sesamoid, or proximal migration of the sesamoids. An occasional grade 2 injury will also warrant radiographic evaluation. A number of other diagnostic methods have been proposed and include stress radiographs to rule out instability, arthrography to document capsular tears, bone scintigraphy to assess bone injury, and MR imaging to better define the soft tissue injury and possibly osseous/articular cartilage trauma. The use of these methods has gained little acceptance and does not appear warranted in the majority of circumstances.

Operative Treatment

Surgical treatment is rarely indicated for first MP sprains. Athletes with persistent symptoms after an adequate course of nonoperative treatment should be further evaluated for a possible loose body within the first MP joint, sesamoid fracture, separation of a bipartite sesamoid, proximal migration of the sesamoids, or evidence of instability which can result in persistent symptoms.

In the study by Clanton and colleagues, one patient underwent delayed surgery for removal of a symptomatic fragment of a fibular sesamoid bone. Three patients, including one with a symptomatic fragment of an additional sesamoid, underwent excision of the distal sesamoid fragment and repair of the capsule. A fourth athlete underwent acute surgical treatment for an avulsion fracture involving the sesamoid.

Figure 5. Grade 3 sprain with separation of a fibular bipartite sesamoid. (Radiograph courtesy of Thomas O. Clanton.)
SUMMARY

Long term morbidity secondary to previous first MP injury has been reported by Coker and associates and involved persistent pain with athletic activities and restricted range of motion. Clanton and coworkers have reviewed 20 athletes with prior turf toe injury with greater than 5 year follow-up noting a 50% incidence of persistent symptoms. Further study is needed regarding the long term effect of turf toe injury, but it is clearly a significant athletic injury that requires appropriate treatment tailored to the severity of the injury.

References