21 Sarrifian, SK: Anatomy of the Foot and Ankle, ed 1. Philadelphia, JB Lippincott, 1983, pp 187-189
22 Wiley JJ: The mechanism of tarso-metatarsal joint injuries.] Bone Joint Surg 53:474-482, 1971
23 Wilppula E: Tarsometatarsal fracture-dislocations: Late results in 26 Patients. Acta Orthop Scand 44:335-345, 1973
24 Wilson DW: Injuries of the Tarso-metatarsal joints: Etiology, classification and results of Treatment. J Bone Joint Surg 54:677-686, 1972

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TURF TOE INJURY

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Acute soft-tissue injury to the foot has become an increasingly recognized problem in sports.[4,5,8,9,20] Foot injuries rank third behind ankle and knee injuries as the most common time-loss injury among athletes at si ;eUniversity.[4] According to the Weekly injury reports, this nemesis persists among me players in the National Footbail League. Of these injuries, a large proportion are sprains of tike forefoot and the greatest proporfio n 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 literatu•e by Bowers and Martin in 1976.[2] 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 shoewear which became popular for use on 'the artificial surfaces

Turf toe injuries can result in significant functional disability. Push-off ts 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 potential long term morbidity and disability. It is for these reasons that a review of the relevant anatomy and Biomechanics, causati re 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

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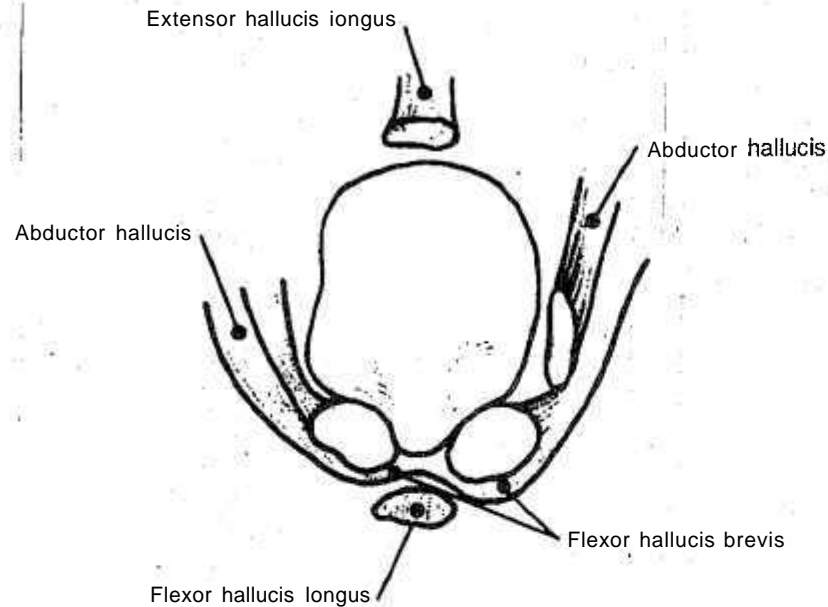
Figure 1. Musculotendinous structures contributing to the capsuloligamentous complex. (Modified from Mann RA, Coughlin MJ: Hallux valgus and complications of hallux valgus. *In* Mann RA [ed]: Surgery of the Foot, ed 5. St. Louis, CV Mosby, 1986, p 66; with permission.)

Figure 2. Diagrammatic representation of the two components of the collateral ligament complex of first MP joint (*From* Clanton TO et al: Injuries to the metatarsophalangeal joints in athletes. Foot Ankle 7:162–176, 1986; with permission.)

sesamoids are enveloped within the double tendon of the flexor hallucis brevis, and connected to the plantar base of the proximal phalanx through the plantar plate. On the medial aspect of the first MP joint, the abductor hallucis tendon contributes to the capsule as it inserts onto the tibial sesamoid, and continues distally to insert onto the plantar medial base of the proximal phalanx. On the lateral side, the adductor hallucis tendon has a similar relationship to the capsule and the fibular sesamoid and continues distally to the base of the proximal phalanx. The medial and lateral aspects of the MP joint are supported by strong collateral ligaments, which have two components, the MP ligament and the metatarsosesamoid ligament (Fig. 2). The plantar plate is a thick fibrous structure firmly anchored to the base of the proximal phalanx, and loosely attached to the neck of the metatarsal via the capsule. The short flexor and extensor tendons blend with the capsule and provide additional support. Along with the long flexor and extensor tendons, all of these structures provide varying degrees of support to the MP joint.[23]

Biomechanically the instant centers for motion for the first MP joint fall within the metatarsal head.[5] Motion occurs between the metatarsal head and the proximal phalanx by a sliding action at the joint surface. In full extension this sliding action gives way to compression of the dorsal articular surfaces of the metatarsal head and proximal phalanx.[5] Owing to the cam effect of the metatarsal head, various portions of the collateral ligament complex are under tension during different stages of the joint range of motion.
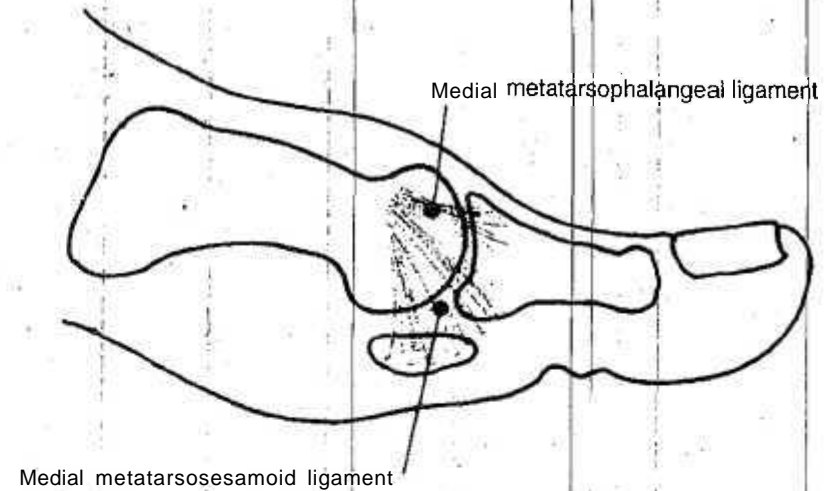
The complex characteristics of the surrounding structures of the first MP joint reflect the demands placed upon this region. The great toe typically carries more than twice the load as compared to the lesser toes.[22, 24] The maximum force acting across the first MTP joint is equal to 40% to 60% of the body weight.[24] 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.[4]

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.[14] 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.[1] Yet, restriction of first MP joint dorsiflexion from 25 deg to 30 deg by stiff-soled shoewear occurs without significantly affecting gait.[1]

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.[2, 3, 25] 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.[2] With age, synthetic surfaces lose resiliency and shock absorption capacity. Clanton and colleagues analyzed the relationship between turf toe 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.[5] There was no significant change in the incidence of turf toe injuries documented on the different artificial surfaces during this period.

Nigg and Segesser[19] 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 acting 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.[5]

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 riot observed a similar increase in incidence of turf toe injuries, according to published reports.[12, 17, 18]

ft 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.

Shoewear

The change from traditional grass to the artificial variety necessitated a change in shoewear. 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.[25] 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 modem 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.[5]

First MP Range of Mption

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.[9] 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 deg.[5] Rodeo and colleagues found no such relationship in their study of professional football players, but noted the need for more research on this topic.[20] Therefore, a more conclusive study vVas undertaken. Clanton and colleagues[6] evaluated football players and specifically addressed the role of first MP motion and turf toe injuries.[7] 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 determining preseason dorsiflexion, plantar flexion, or total range of motion value in the uninjured athletes, however, significant differences in dorsiflexion and total range of motion were observed between uninjured and previously injured athletes! Dorsiflexion and total range of motion were ipwer in the previously injured athletes. Dorsiflexion appears to be the most important range of motion variable affected by turf toe injury. Plantar flexion was not significantly different when comparing the injured and uninjured athletes. Whether this results in an increased risk of re-injury or potential future disability is unknown. Additional follow-up of these athletes is required.

Miscellaneous Causative Factors

Other causative factors contributing to turf toe injures have been suggested. These include player position, player weight, age, years of participation, ankle range of motion, pes planus, and a flattened first metatarsal head.[7, 9, 20] Coker and colleagues[9] first suggested that running backs were at increased risk of turf toe injury. This was confirmed by Rodeo and colleagues in a subsequent study.[20] They concluded that offensive players were at a higher risk than defensive players with running backs, wide receivers, and linemen at greatest risk."

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 increase numbers for the purpose of obtaining statistically valid numbers in each group.[5, 7] Player weight had no bearing on injury risk.[7] 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 mean ankle dorsiflexion in uninjured players (7.9 deg). A final predisposing fact Dr that has been unconfirmed by subsequent reports is flattening of the first metatarsal head as noted by Coker and associates.[9]

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 joints. In this circumstance, the foot is typically in a dorsiflexed position with the forefoot fixed on the ground and the heel raised. 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[9] felt that this mechanism was most responsible for the symptoms of a more chronic nature. Rodeo and coworkers[20] 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[16] have reported this mechanism of injury in a basketball player who externally rotated on a fixed forefoot. This resulted in significant instability of the first MP joint with varus stress. 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.[16]

Figure 3. Mechanism of injury—hyperextension. A. Player falling towards the back of the leg and foot of an opponent pSayer. 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 arid 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 of performance. In order to plan treatment and allow some prediction for return to play, the authors created a' classification system fpr these injuries that has since been modified slightly.[5,11] It is important to recognize that turf toe constitutes a spectrum of 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 the range ot motion. The athlete is usually 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 mption. 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

Figure 4: Grade 2 sprain: Moderate swelling and presence of ecchymosis. (Photograph courtesy of Thomas O. Clanton.)

junction (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.[15] 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.

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

TREATMENT

Nonoperative Treatment

Initial treatment of first metatarsophalangeal joint sprains includes the typical R.I.C.E. formula of rest, ice, compression, elevation, Early joint mobilization is crucial because loss of motion is a common sequela of injury. Rest is the key component of treatment, and usually the most difficult to control and enforce. The difficulty in compliance stem's from the assumption by both the player and coach that this is a minor injury. Unfortunately, returning too early to competition almost always extends the convalescence and results in a more prolonged disability.

Cryotherapy is best delivered in 10- to 20-minute intervals over the first 48 hours after injury. This therapy is accomplished by placing the foot in a bucket of ice water or a cold water whirlpool. Progression to contrast whirlpool treatment commences after 48 hours. Compression is accomplished by taping the toe. or wrapping the toe with a compressive dressing. Nonsteroidal anti-inflammatory medication is also prescribed.

Another component of treatment is equipment modification. The goal is to reduce the stresses across the forefoot, and this is accomplished by reducing the flexibility of the shoewear. Increased stiffness in the athletic shoe helps prevent hyperextension (or hyperflexion) of the MP joints. This can be achieved by placing an insole that includes a stainless spring-steel plate in the forefoot region into the turf shoe (Fig. 6). If the stiffened insole is not tolerated well by the athlete, or a more chronic condition exists, a custom insole which better conforms to the foot is fabricated. This insole is designed with a Morton's extension and is formulated from a stiff enough material to limit first MP joint movement (Fig. 7).

The athlete with a grade 1 injury typically continues participation as symptoms allow. The toe is taped, and a stiffened insole is used in both practice and games. There is usually no loss of playing time. Grade 2 injuries usually result in loss of playing time ranging from 3 to 14 days. A grade 3 injury will typically require the athlete to use crutches for ambulation over the first 1 to 3 days. Expected loss of playing time is longer, often ranging from 2 to 6 weeks.

The majority of first MP joint sprains, regardless of grade, if properly treated and protected will heal in a 3- to 4-week period. The Use of cortisone or anesthetic injection is not indicated in this type injury and can result in exacerbation of the original injury leading to a more prolonged recovery.

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 aVulsed bone.[4] Rodeo and coworkers recently reported on athletes with diastasis of a bipartite tibial sesamoid.[21] In three patients, observation and protect ok resulted in progressive widening of the sesamoid fragments. They were treated with excision of the distal sesamoid fragment and repair of the capsule. A fourth athlete underwent acute surgical treatment, again/involving distal medial sesamoid fragment exci-
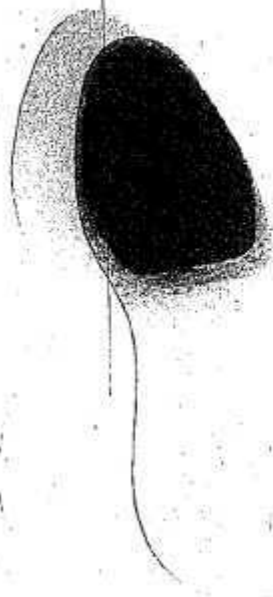
Figure 6. Example of commercially available orthotic device with steel spring plate in the forefoot. (From Clanton TO, Schon LS: Forefoot sprains. In Mann RA, Coughlin MJ [eds]: Surgery of the Foot and Ankle, ed 6. St. Louis, CV Mosby, 1993, pp. 1191–1200; with permission.)
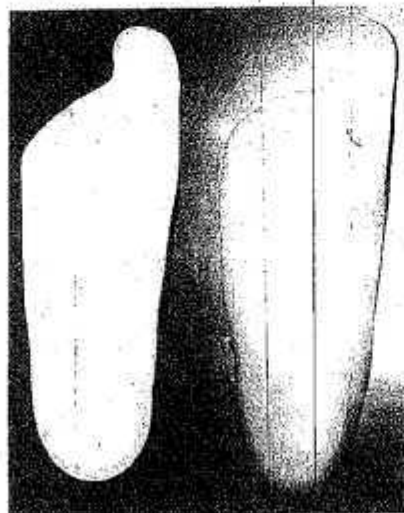
Figure 7. Example of custom-made orthotic device, dorsal and plantar views (From Clanton TO, et al: Injuries to the metatarsophalangeal joints in athletes, Foot Ankle 7:162–176, 1986; with permission.)

sion and capsular repair, All players in their study had a full return jo sports activity.[21]

SUMMARY

Long term morbidity secondary to previous first MP injury has been reported by Coker and associates[9] and involved persistent pain with athletic activities and restricted range of motion. Clanton and coworkers[5] noted hallux valgus and early hallux rigidus as specific long term sequelae. Clanton and Seifert[6] 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

1. Bojsen-Moller F, Lamoreaux L: Significance of free dorsiflexion of the toes in walking. Acta Orthop Scand 50:471–479, 1979

2. Bowers KD Jr, foarttrl RB: Turf-toe: A shoe related foothill injury. Med Sci Sports Exerc 8:81–83, 1976

3. Bowers KD Jr, Martin RB: In pact absorption, new and old astroturf at West Virginia. Med Sci Sports Exerc 6:217–221, 1974

4. Clanton TO: Etiology of injury to the foot and ankle. In Delee JC: Drez D (eds) Orthopaedic Sports Medicine: Principles and Practice. Philadelphia, WB Saunders, 1994, p 1642–1704

5. Clanton TO, Butler JE, Eggert A: Injuries to the metatarsophalangeal joints in athletes Foot Ankle 7:162–176, 1986

6. Clanton TO, Seifert S: Long-term sequelae of turf toe injury. Unpublished observations study in progress

7. Clanton TO, Eggert KE, Pivarnik JM, et al: First metatarsophalangeal joint range of motion as a factor in turf toe injuries. Submitted for sub ication, 1994

8. Clanton TO, Schon, LS: Forefoot sprains. In Mann ILA, Coughlin MJ (eds): Surgery of the Foot and Ankle, id 6. St. Louis, Mosby, 1993, p 1191–1200

9. Coker TP, Arnold JA, Weber DL: Traumatic lesions of the metatarsophalangeal joint of the great toe in athletes. Am J Sports Med 6:326–334, 1978

10. Coopbr DL, Fair J: Turf toe. Physician Sports Med 6:139, 1978

11. Coughlin MJ: Conditions of the forefoot (turf toe). In Delee C,:Drez D (eds): Orthopedic Sports Medicine: Principles and Practice. Philadelphia, WB Saunders, 1994, pp 1859–1866

12. Ekstrand J, Nigg BM: Surface-related injuries in soccer. Sports Med 8:56–62, 1989

13. Jahss MH: Traumatic dislocations of the first metatarsophalangeal joint Foot Ankle 1:15–21, 1980

14. Joseph j: Range of movement of the great toe in men. J Bone Joint Surg (Br) 36:450–457, 1954

15. Mann RA; Personal communication, 1993

16. Mullis DL, Miller WE: A disabling sports injury of the great toe. Foot Ankle 1:22–25, 1980

17. Nelson WE, DePalma 8, Gieck JH: Intercollegiate lacrosse injuries. Physician Sports Med 9:86–92, 19S1

18. Nielsen AB, Yde J: Epidemiology and traumatology of injuries in soccer. Am J Sports Med 17:803–807, 1989

19. Nigg BM, Segesspr B: The influence of playing surfaces on the load on the locomotor system and on football and tennis injuries. Sports Med 5:375–385, 1988

20. Rodeo SA, O'Brien S, Warren RF, et al: Turf toe: An analysis of metatarsophalangeal joint sprains in professional football players. Am J Sports Med 18:280–285, 1990

21. Rodeo SA, O'Brien S, Warren RF, et al: Diastasis of bipartite sesamoids of the first metatarsophalangeal joint. Foot Ankle 14:425–434, 1993

22. Sammarco GJ: Biomechanics of the foot. In Frankel VH, Nordin M (eds): Biomechanics of the Skeletal System. Philadelphia, Lea & Febiger, 1980, p 193–219

23. Sarrafian SK: of the foot and ankle: Descriptive, Topographic, Functional. Philadelphia, JB Lippincott, 1983

24. Stokes IAF, Hutton WC Stott JRR: Forces under the hallux valgus foot before and after surgery. Clin Orthop 142:64–72, 1979

25. Whitehurst JR: The astrodome turf and lower extremity injuries. Journal of the American College Health Association 17:136–137, 1968

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