Forefoot Injuries in Sports

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Abstract
Forefoot injuries are common injuries in high-impact sports. The forefoot experiences a large amount of stress during the late stance phase of the gait cycle. Repetitive load applied to the forefoot without adequate rest can lead to tissue breakdown, resulting in injury. Forefoot sporting injuries can deteriorate gait function, sporting performance, and quality of life. In this article, we review the typical presentation, approach, and treatment modalities of the commonest forefoot sporting injuries. These include metatarsal stress fractures, second metatarsophalangeal joint (MTPJ) instability, turf toe injury, sesamoid pathologies, as well as hallux valgus and rigidus. Metatarsal stress fractures are frequent overuse injuries. They can be managed conservatively with activity modification and protected weight-bearing or surgically with open internal fixation. Second MTPJ instability typically involves disruption of the second MTPJ ligamentous joint capsule. Management of this condition includes customized orthotics, physiotherapy, hydrocortisone and lignocaine (H&L) injections, osseous procedures for phalangeal alignment, and plantar plate repairs. Turf toe injury refers to a hyperextension injury of the plantar capsuloligamentous structure of the hallux MTPJ. Plantar plate repairs are typically indicated in grade III injuries or when conservative treatment has failed. Sesamoid injuries include stress fractures, infections, degenerative disease, and osteochondral lesions. Customized orthotics limiting flexion across MTPJ while providing sesamoid stress relief is helpful, while surgical treatment involves fixation with possible bone grafting or partial or sometimes complete sesamoidectomy. While hallux valgus and rigidus are not specific to sportsmen, treatment should take into account the patient’s athletic demand. These conditions are typically treated surgically with realignment osteotomies if refractory to conservative treatments such as foot orthoses and physiotherapy.

Keywords: Foot, Foot ankle surgery, Foot injury, Metatarsal, Sesamoid, Sports.

Introduction
Forefoot injuries are common in athletes who participate in high-impact activities involving significant amount of running and jumping. Poor management of forefoot injuries can prolong time return to sports and the preinjury level of sporting activities. For the purpose of this review, we define forefoot as the structures in the foot extending from the tarsal-metatarsal joint to the toes. Common forefoot sporting injuries include metatarsal stress fracture, second metatarsophalangeal joint (MTPJ) instability, turf toe injury, and sesamoid pathologies. Other common pathologies include hallux valgus and hallux rigidus. In this article, we will review the diagnosis and management of these forefoot sporting injuries.

Anatomy and Biomechanics of the Forefoot
The forefoot comprises of structures in the foot extending from the tarsal-metatarsal joints to the tip of the toes, namely the 5 metatarsals, 14 phalanges, and 2 sesamoid bones. The first MTPJ is surrounded by a capsular ligamentous complex that contributes significantly to the stability of the first MTPJ. It consists of the medial and lateral collateral ligaments, plantar plate, adductor hallucis, abductor hallucis, and flexor hallucis brevis. The sesamoid bones arise within the tendons of the flexor hallucis brevis and articulate with the plantar aspect of the first metatarsal head. They act as pulleys to transmit forces from the flexor hallucis brevis through the plantar plate to the first proximal phalanx base and elevate the first metatarsal head, thereby providing a moment arm that augments plantar flexion of the first MTPJ.¹–⁴

The foot experiences a high amount of stress during locomotion. Biomechanical studies have shown that the peak vertical forces on the foot can increase up to 120% of body weight during walking, and up to 220% of body weight during running.⁵

Metatarsal Stress Fracture
Presentation
Metatarsal stress fractures are frequent overuse injuries that occur in athletes. They typically present with an insidious onset of pain that occurs during periods of activity and is relieved by rest. The second and third metatarsal bone accounts for 80–90% of metatarsal stress fractures.⁵–¹² Due to the plantar-oriented forces that occur during weight-bearing, the most common area where fractures occur is over the metatarsal neck.¹³,¹⁴ However, notable exceptions are dancer’s fracture (proximal second metatarsal fracture) and Jones fracture (proximal fifth metatarsal fracture).¹⁵ Biomechanical alterations that result in repetitive stress over the metatarsals such as gastrocnemius tightness, cavovarus foot, pes

MINI SYMPOSUM: FOREFOOT DISORDERS

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The center of pressure is shifted under the forefoot during the late stance phase with the first to third metatarsal heads bearing the highest concentration of pressure.⁵–⁸ Repetitive load applied to the forefoot in sporting activities without adequate interim period of rest could hence lead to tissue breakdown with concomitant discomfort and time off sports.

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planus, or other altered foot biomechanics have been implicated in the predisposition to metatarsal stress fractures.\textsuperscript{16–18}

**Imaging**
Stress fractures can be detected via radiographs when bone reaction such as callus formation has begun (Fig. 1).\textsuperscript{19,20} In view of its accuracy, earlier diagnosis, and prognostic value, MRI is the modality of choice when working up for metatarsal stress fracture.\textsuperscript{21,22} When MRI examinations are inconclusive, bone scintigraphy has been recommended by some to aid in the assessment of a stress fracture.\textsuperscript{23} In patients with multiple stress fractures, laboratory tests are useful in evaluating for any underlying metabolic or endocrine cause.\textsuperscript{24}

**Management**
Conservative treatment of metatarsal stress fracture comprises of activity modification with protected weight-bearing.\textsuperscript{25} This involves the use of customized orthotics for shock absorption, cast, or Velcro walking boots.\textsuperscript{26,27} Return to sports should be started at low-intensity level with gradual increments.\textsuperscript{28,29} Such delayed return to sports, coupled with high nonunion rates, makes operative treatment a preferred option for athletes whose priority is an early return to sports.\textsuperscript{18,30}

Operative treatment typically involves open surgery with fracture site curettage with or without reaming of the medullary canal and plate stabilization augmented by the autogenous or allogenic bone graft.\textsuperscript{31–33} Underlying structural abnormalities should also be addressed, for instance, corrective osteotomies for dorsiflexed first ray or cavus foot and gastrocnemius recession for gastrocnemius tightness.\textsuperscript{34–36} Adjunct treatments to improve bone healing in stress fractures, such as low-intensity pulsed ultrasound (LIPUS) and extracorporeal shockwave therapy (ESWT), have been proposed, though their efficacy still remains a subject of controversy.\textsuperscript{37–39}

**SECOND METATARSOPHALANGEAL JOINT INSTABILITY**

**Presentation**
The proposed pathogenesis of second MTPJ instability is varied in the current literature but generally involves lateral capsule and collateral ligament disruption together with plantar plate rupture.\textsuperscript{40–42} Patients typically complain of tenderness over the plantar aspect of MTPJ, tender plantar hyperkeratotic lesions, and toe deformities.\textsuperscript{40,41} First ray pathologies, such as hallux valgus, excessive second metatarsal length, trauma, improper footwear, tight Achilles tendon, and inflammatory arthropathy, have been implicated second MTPJ instability.\textsuperscript{44–46} A dorsal drawer test, or Lachman’s test, where increased mobility of the second MTPJ is observed, indicates plantar plate insufficiency.

**Imaging**
Radiographs and MRI are commonly used in the assessment of second MTPJ instability (Fig. 2). Anteroposterior radiographs of the foot allow for evaluation of the forefoot cascade and shape of the second metatarsal head, while lateral views allow for evaluation of the shape of the foot and relative orientation of the metatarsal heads.\textsuperscript{49}

The MRI is useful in evaluating the integrity of the second MTPJ plantar plate. Signs suggestive of a torn plantar plate include discontinuity of the plantar plate with fluid interposition, presence of pericapsular fibrosis extending from the proximal phalanx base into the intermetatarsal space (pseudoneuroma sign), and increased plantar plate-proximal phalanx distance.\textsuperscript{50} Yamada et al.\textsuperscript{51} found that a plantar plate to proximal phalanx distance of greater than 0.275 cm has a sensitivity of 65% and specificity of 90% in diagnosing plantar plate tears.

When imaging investigations are inconclusive, lesser MTPJ arthroscopy is an emerging diagnostic and therapeutic tool for synovectomy, direct plantar plate repair, and loose body removal.\textsuperscript{50,52,53}

**Management**
Conservative management of second MTPJ instability includes customized orthotics, shoe wear modifications, and physiotherapy for calf stretches.\textsuperscript{54,55} Pharmacological treatment such as nonsteroidal anti-inflammatory drugs and hydrocortisone and lignocaine (H&L) injections aid in symptom relief, although multiple corticosteroid injections risk compromising MTPJ stability.\textsuperscript{50,56}

Surgical management of second MTPJ instability mainly involves osseous procedures for phalangeal alignment and soft-tissue repairs. Osseous procedures for phalangeal alignment

![Figs 1A and B: Radiograph of right second metatarsal stress fracture in a dancer\textsuperscript{20}](image1)

![Figs 2A to C: Radiograph of forefoot (A) and MRI Forefoot coronal view (B) showing fourth metatarsal head widening and flattening suggestive of dysplasia, secondary to chronic instability. Sagittal view of MRI (C) also show dorsal spurs and cyst formation](image2)
include a Weil’s recession osteotomy for excessively long second metatarsal, MTPJ synovitis, and Morton’s neuroma, as well as a dorsiflexion osteotomy for Freiberg’s infraction.\textsuperscript{52,58} Increasingly, there has been a focus on soft-tissue procedures, which include plantar plate reconstruction, collateral ligament repair, and tendon transfers (extensor digitorum brevis, extensor digitorum longus, flexor tendon). Plantar plate reconstruction is an increasingly popular procedure, with direct repair of plantar plate back onto the base of the proximal phalanx of the toe with nonabsorbable sutures or suture anchor devices.\textsuperscript{52,59} No standard postsurgical rehabilitation program has been established but a postoperative anti-extension splint with a forefoot off-loading orthotic for 4 weeks is recommended.

**Turf Toe Injury**

**Presentation**

Turf toe injury is recognized as a hyperextension injury to the plantar capsuloligamentous structure of the hallux MTPJ. It was first described in 1976 by Bowers and Martin\textsuperscript{60} at the University of West Virginia who documented 5.4 cases of such injuries per season in football players at the university. They attributed the injury to a combination of hard artificial turf and flexible footwear, which were recently introduced to football at that time. Turf toe injury has since been found not to be exclusive to football and has been seen in a number of other sports such as basketball, baseball, soccer, Taekwondo, and sprinting.\textsuperscript{61} The classical mechanism of injury involves a combination of a hard artificial turf, flexible footwear, and an axial loading foot in equinus causing hallux hyperextension.\textsuperscript{62}

Apart from metatarsalgia, signs of turf toe injury include ecchymosis and tenderness over the hallux MTPJ, weakness with plantarflexion, and a positive dorsoplantar drawer test. Turf toe injury is graded according to the extent of plantar capsule disruption. A common grading system proposed by Anderson\textsuperscript{63} classifies turf toe injury into three different grades, ranging from stretching of and partial tears of the plantar complex to complete tears, each with their commonly associated signs and symptoms (Table 1).

**Imaging**

Radiological evaluations are part of the workup for hyperextension injuries of the toe. Initial investigation includes an AP foot X-ray as well as a forced dorsiflexion lateral foot X-ray. In complete plantar complex tears, proximal retraction of the sesamoid bones can be appreciated on the lateral foot radiographs with the hallux in dorsiflexion.\textsuperscript{64} Comparison with the contralateral foot radiographs would aid with detecting this difference.

MRI remains the imaging modality of choice when evaluating plantar plate injuries. Sprains and partial thickness tear would appear as either thinning or thickening with indistinctness of the plantar plate, while full-thickness tears would appear as focal discontinuity of the plantar plate with retraction and a fluid gap.\textsuperscript{65} Nonetheless, plantar plate recesses at the proximal phalangeal attachments can be a normal variant, and caution must be taken to not overcall partial tears.\textsuperscript{66} Acute injuries usually demonstrate soft tissue edema, which is absent in chronic injuries. Chronic injury might lead to development of osteophytes at the first metatarsal head, leading to hallux rigidus.\textsuperscript{67}

**Management**

Treatment of turf toe injuries depends on the degree of plantar complex injury. Most turf toe injuries can be treated conservatively with rest, ice, compression, and elevation (RICE) and orthotics.\textsuperscript{68,69} Anti-inflammatories and analgesics can help decrease pain and swelling. A short period in a walking boot or a toe spica extension is beneficial (Fig. 3).\textsuperscript{70} Taping the hallux helps to decrease movement at the MTPJ while providing compression. The patient should be kept on a weight-bearing as tolerated regimen.

Surgical interventions are typically indicated only for grade III injuries or when conservative treatment has failed. Typical indications for surgery include large capsular tear with joint instability, sesamoid diastasis, traumatic hallux, loose bodies, or chondral injuries.\textsuperscript{71} Reconstruction of turf toe injury classically involves a medial “J” incision, whereby the incision extends along the hallux MTPJ flexion crease.\textsuperscript{72} Surgical repair of the plantar plate involves repair with nonabsorbable sutures placed in an interrupted fashion, suture anchors, or a drill hole technique followed by medial capsular imbrication. Alternatively, particularly when there are complete plantar plate ruptures, a dual-incision technique with incisions along the medial and lateral border of the hallux MTPJ can be used to gain access to both the medial and lateral aspects of the plantar capsular ligamentous complex.\textsuperscript{73} Postoperatively, the patient is kept nonweight-bearing in a removable toe spica splint, with gradual return to full weight-bearing from the 4th week onward.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>I</td>
<td>Stretching of plantar complex</td>
</tr>
<tr>
<td></td>
<td>Localized tenderness, minimal</td>
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<tr>
<td></td>
<td>swelling and no ecchymosis</td>
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<td></td>
<td>over the first MTPJ</td>
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<tr>
<td>II</td>
<td>Partial tears</td>
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<tr>
<td></td>
<td>Diffuse tenderness, moderate</td>
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<tr>
<td></td>
<td>swelling, ecchymosis and</td>
</tr>
<tr>
<td></td>
<td>restricted movement with pain.</td>
</tr>
<tr>
<td>III</td>
<td>Frank tears</td>
</tr>
<tr>
<td></td>
<td>Severe tenderness, marked</td>
</tr>
<tr>
<td></td>
<td>swelling and ecchymosis,</td>
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<tr>
<td></td>
<td>limited movement with pain, and</td>
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<td></td>
<td>positive dorsoplantar test</td>
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![Fig. 3: Toe spica taping\textsuperscript{70}](image-url)
Sesamoid Pathologies

Presentation
Comprising of 9% of foot and ankle injuries and 1.2% of running injuries, sesamoid pathologies are a significant etiology that should be given due consideration during the workup of forefoot pain. Given their location within the tendons of the flexors, sesamoids aid in transmission of force during gait and are predisposed to repeated stress and trauma, making them susceptible to a range of acute and chronic injuries. These includes sesamoid stress injuries or sesamoiditis that are due to repetitive trauma, sesamoid fractures, infections, degenerative diseases, and osteochondral lesions (Fig. 4). Structural variations such as pes cavus, significantly plantarflexed first ray, ankle equinus, abnormal sesamoid size or rotations, and absence of metatarsal crista have been implicated as predisposing factors to sesamoid pathologies. Sesamoid pain is classically described as an activity-related pain with localized discomfort on the compression test.

Imaging
While MRI is diagnostic for sesamoid pathologies (Fig. 5), radiographs remain a useful modality in evaluating sesamoid injury. Standard radiographs comparing contralateral foot X-rays are useful, while an additional axial sesamoid view taken for a tangential view of the sesamoids and less metatarsal heads can be very informative (direct beam at forefoot in a tangential manner with forefoot in a dorsiflexed position) (Fig. 6). The existing literature has also suggested a role for CT and image-guided injections targeting a symptomatic sesamoid.

Management
Nonoperative treatment of sesamoid injury includes period of immobilization or enforced rest in walking boots followed by customized orthotics, such as those limiting flexion across MTPJ or providing sesamoid stress relief. However, symptomatic nonunion may persist after nonoperative treatments.

Operative treatment consists of options of surgical fixation with possible bone grafting, as well as partial or complete sesamoidectomy. If surgical fixation is indicated, screws need to be placed perpendicular to the fracture line to prevent fracture displacement and achieve compression, thereby necessitating higher technical expertise. Sesamoidectomy is often advocated as a good alternative, with a recent systematic review by Shimozano et al. demonstrating that sesamoidectomy for hallux sesamoid disorders yielded good clinical outcomes with high rate of return to sports. The surgical approach for sesamoidectomy would depend on the sesamoid to be removed and involves meticulous repair of the plantar capsule and flexor hallucis brevis tendon. As a result, a dedicated postoperative rehabilitation program is often required.

Others
Other common forefoot conditions affecting sportsmen include hallux valgus and hallux rigidus. While they are not specific to sportsmen, treatment for symptomatic hallux valgus and hallux rigidus should take into consideration the patients’ athletic demands. Hallux rigidus is commonly seen in runners and is generally perceived to be secondary to chronic repetitive trauma to the first MTPJ and typically presents with pain during the toe-off phase of the gait cycle. If the condition is refractory to conservative treatment with foot orthoses or taping and physiotherapy, surgical treatment with dorsal first metatarsal cheilectomy may be considered. The Valenti procedure is also advocated as it allows increased postoperative dorsiflexion and range of motion, thereby quicker return to sport. First MTPJ fusion offers good pain relief but should be offered judiciously as it will alter the forefoot loading patterns and the gait of an athlete.
Akin to hallux rigidus, symptomatic hallux valgus should be treated conservatively. Failure of conservative treatment may warrant a corrective osteotomy with debulking and tightening of medial capsule. In the scenario where pain is isolated to a prominent medial eminence with only mild deformity parameters, a minimally invasive hallux valgus correction may be considered.

**References**

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