CLINICAL APPROACH TO COMMON FOOT & ANKLE STRESS FRACTURES IN ATHLETICS

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INTRODUCTION

Stress fractures are a common injury in sports (1.54 - 5.70 per 100 000 Athlete Exposures)[1]. Elite Track and Field athletes have been shown to be particularly susceptible to this kind of injury, presenting with the highest frequency of bone-stress injuries in both the 2012 London Olympics and 2016 Rio Olympics[2]. With the seventeenth edition of the IAAF World Championships to be held in Qatar this September, the medical staff at Aspetar Orthopaedic and Sports Medicine Hospital are preparing to deliver care to the participating athletes who are at increased risk for this type of injury.

The incidence and location of stress fractures varies between sports and among gender[1]. In athletics stress fractures are typically observed in the female long-distance runners. In these athletes the repetitive load and impact absorbed by the foot and ankle can cause distinct micro-fractures and abnormal bone remodelling. When left untreated this process can progress to form a fatigue-type stress fracture[3]. Female athletes are at increased risk of stress fractures in comparison to their male counterparts as part of the Relative Energy Deficiency in Sport (RED-S) syndrome; a relative energy deficiency impairing physiological functions, including metabolic rate, menstrual function and bone health[4,5]. In female athletes, and to a lesser extent in male athletes, this unique risk factor contributes to the occurrence of insufficiency-type stress fractures, that may occur, even in response to normal strain[3]. The location of stress fractures varies between sports, however stress fractures of the foot and ankle are most frequently observed in the tibia, followed by stress fractures of the metatarsals, fibula and navicular bone[1,2].

The importance of a multidisciplinary medical support team in elite sports is well established. This is particularly true in the management of bone stress injuries, which can potentially be diagnosed in the prodromal stage. If diagnosed early, progressive load management with additional conservative measures (e.g. cushioned footwear; foot orthotics and

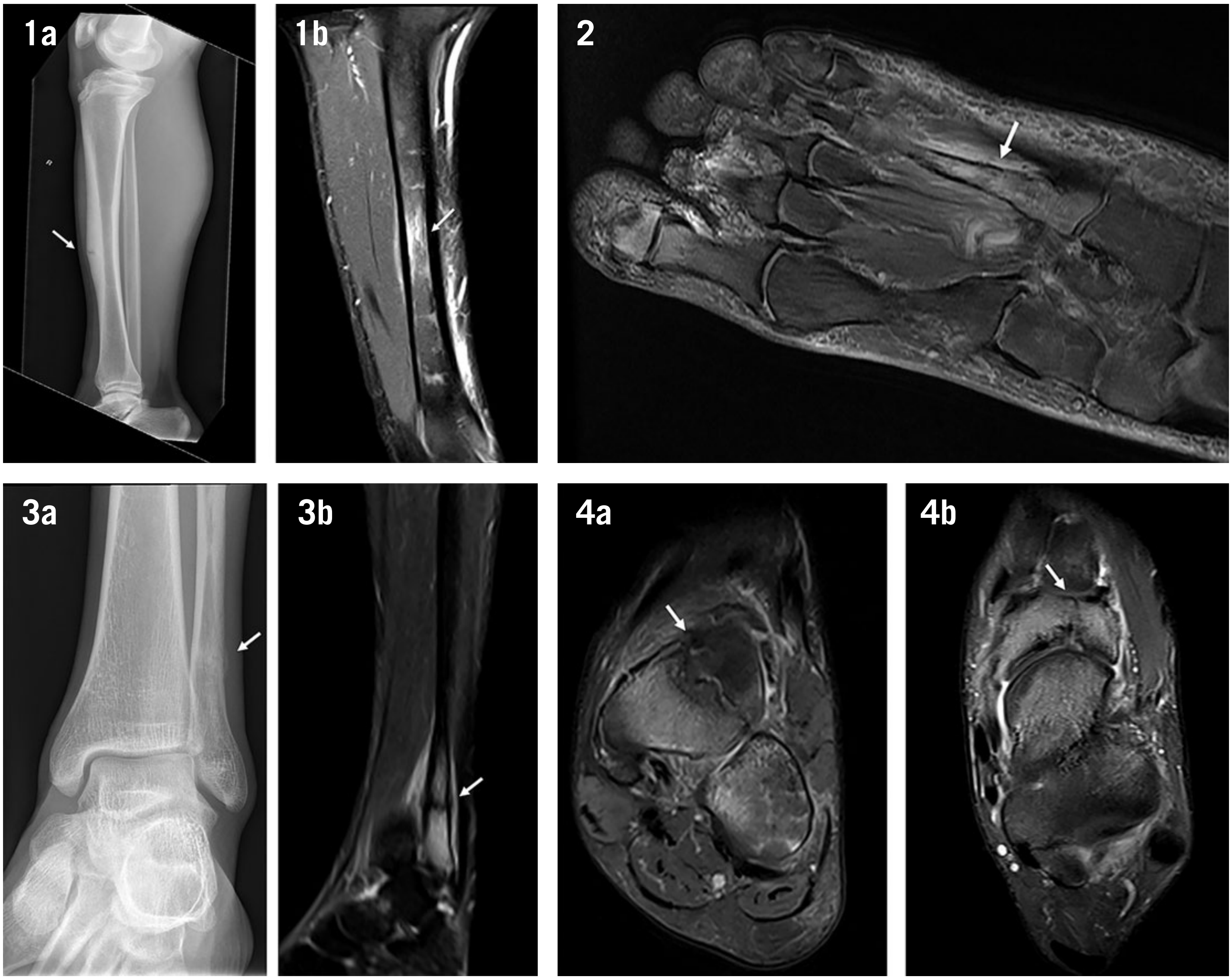

Figure 1: Tibial stress fracture of the anterior cortex. (a) Conventional sagittal radiograph showing endosteal thickening, periosteal reaction and an incomplete fracture line through the anterior tibial cortex (b) Coronal T2-weighted image demonstrating periosteal and bone marrow edema.

Figure 2: Proximal IV metatarsal stress reaction; Long-axis T2-weighted image demonstrating extensive bone marrow edema of the distal metatarsal IV and surrounding soft-tissue edema.

Figure 3: Stress fracture of the distal fibula. (a) Conventional coronal radiograph demonstrating periosteal reaction and endosteal sclerosis (b) Coronal T2-weighted image showing diffuse bone marrow edema and a discrete fracture line.

Figure 4: Navicular stress fracture (a) Coronal and (b) Axial T2-weighted images demonstrating bone marrow edema and a clear fracture of the navicular bone (modified Saxena type 3).

vitamin D and Calcium supplementation) may help to prevent bone stress injuries evolving into stress fractures, reducing time lost from participation[6,7]. However, the clinical presentation of stress injuries is not always clear cut and stress fractures may occur despite preventative measures by the medical and coaching teams.

When faced with the adversity of a stress fracture, the main concern of athletes is: 'What treatment option will allow me to return to sport (RTS) quickest?'. For the medical support team to adequately answer this question, it is important to understand that treatment should be tailored to the healing propensity of the stress fracture. Stress fractures are therefore classified as low-risk or high-risk, depending on their healing propensity (Table 1). Based on available evidence we will discuss the diagnosis, management options and prognosis of (1) Tibial, (2) Metatarsal (3) Fibular and (4) Navicular stress fractures (Figures 1-4).

TIBIAL STRESS FRACTURES

Tibial stress fractures are the most common lower extremity stress fractures among active individuals (e.g. military recruits and athletes). Most commonly, tibial stress fractures occur at the posteromedial cortex as a result of forces experienced during walking and running[8]. These forces are hypothesized to be a combination of impaction forces and muscular forces of the gastrocnemius-soleus complex and deep plantar flexors[9]. A less common (but significantly more devastating) entity is the anterior tibial cortex stress fracture. In contrast to posteromedial cortex fractures, they result from forces experienced during jumping.[10] Anterior tibial cortex fractures are considered high-risk stress injuries as they carry significant risk of complete fracture and non-union[11].

Symptoms of tibial stress fractures include pain induced by exercise, point tenderness and swelling over the tibial shaft. However, classic symptoms might be absent in some patients. The diagnostic work-up of tibial stress fractures is initiated with conventional imaging. However, radiographic findings may lag behind clinical symptoms by 2-3 weeks, often rendering conventional imaging insensitive[12]. Radiographs may demonstrate decreased cortical density, periosteal reaction, endosteal thickening and intramedullary sclerosis. A discrete fracture line is a late finding. In case of negative radiographs, but high clinical suspicion, Magnetic Resonance Imaging (MRI) is the preferred imaging technique. MRI might be used to confirm the diagnosis and classify the severity of the bone stress injury according the modified Fredericson classification[13]. (Table 1)

Treatment of posteromedial tibial fractures is primarily conservative as they have a high propensity to heal. Conservative rehabilitation is focused on activity modification with continued weight-bearing as tolerated [14]. After the patient has been able to bear weight pain-free for two weeks, progressive return to full impact activities can be initiated. Non-steroidal anti-inflammatory drugs (NSAIDs) should be avoided as they may hamper bone healing[15]. In contrast, anterior tibial cortex stress fractures are considered high risk as they are associated with high rates of non-union and complete fracture[11]. This can be contributed to poor vascularity, absence of musculotendinous support and structural tension on the anterior cortex. Conservative treatment of these fractures often is often unsatisfactory, with high rates of non-union and low percentages of return to sport[16]. However, randomized trials comparing conservative treatment versus primary surgical intervention are lacking.

The prognosis of tibial stress injuries depends on their severity[13], ranging from a mean time of 16 days for grade 1 injuries to a mean 71 days for grade 4b injuries. Anterior tibial stress fractures were found to be able to return to sport at 24 weeks after conservative treatment. However, if conservative treatment failed (53%), return to play was 28.4 weeks after subsequent surgery[11]. Small case series have demonstrated quicker return to play with secondary tension band plating, making it an interesting option in selected patients[16].

TABLE 1

High Risk	*Low Risk*
Fifth metatarsal	*Medial tibia*
Anterior tibia	*Metatarsals I-IV*
Navicular	
Medial malleolus	

Table 1: Classification of stress fractures according to healing propensity.

TABLE 2

Grade 0	*No abnormality*
Grade 1	*Periosteal edema with no associated bone marrow signal abnormalities.*
Grade 2	*Periosteal edema and bone marrow edema visible only on T2-weighted images.*
Grade 3	*Periosteal edema and bone marrow edema visible on both T1 and T2 weighted images.*
Grade 4A	*Multiple focal areas of intracortical signal abnormality and bone marrow edema visible on both T1-weighted and T2-weighted images.*
Grade 4B	*Linear areas of intracortical signal abnormality and bone marrow edema visible on both T1 and T2 weighted images.*

Table 2: (Modified) Fredericson classification for tibial stress fractures (Kijowski R et al. 2012 Am J Roentgenol).

TABLE 3

Type 0.5	*Stress reaction; signal change on MRI noted, but stress fracture not imaged on CT*
*Type 1**	*Fracture of dorsal cortex*
*Type 2**	*Fracture of dorsal cortex into navicular body*
*Type 3**	*Complete propagation through both cortices*

Table 3: (Modified) Saxena Classification for Navicular stress fractures.

METATARSAL STRESS FRACTURES

Metatarsal stress fractures are the second most common stress fracture of the foot and ankle. They are typically seen

in military personal performing marches (hence, march fractures). Stress fractures most frequently affect the diaphysis and distal part of metatarsal III. This can be attributed to the low bending stiffness of this metatarsal, due to its ligamentous support[17]. Most stress fractures of metatarsal I-IV are considered low risk as they possess a high healing propensity. Metatarsal V stress fracture typically involve the diaphysis and should be differentiated from the more proximal traumatic avulsion fractures. They are hypothesized to result from forces experienced as the result of bone morphology, cavus foot type or inappropriate foot wear[18]. Metatarsal V fractures are classified as high-risk stress fractures as they often result in non-union as a result of poor vascular supply[19].

Symptoms of metatarsal stress fractures include dull ache or pain at the base of the affected metatarsal during weight bearing exercise, often coinciding with increase of training intensity or training volume. In case of a metatarsal II-IV stress fracture, radiographs typically demonstrate periosteal reaction and cortical lucency. Radiographs of first metatarsal stress fracture typically demonstrate linear sclerosis perpendicular to the direction of stress[20]. MRI findings include intramedullary edema, periosteal edema and a fracture line in severe cases. Various classifications have been proposed to describe fifth metatarsal stress fractures [18,21,22]. However, the Torg classification is the most commonly used[23]. (Table 2).

Treatment of metatarsal II-IV stress fractures consists of activity modification and continued weight bearing, as they possess a high healing propensity. Surgical treatment is reserved for those cases with dorsiflexion of fracture fragments or in case of non-union (high tendency in base of metatarsal II)[8]. In elite athletes, metatarsal V stress fractures are advocated to be treated surgically, as conservative treatment may result in increased risk of non-union and may delay return to sport[24]. Fracture fixation using a single intramedullary screw is the current standard of care[25].

Return to sport in Track and Field athletes for conservatively managed metatarsal II-IV fractures is a mean 11.7 weeks[26]. However, this outcome is based on a small case series of ten patients as return to play data in athletics is lacking. In football players return to play times after a fifth metatarsal (stress) fractures were found not to differ between conservative and surgical treatment (74 days vs. 80 days) if consolidation occurred (33% vs. 75%)[27]. However, conservative treatment is often related to healing problems, delaying return to play. In professional soccer players mean return to play after intramedullary fixation of fifth metatarsal stress fractures was established to be 10.5 weeks[25].

FIBULA STRESS FRACTURES

Fibula stress fractures are rare but should be considered in the long-distance running and track and field athlete. They account for 4.6% to 21% of all stress fractures and are the most common within 4 to 7cm from the distal tip of the lateral malleolus[28]. They are considered low risk as the fibula only bears 10% of the load during activity and the risk of displacement is minimal[29,30]. The cause of fibular stress fractures is attributed to an increased traction and torsional force from the plantar flexors and peroneal muscles (e.g. during excessive pronation or supination). This mechanism is hypothesized to overload the lateral compartment increasing stress on the fibular structure[31].

Symptoms, like most stress fractures, start vague and are often described as persistent pain or tenderness over the fibula, with occasionally referred knee pain. Symptoms are often aggravated with activity such as running and jumping[14,29]. Standard radiographic changes consist of a sclerotic or radiolucent line at the level of lateral malleolus but can be negative in up to 40% of cases[32]. Early stage MRI is recommended, as it will be able to pick up periosteal reaction and fibular bone marrow edema[33].

Most athletes can be treated conservatively as the fibula is a non-weightbearing osseous structure[30]. Conservative treatment consists of immobilisation with a non-weightbearing walker or removable cast for 2-6 weeks followed by a gradual return to activity and sports, as symptoms allow. Contributing biomechanical factors of foot and ankle such as excessive pronation/supination should be addressed accordingly with footwear and, where necessary, foot orthotics.

Athletes with this type of stress fracture will take about 13 weeks to return to sport, however, some advocate a quicker return to sport under the provision that the athlete is

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pain free while using a brace during sport activities and is monitored closely[32]. In the event of a delayed union, prolonged casting can be considered. Non-unions often require surgical intervention, however, literature on treatment of these injuries is lacking. [31].

NAVICULAR FRACTURES

Navicular stress fractures represent 14%-25% of all stress fractures. In contrast to most stress fractures, they are predominantly in male athletes (e.g. hurdling, jumping).[8] The middle third of the navicular bone is the most frequently affected area. It is relatively avascular, with a negative impact on healing.[34] The navicular bone is important for stability of the medial longitudinal arch and is subjected to high compression forces during the propulsive phase of gait. A cavus foot type, reduced ankle dorsiflexion and an index-minus morphotype all amplify compression loading in the navicular, increasing the risk of a bone stress reaction[35]. Navicular stress fractures are classified as high-risk stress fractures due to limited vascularity[14].

Symptoms of navicular stress fractures include dull pain over the medio-dorsal aspect of the foot and palpation tenderness over the navicular bone, (N-Spot). Clinically, symptoms can be aggravated by functional tests (e.g. single leg hopping, tip-toe walking). Most navicular stress fractures do not involve the plantar cortex, making them difficult to identify on radiographs[34]. Plain radiographs may show a sclerotic or radiolucent line extending from the superior tension side of the navicular bone, but it often lacks sensitivity[28]. MRI is the gold standard for diagnosing navicular bone stress injuries. Bone stress injuries of the navicular are classified using the Saxena classification[36,37].

Conservative treatment may be considered if the navicular stress injury is diagnosed in an early stage (Saxena Type 0.5). Conservative treatment consists of immobilization and non-weight bearing for 1-3 weeks until tenderness on palpation of the N-spot is absent[38]. The subsequent progressive loading programme may take up to 4-6 months[34]. However, in case of a delayed or non-union, a more aggressive approach by open reduction internal fixation (ORIF) should be applied. For the elite athlete, surgical treatment is preferred as it minimises the risk of non-union and ensures a clear RTS timeframe[34].

Return to sports outcome data after treatment of navicular stress fractures is scarce. The average return to sport after conservative treatment has been reported to be > 6 months. Return to sport after a surgical treatment of type 2 and 3 navicular stress fractures averaged 4.2 (±1.5) months[36,38].

CONCLUSION

A multi-disciplinary approach by the coaching staff and medical support team is essential to diagnose bone stress injuries in the prodromal stage and minimize injury time loss. If diagnosed early, progressive load management with additional conservative measures can prevent progression of bone stress injuries. Management of stress fractures should be tailored to the healing propensity of the stress fracture.

1. Most stress fractures of the posterior tibial cortex can be treated conservatively. A subset of patients with anterior tibial stress fractures might benefit from surgical treatment, however, high quality evidence is lacking.
2. Stress fractures of metatarsal II-IV have a good healing tendency; Metatarsal V stress fractures should usually be treated surgically due to risk of non-union.
3. Conservative treatment seems suitable for most uncomplicated fibula stress fractures, however, faster return to sports might be possible with surgical management in elite athletes.
4. Stress fractures of the navicular bone are considered high risk and are often treated surgically.

References

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