Stress Fractures: A Growing Concern during the COVID-19 Pandemic

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ABSTRACT
During coronavirus disease-2019 (COVID-19) pandemic, public health measures to encourage social distancing have been implemented, including a temporary shutdown of gyms, organized sports, and social activities. Although such policies have helped contain the virus, they have had a secondary effect on the increasing incidence of patients presenting with stress fractures in the lower limb. This is mainly due to the environmental restrictions from the COVID-19 crisis, leading to suboptimal conditions in exercise performance. We present an overview on this topic for healthcare professionals in primary and secondary care and our recommendations for its management during the COVID-19 pandemic and beyond.

Keywords: Ankle joint, COVID-19, Foot injuries, Risk factors, Sports, Stress fracture, Trauma.

INTRODUCTION
Stress fractures are partial or complete fractures of bone resulting from high numbers of cyclical overloading with an intensity lower than the maximum bone strength on non-pathological bone tissue.1–3 It predominantly affects the lower limbs, reflecting the repetitive loading exerted on these weight-bearing regions compared to those without this function.4 The most common site is the tibia, followed by the fibula, metatarsals, and navicular bones. During coronavirus disease-2019 (COVID-19) pandemic, there has been a closure of gyms and fitness centers, leading to a rise in outdoor exercises, including long-distance running, by the public.5 While runners have been able to maintain good physical and mental health during the crisis, they are unfortunately the cohort most susceptible to stress fractures in the long bones of the lower limbs.6,7 At our institution, there has been an increase in the incidence of patients presenting with stress fractures during the COVID-19 crisis. This review provides an overview of stress fractures and the available management strategies for healthcare professionals.

Pathophysiology
The appearance of microfractures develops after cyclical and repetitive overloading. This is generally from a sudden increase in the intensity of the runner’s physical activity. Remodeling of the bone tissue to adapt to this new environment is suboptimal, creating an incomplete microlesion repair.8,9 The abnormal remodeling is secondary to an imbalance in osteoclast and osteoblast activity, resulting in more bone resorption and a weakened bone vulnerable to injury. Initially, elastic deformity occurs, progressing to plastic deformity and subsequently a microfracture. Without intervention, a complete bone fracture results.10

Furthermore, when fatigue, weakness, or lack of muscle preparation occur (through a lack of warm-up or warm-down stretches and exercises), this can minimize the dispersion and load distribution on the bone tissue. Microlesions may then develop due to the loss of this protective effect.11,12

RISK FACTORS
The factors associated with the development of stress fractures in individuals during COVID-19 can be divided into extrinsic and intrinsic factors. Extrinsic factors related to sports movements, nutritional habits, type of equipment used, and ground surface.13–15 A large proportion of patients have taken up running during the COVID-19 period knowing that exercise is a key pillar for maintaining mental and physical health and COVID-19 prevention.5,16,17 Unfortunately, a proportion of these people fall into one of the following three extrinsic categories for stress fractures: those with normal bones undergoing a rate of physical activity they are unaccustomed to,3 those training in suboptimal conditions (i.e., improper footwear, hard terrain),2,15 and those with poor metabolic bone health including low vitamin D levels. The latter is particularly true within the pandemic as strict quarantine measures have led to lower exposure to sunlight.18 Intrinsic factors include muscle conditions, hormonal states, gender, ethnicity, and age.12–14,19,20 Many runners have diverse anatomical variations of their lower limb, altering the biomechanical load distribution, and increasing the risk of stress fractures. These include discrepancy in lower limb length, short tibia, genu valgum, and short stature.3,19,20 Further risk factors include stiffness in the feet, alterations to plantar arch, and runners with pronounced high arch (Fig. 1).21,22

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Clinical History and Examination

During the pandemic, access to general practice (GP) and other healthcare sectors has been difficult. Many non-essential face-to-face visits have been canceled and replaced with remote consultations (e.g., phone calls/virtual consultations). Thus, it is important to appropriately elicit the diagnosis of stress fractures from the verbal history when patients are unable to present themselves. Specific complaints include “pinpoint” pain that is alleviated by rest and progressively worsens with activity. Other complaints include the onset of pain following a history of abrupt or increased physical activity with insufficient rest intervals. Intrinsic factors are important to identify so one should elicit information regarding body mass index, previous fractures, menstrual and puberty history, and nutritional evaluation. Pain may be triggered by a tuning fork tapped on the site of the suspected lesion (if face-to-face consultation is possible) and by the hop test (which could be performed remotely). Furthermore, simple blood investigations to include serum calcium, phosphorus, creatinine, and 25-hydroxy vitamin D tests should be performed and can be safely taken at GP surgeries with additional infection prevention processes in place.

Imaging

Simple Radiographs

Appropriate imaging is essential when there is a high index of suspicion of a stress fracture. Imaging features are determined predominantly according to two factors: the relative proportion of cortical to the trabecular bone and the injury chronicity. In locations with a higher proportion of cortical bone, such as long bone diaphysis, the earliest radiological sign is the ‘grey cortex’ sign, referring to subtle cortical lucency at the microlesion with osteoclast resorption. As the injury propagates a periosteal reaction and endosteal callus formation results (Fig. 2). In higher-grade injuries, it is imperative to not miss the ‘dreaded black line’, a sign of poor prognosis with a high probability of complete fracture evolution. In locations with a higher proportion of trabecular bone, such as long bone metaphysis, the initial signs are subtle blurring and faint sclerosis of the trabeculae. Following this, bone deposition and microcallus formation along the remodeled trabecular strut occurs, producing linear intramedullary sclerosis (Fig. 3).

Although X-rays are the initial imaging of choice, they have a poor sensitivity (ranging from 12 to 56%). Furthermore, these early radiological signs may take several weeks to evolve.

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is the most sensitive (99%) and specific (97%) imaging modality to diagnose stress fractures in the absence of radiological alterations. Periosteal edema and marrow edema are early MRI features and are best demonstrated on fluid-sensitive sequences. As the severity of the injury progresses, a hypointense fracture line can be seen (Fig. 4). Periosteal and endosteal new bone formation are hypointense in all sequences. In addition to its sensitivity and specificity, the imaging parameters obtained with MRI enable it to divide stress fractures into four stages as per Arendt and Griffiths (Table 1). We advocate healthcare physicians to follow such an algorithm for those having...
sustained a stress fracture during COVID-19 as it defines the length of resting time required before returning to a pre-injury state. This can help minimize propagation as the MRI will minimize a missed diagnosis and re-presentation in the acute clinical setting while Griffith et al.’s algorithm encourages a clear rehabilitation protocol that can be followed up with telephone (rather than face-to-face) consultations.

Computed Tomography Scans
At present, computed tomography (CT) is not considered to be a first- or second-line imaging modality for the diagnostic evaluation of suspected stress injury. However, where MRI results are equivocal, it may have a role, owing to its high specificity for stress fractures. The findings are similar to plain radiography including sclerosis, new bone formation (Fig. 5), periosteal reaction, and fracture lines (Fig. 6).

TREATMENT
Stress fracture treatment is based on the prevention of new episodes and recovery of the injured area. Delayed treatment can cause fracture displacement requiring operative intervention.

Conservative Management
A proportion of individuals running outdoors during the COVID-19 era have otherwise led a sedentary, physically inactive lifestyle.
These individuals would benefit from gradual progressive initiation of vigorous physical training and setting incremental goals. For example, if their goal is to do the well-known Couch to 5K UK program, they should gradually build-up to this on a build-up to this on a week by week basis as per training program. Furthermore, the social inactivity during COVID-19 has led to increasing running miles in fit individuals to avoid the boredom of lockdown. Unfortunately, this comes with a 1.5–6x increased risk of a stress fracture. We advise modulations in the amount of running completed to reduce the total amount of activity performed. This includes cross-training or alternative activities in achieving the same fitness goals, e.g. to meet cardiovascular goals via running or cycling on alternate days. Appropriate footwear in the form of proper running shoes and shock-absorbent insoles also play key roles in preventing stress fractures. It is thought that they may dampen the damaging bending moments of inertia of bone. This is particularly important in individuals who are likely to run on hard surfaces outdoors. Also, advice on terrain, i.e., softer cross-country rather than hard road surfaces, stretches, warm-up/down.

Analgesia such as anti-inflammatories should be used but with caution and only for short periods. This is due to the conflicting reports in the literature on its effect on bone healing and risk of gastrointestinal (GI) consequences. We recommend the patient to be re-examined every 2–3 weeks to monitor symptoms and whether the pain is improving. This can be through a virtual fracture clinic or telephone consultations. For those patients who have sustained stress fractures in the lower limb, particularly the tibia and fibula, it should be emphasized to them that it can take 6–12 weeks to heal, and they can facilitate this process through engaging in physiotherapy and controlled exercise program. Again, this rehabilitation can be performed remotely if face-to-face consultations are not possible.

**Prevention**

The risk factors contributing to the occurrence of these fractures need to be modified and followed up. Patients must have control of their physical activity with steady progress and adequate recovery time.

Despite an increase in the number of people running, the COVID-19 outbreak has restricted the duration of outdoor sun exposure, and thus vitamin D absorption, due to strict quarantine measures. Vitamin D plays a key role in regulating diverse biological processes including skeletal health. Binding to the vitamin D receptors on osteoblasts and osteoclasts modulates bone mineralization and resorption. Binding to other cells such as hypertrophic chondrocytes, modulates their proliferation, function, and survival. Vitamin D also alters the lipid composition of the bone matrix and anabolic response to mechanical loading. Thus, circulating vitamin D levels are positively associated with bone strength, cortical volume, and mineral density. As a result, vitamin D intake is the key to preventing stress fractures, and there are increasing concerns lockdown measures are leaving running enthusiasts vitamin D deficient and prone to such injury. This is particularly the case for those highest at risk of deficiency to include the elderly, patients with osteoporosis, and certain ethnic minorities. Furthermore, insufficient vitamin D levels have been shown to aggravate the pathological sequelae of COVID-19, including increased hospitalization and mortality. Therefore, patients should be educated on its supplementation and its vital synergistic effects.

Vitamin D is a safe treatment with a high therapeutic index and reduces fracture risk further when combined with calcium. Recommendations for those at risk include 800–1,000 international units (IU) and perhaps as high as 2,000 IU. Also at least 1,000 mg of calcium per day is required for optimal bone health.

Even if an individual incorporates these preventative strategies, early recognition of symptoms and appropriate advice and treatment of stress fractures is paramount.

**Surgical Treatment**

Orthopedic intervention is usually only required in high-risk fractures which leads to non-consolidation. Although neck of femur fractures fall into this category, those who have been acclimatizing to long-distance running may get high-risk fractures in the anterior cortical bone of the middle third of the tibial diaphysis or in the fifth metatarsal base and navicular bone (Fig. 7). Some of these fractures may require surgical stabilization to avoid poor outcomes.

**Returning to Sports**

Return to sports involves a multitude of factors to include injury site, sporting activity, modifying the risk factors, and severity of the injury. Those who are low-risk injuries treated non-surgically can take 1–4 months to return to their activities. We advise patients who have sustained stress fractures during COVID-19 to meet the following criteria before return to sporting activities: the absence of pain at the affected site especially during aggravation, no worsening of symptoms during pain provocation tests, and absence of abnormalities on follow-up imaging. However, most importantly, we advise these individuals to identify their intrinsic and extrinsic risk factors that caused the original injury so that modifications can be made to prevent the recurrence of the injuries.

**Conclusion**

In the COVID-19 era, our practice has seen a local increase in patients presenting with stress fractures in the lower limb because of behavioral changes and increased exercise (particularly running). We present a summary with the key messages for readers in Table 2. A multicenter national audit should be conducted to see whether there is a national increase in overall numbers. This review will help...
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Table 2: Key take-home messages for stress fractures

<table>
<thead>
<tr>
<th>Category</th>
<th>Key Message</th>
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<tbody>
<tr>
<td>Pathophysiology</td>
<td>Sudden increase in patient activity or muscle fatigue</td>
</tr>
<tr>
<td>Risk factors</td>
<td>Extrinsic: sports movements, nutritional habits, equipment used, and terrain</td>
</tr>
<tr>
<td></td>
<td>Intrinsic: age, gender, ethnicity, hormonal status</td>
</tr>
<tr>
<td>Clinical history and examination</td>
<td>‘Pinpoint’ pain, pain onset following a history of abrupt physical activity</td>
</tr>
<tr>
<td>Investigations: blood tests</td>
<td>Serum calcium, phosphorus, creatinine, and 25-hydroxy vitamin D</td>
</tr>
<tr>
<td>Investigations: imaging</td>
<td>X-rays: poor sensitivity (56%)</td>
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<tr>
<td></td>
<td>MRI: most sensitive (99%) and specific (97%)</td>
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<tr>
<td>Treatment</td>
<td>Conservative: gradual progression of training, activity modulations, appropriate footwear, analgesia, physiotherapy</td>
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<tr>
<td></td>
<td>Refer to orthopedics: high-risk fractures in the middle third of tibial diaphysis, fifth metatarsal base, or navicular</td>
</tr>
<tr>
<td>Prevention</td>
<td>Vitamin D: 800–1,000 IU with at least 1 g calcium per day</td>
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healthcare professionals in primary care in the timely diagnosis of these injuries and assist in predicting workload and allocating resources for appropriate treatment.

References


