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Stress Fractures in 2011: Practical Approach

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1. Introduction

Stress fractures occur when excessive loads are applied to a bone whose mechanical strength is normal. Bone insufficiency fractures, in contrast, are due to physiological loads applied to bone of inadequate mechanical strength [1]. This contradistinction is obviously an oversimplification. In practice, a continuum exists between these two clearly defined situations.

The objective of the third ODISSEE meetings [2,3] held under the aegis of the GRIO was to review current knowledge on stress fractures. The pathophysiology of stress fractures is still poorly understood. When loads are applied to a bone, particularly in a repetitive manner, an elastic deformity occurs, followed by a plastic deformity and, finally, by microfractures. Bone strength varies across individuals. It depends not only on the intrinsic qualities of the bone tissue, but also on the magnitude and repetitiveness of the loads applied to the bone. Bone tissue fatigue is an inability to repair the microdamage caused by mechanical loading. The number and length of the microfractures increase, resulting in a fracture with clinical symptoms and radiographic changes [4]. Stress fractures are a common reason for physician visits among athletes and military recruits. They account for 5% to 14% of all physician visits, depending on the study population [5,6].

Although stress fractures can arise at any site, the most common locations are the tibia, particularly in runners; the metatarsals (most notably the second and third metatarsals) in hikers, runners, dancers, and military recruits; the iliopubic and ischiopubic rami of the pelvis in military recruits, gymnasts, dancers, and soccer players; and the femur in cross-country runners. The calcaneus is also a common site of involvement in all populations. Stress fractures are rare at the upper limbs, except in high-level gymnasts [7].

2. Risk factors

A few longitudinal studies in large populations have identified risk factors related to sporting activities, nutrition, hormones, bone characteristics, and biomechanics. The role for other factors in the development of stress fractures is less clear (cross-sectional studies in small cohorts).

2.1. *Sporting activities*

A sudden increase in training or competition intensity and a recent change in the training surface are well-established risk factors. Although several studies suggest a role for inappropriate or worn footwear, there is no definitive proof that the stress fracture risk is influenced by a recent change in footwear, the cost of footwear, or the use of shock-absorbent insoles [8].

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2.2. Hormonal factors

A low calorie intake and a high level of repetitive physical activity are associated with a high prevalence of menstrual disorders in young female athletes. Furthermore, a history of amenorrhea or dysmenorrhea is associated with an increased risk [relative risk, 2-4] of stress fractures in female athletes [9,10]. The bone tissue alterations related to the combination of hormonal disorders and inadequate nutrition contribute to the development of stress fractures (probably in combination with intrinsic bone abnormalities).

2.3. Nutritional factors

A prospective study in 800 military recruits in Finland showed that low 25(OH) D3 levels were associated with an increased risk of stress fractures [11]. The relative risk was 3.6 in the subgroup with 25(OH) D3 levels lower than 75 nmol/L.

In a prospective study of 125 elite cross-country runners aged 18 to 26 years [6], a high dietary calcium intake was associated with a 68% reduction in the stress fracture risk ($P<0.05$). However, there is no proof that a low calcium intake is associated with an increased risk. Nutritional risk factors seem to include calorie intake restriction, the consumption of low-calorie products, and a low-fat diet [10].

2.4. Anthropomorphic characteristics

Anthropomorphic features consistently associated with an increased stress fracture risk [9,12,13] include low body weight, short stature, body mass index lower than 21 kg/m^2, brevity of the tibias, and leg-length discrepancy.

Several studies suggest, but do not prove, that the risk of stress fractures, particularly of the tibia in runners, may be influenced by foot arch height, marked varus of the foot, or limited dorsiflexion of the ankle [9,10].

2.5. Bone tissue characteristics

In a prospective study of 693 female military recruits, who were compared to 626 male recruits from an earlier study, dual-energy X-ray absorptiometry was performed before a 12-week training program [12]. The 37 (5.3%) women who experienced stress fractures during training had significantly lower baseline values for bone mineral density (BMD) at the tibia (-5.2%) and femur (-4.4%) compared to the women without fractures. Nevertheless, the BMD values in the fracture group were within the normal range. No significant BMD differences were found between the males with and without stress fractures. Males with fractures had narrower tibias and femurs than did males without fractures.

2.6. Biomechanical parameters

Several studies suggest that a longer time spent in peak rearfoot eversion (i.e., running with the foot in exaggerated pronation) may be associated with an increased stress fracture risk [13,14]. This risk factor is of particular interest as it may be amenable to correction with adequate footwear or insoles. The available data are conflicting for all the other biomechanical factors studied to date, such as coxofemoral adduction and impact force during running.

3. Diagnosis

3.1. Clinical criteria

The diagnosis of stress fracture relies chiefly on the clinical findings. The typical presenting symptom is mechanical pain, often abrupt and severe, occurring after a recent increase in training or competition intensity or a recent change in the training surface. However, stress fractures may be caused by an apparently unremarkable episode of exercise (e.g., long walk, brief hike, ball game) in an individual who is usually physically inactive.

Less typical presentations are associated with diagnostic delays. Thus, moderate pain occurring only during physical activities may suggest another abnormality, such as a tendon injury.

Imaging studies should be obtained routinely.

3.2. Available imaging techniques

3.2.1. Ultrasonography

Ultrasonography is a widely available and inexpensive technique that is extremely useful for the early diagnosis of stress fractures in shallow bones, such as the foot bones. The direct sign is focal unevenness of the cortex or a cortical break. Indirect signs may be visible, such as a hematoma at the surface of the periosteum [15]. Ultrasonography allows elimination of Morton's neuroma, the main differential diagnosis in patients with metatarsal stress fractures, although the typical clinical presentations differ markedly.

3.2.2. Standard radiographs (Fig. 1)

Initially, standard radiographs are often normal or show only an area of cortical haziness. Later on, in 50% of cases, a periosteal reaction containing a hairline crack becomes visible. The final stage is bone sclerosis indicating the formation of a callus [7,15].

3.2.3. Technetium bone scanning (Fig. 2)

Bone scanning shows an early increase in technetium uptake [15]. A finding of multiple or bilateral hot spots argues against a stress fracture and suggests a bone disease instead (e.g., osteoporosis or osteomalacia).

3.2.4. Magnetic resonance imaging (MRI) (Fig. 3) and computed tomography (CT)

MRI is sensitive for detecting early edema of the bone and adjacent soft tissues. The fracture line is less often visible. Fredericson et al. described five MRI stages [16]:

- Stage 0: normal;
- Stage 1: periosteal edema;