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Treatment of Stress Fractures: The Fundamentals

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In 1855, Breithaupt [1] first described the overuse injury to the fifth metatarsal in marching Prussian soldiers. The injury, commonly known as “march fracture,” was not confirmed until 40 years later with the advent of radiography. It was not until 1958 that Devas [2] first reported this injury in athletes. The stress fracture is now recognized as a common source of pain and dysfunction in an active population. It is this important first step of recognition that allows for an accurate diagnosis and subsequent treatment plan. Because of the often-insidious onset of symptoms, a high index of suspicion is required. By being familiar with a sport and its associated injuries, the clinician is better positioned for a more timely diagnosis. In other words, you cannot treat what you are not looking for.

Several studies have addressed the epidemiology of stress fractures, highlighting the sports in which injury is more common. For example, Johnson and colleagues [3], in a 2-year prospective study on the incidence of stress fractures in the collegiate athletes, the stress fracture rate in males was highest in track-and-field (9.7%), followed by lacrosse (4.3%), crew (2.4%), and football (1.1%). In the female population, the stress fracture rate was also highest in track-and-field (31.1%), followed by crew (8.2%), basketball (3.6%), lacrosse (3.1%), and soccer (2.6%).

Several studies have also reported on the anatomic distribution of stress fractures, with the most common sites being the tibia, metatarsals, and fibula [4,5]. Bennell and colleagues [4] followed 111 competitive track-and-field athletes over 12 months and reported 26 stress fractures, with 46% of injuries involving the tibia, 15% the navicular, and 12% the fibula. Smrcina [6] also reported that 95% of all stress fractures occur in the lower extremity. The predominance of lower-extremity involvement reflects the high repetitive loads typically experienced by a weight-bearing bone compared with the non-weight-bearing upper extremity. That is not to say that the upper extremity is free from destructive force. Racquet and overhead throwing sports create high levels of stress in

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a repetitious fashion, the ingredients necessary for a stress fracture. Motion analysis of the baseball player has confirmed the significant forces that occur at the shoulder and elbow during the overhead throwing motion. Subsequently, humeral shaft, olecranon, and clavicle stress fractures have been reported in the throwing athlete [7–9]. In the tennis player, stress fractures have been reported in the humerus [10], distal radius [11], and ulna [12,13]. With ulnar fractures, the injury involved the nondominant arm in players using a two-handed backhand. Again, knowing the sport and location in which a stress fracture is likely is the first step in making the diagnosis, allowing for an appropriate treatment plan.

TREATMENT PRINCIPLES

When considering treatment plans for a stress injury, one must understand why the injury occurs in the first place. Stress injuries occur when a physiologic load is placed on a bone in a repetitive fashion at a rate at which the body does not have time to recover. The load is considered insufficient to cause acute injury but, when combined with a cyclic pattern, can result in chronic injury. It is the “right” (or better stated, “wrong”) combination of load, repetition, and inadequate recovery that eventually results in injury. Extrinsic and intrinsic factors may contribute to the occurrence of a stress fracture and, alternatively, provide an avenue of treatment. Extrinsic factors that have been suggested as leading to injury include training regimens, playing equipment (footwear, playing surface), and nutritional habits. Intrinsic factors include anatomic variation, muscle endurance, and hormonal effects.

EXTRINSIC TREATMENT

Training Regimen

An increase in activity is often the triggering event for a stress injury. Numerous military studies have shown the high rate of stress injury during basic training for which a progressive and demanding exercise regimen is required [14–20]. These military studies provide a relatively uniform patient population that, by order of the commanding officer, is highly compliant. When an increase in activity is noted in the patient’s history, activity modification is often the starting point for treatment. With activity modification, the athlete is simply unloading the injured bone, allowing the natural repair process to catch up while doing no further harm. In addition, when taking a history of the athlete’s training, it is often helpful to further define the increase in activity with regard to duration, intensity, or frequency of training. This information may allow the clinician to recommend a more acceptable level of activity modification, such as restricting a runner’s distance to a preinjury level while allowing the athlete to satisfy his or her subjective need to run three times per week. It is also important for the athlete to understand that the initial activity modification is only a starting point and that it may require adjustment if symptoms persist. Often, the most important part of modifying an athlete’s activity is providing a formal plan to guide the recovery. Rarely is the recommendation, “Don’t play your

sport for 6 weeks” acceptable to the competitive athlete. A more practical approach for the runner who “needs to run” is to instruct the athlete to half the distance and then increase by 10% per week. If discomfort arises at any time, the athlete must return to the previous level for an additional week. Although not always successful, the plan provides the athlete with reasonable guidelines and allows for continued running.

Equipment

An athlete’s equipment not only includes what they wear but also the surface on which they play. The most common equipment modification deals with footwear. Several studies have looked at the effect of increased cushioning on the incidence of stress fractures [21–23]. These studies tend to support the use of cushioning in the prevention of injuries to the foot, with a variable effect on tibial injuries. For instance, a randomized prospective study by Milgrom and colleagues [21] of 390 military recruits showed a lower incidence of metatarsal stress fractures during military training with modified basketball shoes compared with standard-issue boots. The study did not show the same reduction in tibial stress fractures. Another military study by Stacy and Hungerford [23] also showed a reduction in training injuries when soldiers of the New Zealand Army switched to running shoes during basic training. Although these studies do not directly address the use of a well-cushioned shoe or orthotic in the treatment of existing stress fractures, any modification that reduces impact would appear to be a reasonable treatment in shifting the balance from breakdown to repair.

The surface on which an athlete participates may also have an effect on stress fractures. It has been implied that the more rigid the surface, the greater the risk for stress injury. In turn, a change in the running surface may have a significant effect on symptoms. For instance, a change from asphalt to a well-cushioned treadmill may allow the runner to maintain his or her mileage while reducing symptoms. Several studies however, have reported that hard surfaces are not associated with an increased risk of overuse injury [24–27]. In addition, Voloshin [28] studied the ability of different surfaces to absorb shock. He reported the opposite of what one might expect, noting that a grass surface absorbed less shock than an asphalt surface. From this evidence, one can extrapolate that the stress delivered to the bone is not just a product of ground reaction forces but a result of combined forces including those generated through muscle contraction. At present, the literature does not provide a definitive answer; the clinician must resort to a trial-and-error approach when recommending a change in running surfaces.

Nutritional Habits

Proper nutrition is necessary for optimal bone health in the young athlete. In a retrospective study, Myburgh and colleagues [29] reported a lower intake of calcium in athletes who had stress fractures. Disordered eating patterns must always be considered and corrected whenever a stress fracture is diagnosed. This is especially true in the female athlete who has multiple stress fractures. In such

circumstances, the athlete must be evaluated for the female athletic triad [30], consisting of disordered eating, amenorrhea, and osteoporosis. Severe eating disorders are considered medical emergencies and often require a multidisciplinary approach including nutritional and psychologic counseling.

INTRINSIC TREATMENT

Anatomic Variation

Variations in anatomy have been implicated as a cause for lower-extremity stress fractures. An example of this is Morton's foot with a short, hypermobile first ray and a long second ray. In a study of second metatarsal fractures in ballet dancers by Khan and colleagues [31], six of the eight case reports were noted to have Morton's foot. Giladi and coworkers [32] reported the higher incidence of tibial stress fractures in male recruits who had greater passive external rotation of the hip ($>60^\circ$). Finally, Bennell and colleagues [33] reported that 70% of athletes diagnosed with a stress fracture had a limb-length discrepancy. With the recognition of these anatomic variations, treatment is simply limited to the correction of limb-length discrepancies and to educating the athlete on the increased risk of injury.

Muscle Endurance

Markey [34] proposed that muscle mass may disperse impact loads to bone and when muscles fatigue, the protective function is lost, resulting in an increased risk of stress fracture. Several military and athletic studies have suggested that the out-of-shape athlete is at greater risk for injury [35–37]. Winfield and colleagues [37] studied the incidence of stress reactions in 101 female US Marine Corps trainees for 10 weeks during physical training. They noted a higher rate of injury in trainees who ran fewer miles (<2.8 miles per session) before commencement of training. It can be concluded that the least physically fit individuals would have the lowest muscle mass and endurance and tend to have the lowest bone density, making the bone more susceptible to injury. Strengthening the muscle groups around a stress fracture may provide controlled loading for bone remodeling and, subsequently, reduce the risk for recurrence.

Hormonal Factors

Low estrogen environments in the female athlete are associated with loss of bone-mineral density, predisposing the athlete to stress fracture. Myburgh and colleagues [29] found that runners who had decreased bone-mineral density were at greater risk for stress fracture. Several studies have shown that amenorrheic and oligomenorrheic athletes are especially at high risk of bone loss [34,37]. A complete menstrual history is required whenever a diagnosis of stress fracture is made in the young female athlete. Hormonal replacement therapy may provide some benefit in the maintenance of bone-mineral density in the amenorrheic athlete but must be in conjunction with nutritional and lifestyle counseling.

OTHER TREATMENT MODALITIES

Ultrasound

A number of studies have shown that ultrasound is effective in reducing the healing time of acute fractures. In a prospective double-blind randomized study of 67 tibial shaft fractures, Heckman and colleagues [38] reported a significant decrease in healing time with the addition of ultrasound (86 ± 5.8 days versus 114 ± 10.4 days). Kristiansen and coworkers [39], in a prospective double-blind study of distal radius fractures, also noted a significant decrease in healing time (61 ± 3 days versus 98 ± 5 days). The literature is less supportive when directly addressing stress fractures. Rue and colleagues [40] performed a randomized double-blinded study of 26 midshipmen who had 43 tibial stress fractures. Pulsed ultrasound was applied daily for 20 minutes, but no significant reduction in healing time was found. The investigators recommended additional study using a higher dose and possibly longer period of treatment. At present, there is no definitive evidence that ultrasound may improve or accelerate the healing of stress fractures.

Electrical and Electromagnetic Fields

The clinical effect of electrical and electromagnetic fields on enhancing stress fracture healing is not clearly defined by the literature. Most studies deal with their effect on delayed unions or nonunions and are not specifically designed to evaluate the efficacy on stress fractures. Two studies [41,42] often cited in support of electromagnetic field treatment were unblinded without controls. Compounding the confusion is the various options in which a current may be directed to the fracture site. The modalities of bone-growth stimulation available include direct-current stimulation with percutaneous or implanted electrodes, electromagnetic stimulation by inductive coupling using time-varying magnetic fields, and capacitive-coupling stimulation using electrodes placed on the skin.

Borsalino and colleagues [43], in 1988, published a double-blinded placebo-controlled prospective study on the healing effects of femoral intertrochanteric osteotomies. Significant increased bone healing was identified by greater bone density and trabecular bridging in the treatment group. The study supported the use of bone stimulators as an adjunct to treating acute fractures, but because stress fracture behavior is often very different from acute traumatic fracture behavior, the study provides little support for their use on stress fractures.

Sharrard [44], in 1990, published a study on pulsed electromagnetic fields on delayed tibial unions. The trial took place over a 12-week period and had a successful union rate of 45% in the treated group compared with 14% in the placebo group. Scott and King [45] reported on the effect of capacitive-coupled electrical fields on 23 long-bone nonunions. Sixty percent of the nonunions treated with the coupled electromagnetic field healed in a mean of 21 weeks, whereas none of the placebo-controlled group went on to union. Although these two studies suggest a positive effect on bone healing in a nonunion, one must again take a mild leap of faith when applying these results to stress fractures.

Intravenous Pamidronate

Stewart and colleagues [46] reported on the use of intravenous pamidronate on five symptomatic collegiate athletes who had tibial stress fractures. Pamidronate is a second-generation bisphosphonate that is currently used in the treatment of osteoporosis, hypercalcemia, and metastatic bone disease. It is thought to affect osteoclastic activity by binding to calcium phosphate crystals. With decreased osteoclastic activity, the osteoblasts may catch up, allowing the bone to heal. A 30-mg test dose was given intravenously over 2 hours, followed by four additional treatments at weekly intervals in 60-mg or 90-mg amounts. With the initial treatment, four of five subjects were able to continue training without symptoms within 72 hours. The fifth patient missed 3 weeks of training. At a minimum of 49 months of follow-up, all athletes remained asymptomatic. These investigators believe that the treatment is promising and plan to do a prospective study.

HIGH-RISK STRESS FRACTURES

Any treatment plan for stress fractures must also take into consideration the inherent and specific risk for further injury. It is helpful when devising a treatment plan to understand the difference between the “safe” and “high-risk” stress injury. A stress fracture may be considered higher risk if it has a high propensity to progress to a complete fracture. In addition, the morbidity associated with the completed or possibly displaced fracture must also be considered. Essentially, the higher the risk, the greater the benefit of early surgical intervention to prevent further morbidity. Ultimately, the final grouping of a stress fracture into a high- or low-risk category is somewhat arbitrary; the clinician must be aware of the relative risk associated with each fracture.

The stress fracture most commonly associated with a high level of morbidity after completion is the femoral neck fracture occurring on the lateral or tension side. Delayed diagnosis of such an injury could result in a displaced fracture, with the possibility of avascular necrosis. In one study by Johansson and colleagues [47], 60% of athletes who had an appropriately treated displaced femoral neck fracture were unable to return to their preinjury activity level. The anterior cortex of the middle third of the tibia is another fracture that, if ignored, may progress to catastrophic failure and be prone to delayed union and non-union. Although less likely to progress than the femoral neck stress fracture, the morbidity associated with a midshaft tibial fracture must be considered when weighing the risks and benefits of early surgical intervention.

Stress fractures at higher risk for complete fracture but with less associated morbidity include the base of the fifth metatarsal and the tarsal navicular. In the elite-level athlete, early surgical intervention is considered for both of these fractures, although nonsurgical intervention is often the first treatment option.

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