

Review Article

Tibial Stress Fracture is there a Need for Vitamin D Supplementation?

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Keywords

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Abstract

Treating vitamin D deficiency is of key importance in preventing stress fractures. The importance of nutrition in athletes is essential, especially in the female athlete. Both inadequate intake of calcium, vitamin D or inadequate caloric intake, are associated with reduced bone mass. Vitamin D deficiency leads to the pathogenesis of osteoporosis, which further increases the risk of fragility fractures. The article describes numerous risk factors that also increase the risk of tibial stress fractures, with previous stress fracture consistently the strongest predictor of subsequent stress fractures in both sexes. Assessment and management of tibial stress fractures depends on whether the anterior or posterior cortex is involved. Rehabilitation and management options are discussed to help rehabilitate this complex pathology. Ongoing studies are encouraged to improve the knowledge, awareness and attitude towards vitamin D. There is a need for a public health initiative to reduce the risk of stress fractures.

ABBREVIATIONS

IU: International Units; TSF: Tibial Stress Fracture; BMD: Bone Mineral Density; BMI: Body Mass Index; OR: Odds Ratio; NSAID's: Non Steroidal Anti-Inflammatory Drugs; VAS: Visual Analogue Scale; DWR: Deep Water Running

INTRODUCTION

Vitamin D is both a nutrient and a hormone which provides a wide variety of benefits to human health. It is estimated that 1 billion people worldwide are vitamin D deficient [1]. Treating vitamin D deficiency is of key importance in preventing stress fractures. This review article will summaries the current role of vitamin D in preventing stress fractures and the management strategy for tibial stress injuries.

Dietary Intake

Sonneville and colleagues compared calcium, vitamin D, and dairy intake in athletes with stress fractures. The results show that high vitamin D intake (rather than a high calcium intake) was protective against the development of stress fractures. After adjusting the data for calcium intake and other confounders, the authors found almost a 50 % reduction in the incidence of stress fractures in those participating in a high impact activity [2].

Numerous recommendations have been made for the quantity of vitamin D required. Currently the Institute of Medicine guidelines suggests 600 to 800 international units (IU) of vitamin D are required for adequate bone health in most

adults. Recently McCabe et al., recommend dosages up to 2000 IU, since vitamin D is safe and has a high therapeutic index [3]. There is emerging evidence that vitamin D deficiency can have a profound effect on immunity, inflammation and muscle function. Given that compromised vitamin D levels can potentially impact an athlete's overall health and training efficiency, vitamin D status should be routinely assessed. Athletes need to maintain serum vitamin D concentration of ≥ 30 and preferably ≥ 40 mg/ml [4]. Recommendations will be dependent on the athlete's current vitamin D concentration, but should include regular safe sun exposure and/or dietary supplementation [4].

Risk Factors

A bone mineral density (BMD) with a Z score < -1.0 correlates with increased risk of stress fractures, with an odds ratio(OR) 3.2 (CI 1.4-7.2) [5]. In a prospective cohort study of 259 female athletes there was an accumulative stress fracture risk with additional factors [5]. A combination of low BMD (Z score < -1.0), exercising ≥ 12 hours /week and body mass index (BMI) < 21 kg/m² had an OR of 6.8 (CI 2.6-17.6) and accounted for 46% of their stress fracture population [5]. Kelsey et al., also supports the increasing tibia stress fracture (TSF) risk with reduced bone mineral density, affecting the hip [6].

Purposeful exercise ≥ 12 hours per week increases the risk of stress fracture with an OR of 4.9 (CI 1.4-16.9) [7]. The accumulation of risk factors increases the risk of TSF further [7]. Tenforde et al., showed an increase risk in females running more

than > 32km/week [8]. Loud et al., found sudden increase in training volumes may be more predictive than absolute training time or distance [9].

Previous stress fracture is consistently the strongest predictor of subsequent stress fractures in both sexes [6,8]. A history of previous stress fracture showed an odds ratio (OR) of 6.42 (CI 1.80-22.87) [6]. A previous history of stress fractures is a marker of susceptibility above and beyond that of bone mineral density or content. Tenforde et al., also supports previous stress fracture risk, the odds ratio for previous stress fracture history for females and males is 5.83 (CI 2.32-14.67) and 5.73 (CI 1.52-21.67) respectively [8].

Menstrual irregularity in the female athlete is risk factor for subsequent stress fractures. Low estrogen concentrations are known to be related to low BMD and accelerated muscle loss [6,10]. Several studies are linked to increase fracture risk with menstrual irregularity [11,12]. Kelsey et al., also found an increase risk; however, this was not statistically significant OR 3.41 (CI 0.69-16.91). Tenforde et al., found a fourfold increase in stress fracture risk with late menarche (≥ 15 years of age) [8].

Athletes need to address modifiable risk factors such as, reduced BMI < 21kg/m², bulimia or any evidence of disordered eating, in order to reduce the risk of TSF. The importance of optimal nutrition for athletes cannot be overstated, particularly for the female athlete. Both inadequate intake of calcium and vitamin D, both required in bone metabolism, and insufficient caloric intake, are associated with reduced bone mass [13].

Training errors are common, the use of 'periodization' as a training method helps optimize gains in performance and minimizes the risk of developing a stress fracture. Periodization involves increasing training over a three week cycle followed by a relative rest week. This allows for rest and subsequent metabolic adaptation to occur. Periodization was first presented by the military to reduce the frequency of stress fractures occurring during training. Incorporation of rest days almost halved stress fractures in Royal Marine training from 7% to 3.8% [14].

Types and grades of tibial stress fracture

It is importance to differentiate the more common posterior TSF, which occurs in 85-95% of cases [15,16] from anterior stress fractures. Posterior TSF have a low risk of non-union, which is thought to be because of improved vascularity posteriorly and increased compressive loads [17-19]. Posterior TSF with normal BMD can be managed conservatively using a graded protocol

based on the degree of symptoms and underlying MRI grading (Table 1).

Management of tibial stress fractures

The first recovery stage involves rest and analgesia, avoiding the use of non-steroidal anti-inflammatory drugs (NSAID's). NSAID's may have adverse effect on bone healing [20]. Weight bearing is allowed as long as the athlete remains pain free, and can be supported with crutches, synthetic or air based Velcro walking boots. The use of a 0-10 visual analogue score (VAS) is a usual adjunct for monitoring pain levels. Simultaneous aerobic training using cycling or swimming can help maintain cardiovascular fitness. Endurance athletes can experience a 7% decline in VO_{2max} within two to three weeks of training cessation [21] and it may reduce recovery time [22] Training accessories such as deep water running (DWR) or antigravity treadmills can be used. DWR allows reduced weight through the submerged limb, with the use of the natural buoyancy of the body, this helps maintain cardiovascular and neuromuscular function [23,24] Antigravity treadmills have similar advantages, but lacks the metabolic demand found with DWR [22].

Progression back to running and other activities is carried out at a low intensity. Only after the athlete has been consistently pain free in day to day activities and fully weight bearing for two weeks should the training recommence. The progression back to running is carried out using the 30:10 rule [25]. The athlete starts running at a third of the normal pace and a third of the typical weekly distance, with rest days and periodization incorporated. This is then increased weekly by 10% increments [26]. Any return of symptoms should warrant careful assessment of the rehabilitation program and stepping down to the previous level where the athlete was pain free.

Bisphosphonates have been used to try to hasten return to play in athletes [27]. They work in theory to reduce bone desorption during the remodeling phase, which may accelerate bone healing. Prophylactic bisphosphonates in military recruits did not reduce the incidence of stress fractures [28].

Anterior TSFs require more aggressive treatment than posterior TSFs. Anterior TSFs have prolonged healing times, typically in excess of 6-12 months [29,30]. Despite the prolonged time spent with non-surgical treatment the union rate is only 7-43% [31,32]. It is not known if given more time these would eventually unite. Nattiv et al., 2013 showed the absence of a fracture line on MRI T1 or T2 sequences was of prognostic value [33]. The presence of no fracture line on MRI sequence will

Table 1: Showing the grade of stress fracture based on plain radiology, bone scintigraphy and MR imaging results. Summarized from the paper Arendt et al and authors clinical experience [19].

Grade	Radiograph	Bone Scan	MRI	Interpretation & rest time
1	Normal	Mild unicortical uptake	Positive STIR image	Periosteal oedema 3 weeks
2	Normal	Moderate unicortical uptake	Positive STIR and T2 images	Marrow and periosteal oedema 3-6 weeks
3	Discrete line	Activity in 50% bone width	Positive T1 & T2 images	Partial fracture 6-9 weeks
4	Fracture or periosteal reaction	Bicortical uptake	Fracture line	Complete fracture 9-12 weeks

usually heal with non-operative management, including weight bearing restriction and immobilization [17]. These must be closely assessed to confirm complete healing before the athlete returns to play.

The literature does not currently identify which anterior stress fractures are likely to have a career ending delay in union/non-union. The presence of an anterior fracture line seen on plane radiographs and reduced total body BMD are significant and independent risk factors for return to sport [33]. In a recent systematic review Mallee et al., found no studies comparing surgical to conservative treatment of anterior TSFs in the literature [34]. A combination of low union rates and potentially career ending time away from sport, it is likely that athletes presenting with an anterior TSF on plain radiographs and altered BMD may benefit from early surgery to reduce the time away from competitive activities.

Surgical management of tibial stress fracture

The evidence behind surgical management of anterior TSFs is lacking and based on low quality case series [31,32,35-37]. The surgical union times typically 10-12 weeks [35,36] with return to sport from 10-16 weeks [35,37]. Anterior plating and tibial nailing is thought to improve the biomechanical stability of the fracture, thus improving the environment for the bone to unite [35-37]. The reduced time to union, and away from sport, needs to be carefully balanced against the potential risks of surgery.

CONCLUSION

Ongoing studies to encourage and improve the knowledge, awareness and attitude towards vitamin D should be carefully considered as an important public health initiative to reduce the risk of stress fractures.

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