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Rapid Communication

Vitamin D, Muscle Strength and Stress Fracture in Athletes Practicing in Indoor and Outdoor Environments

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Introduction

Vitamin D is a group of very important vitamins, which contribute to healthy body function athletic performance [1]. When suffering from vitamina D insufficiency, our body cannot absorb calcium, which is a primary component of the bone and musculoskeletal disorders can affect the athlete [1,2]. The strength and structural integrity of bone are influenced by processes that respond to changes in mechanical load, i.e., during sports practice. However, repeated submaximal loading may be associated with insufficient time for bone deposition to match its removal. Bone may become weakened, and hairline stress fractures may result [1-5]. These injuries are common in otherwise healthy athletes and military recruits, with the reported incidence in averaging 3% in males and 9% in females [2,3], thus, the women might be at a higher risk for Vitamin D deficiency [5,6].

Higher concentrations of vitamin D intake are recommended in sports practice to assure adequate availability in metabolic pathways for optimal physical performance directed to bone density and muscle strength [7]. There are two main forms of vitamin D, vitamin D2 (ergocalciferol) and vitamin D3 (cholecalciferol), which are obtained from different sources such as diet, ultraviolet B radiation exposure, usually involving outdoor training and supplements, often to replace little sun exposure, since most of the training involving the indoor environment. The vitamin D, D2 and D3 are transformed to serum 25-hydroxyvitamin [25(OH)D] in the liver and can be measured in blood samples [8]. In the kidney, 25(OH)D is further transformed into the biologically active compound calcitriol (1,25(OH)2D) [9,10], 1,25-dihydroxyvitamin D3 (1,25(OH)2D3) stimulates intestinal absorption of calcium and phosphate for new bone formation [9]. Most cells and tissues possess Vitamin D receptors (VDRs) to convert vitamin D to its active form [10,11], and calcitriol binds to VDRs in the cell nucleus before exerting a broad range of actions within the body [11-13].

Little is known about whether supplementation with Vitamin D in athletes with deficiency in Vitamin D to improves physical performance of the athletes, especially about muscle strength and prevent stress fracture in the sport. Recently, some recommendations for vitamin D have been revised with base on findings worldwide [10,11]. One of the purposes of this editorial letter is to gain more information about the prevalence of Vitamin D deficiency in different sports practices in indoor and outdoor environment. Another purpose is to examine whether the supplementation of athletes with Vitamin D deficiency can improve athletic muscle strength and prevent stress fracture in athletes. The present study has as special issue on "Muscle Strength and Stress Fracture in Athletes" included reviews studies [14-19] and original research articles [2,20-22] with the most recent and current knowledge on the theme.

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Vitamin D inadequacy may result in declining training quality along with an increased incidence of injury and illness [23]. Vitamin D supplementation has been shown to increase the force and power output of skeletal muscle [24]. This is possibly due to an increase in the sensitivity of calcium binding sites on the sarcoplasmic reticulum, leading to improved cross bridge cycling and muscle contraction [25]. Scientific reports suggests that Vitamin D receptors (VDRs) nearly in every nucleated cell of our bodies. After binding with the membrane and nuclear VDRs, calcitriol may play a number of significant functions in the body, including effects on bone mineralization, normal function of the nervous, immune, endocrine and cardiovascular systems, as well as hormone production [26,27], regulation of the expression of over 900 gene variants [24] and on the normal function of the muscular system [26].

Factors which may inhibit the synthesis of vitamin D in athletes include geographic location, skin pigmentation, indoor training, early- or late-day training and extensive sunscreen use. A meta-analysis with a total of 2313 professional athletes showed that 56% of the athletes had an inadequate 25(OH)D concentration and that these were significantly lower during the winter period. The studies in question assessed athletes inhabiting areas of high and low levels of insolation. Vitamin D deficits were shown to be common in countries of low levels of insolation. It should, however, be noted that vitamin D deficiency is also found in countries of high levels of insolation, with the risk of insucient 25(OH)D levels being much higher in the winter and spring periods compared to the autumn and summer periods [28,29].

Athletes training indoor have been shown to have low 25(OH)D levels [30,31]. In general, individuals participating in indoor sports are at a higher risk of vitamin D insufficiency and deficiency (Hurst et a. 2014), some studies have shown that both groups of athletes (indoor and outdoor training) had reduced levels of vitamin D [28,32,33]. Lombardi et al. (2017) [34] has demonstrated that 32.9% of Italian professional soccer players had insufficient levels of vitamin

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D and 9% showed vitamin D deficiency. Krzywanski et al. (2016) [35] studied 409 Polish athletes and found that 80% of those who trained outdoors and 84% of those training indoors had 25(OH)D deficits. Vitale et al. (2018) [36] also documented insuficient levels of calcidiol in 50.7% elite professional skiers with 29.6% showing deficient levels. According to Chiang et al. (2017) [18] Vitamin D2 was found to be ineffective at impacting muscle strength in review study performed. However, the authors conclude that the Vitamin D3 has been shown to have a positive impact on muscle strength.

A dose-response effect to muscle strength was seen on mean serum 25(OH)D concentrations from vitamin D supplementation. The 12-week supplementation of dosages C3000 IU exceeded sufficiency concentrations of 30 ng/ml (75 nmol/l) at higher latitudes in fall and winter time, when there is minimal sun exposure. The findings were consistent with the sensitivity analysis when the trials with 15% missing outcome data were removed and heterogeneity was reduced to 0%. The supplementation of B2000 IU in athletes with insufficient vitamin D concentrations did not achieve sufficiency at any latitudes in wintertime [37,38], whereas 24 weeks of B2200 IU [39] achieved sufficiency during spring and summer time, when there is adequate sun exposure [39]. Backx et al. (2016) [39] allocated 400, 1100, or 2200 IU to athletes with insufficient vitamin D from March 2013 to March 2014 and compared them with athletes with sufficient vitamin D status. The mean 25(OH)D exceeded 30 ng/ml (75 nmol/l) in June 2013 in all interventional groups and remained sufficient until March 2014. These findings suggest that the supplementation of > or = 3000 IU in fall and winter will achieve sufficiency during wintertime, when the sun exposure is minimal; whereas the continuous supplementation of 2000 IU may achieve and sustain sufficiency in athletes in all geographical locations.

Despite the scientific evidence on vitamin D supplementation to improve muscle strength in athletes with training load in greater exposure of indoor or outdoor environments, results of studies conducted in athletes with vitamin D deficiency are inconclusive. Some of them showed positive effects of vitamin D supplementation on muscle trength and exercise abilities in athletes [40,41], while others did not [42-44]. Second Ksiazek et al. (2019) [17] further research is necessary to characterize the true vitamin D status by simply measuring free vitamin D rather than total 25(OH)D. Importantly, it may be better to assess the relationship between free vitamin D, skeletal muscle function and exercise ability, to understand how these actions affect athletic performance.

Vitamin D and Stress Fracture in Athletes Practicing in Indoor and Outdoor

Stress fractures represent repeated submaximal loading may be associated with insufficient time for bone deposition to match its removal [45]. This injury commonly develop in active individuals as a result of sudden increased or prolonged training at a high level. It is an injury that affects different sports, such as running, jumping, and other high-impact activities resulted in repetitive and cyclic skeletal load with damage to bone [2,46,47].

Several intrinsic and extrinsic factors may contribute to vitamin D status, including skin color, location of sporting activities, and season. Dark-skinned athletes have been shown to have an elevated risk of poor vitamin D status compared to light-skinned athletes [48]. Regression analysis shows statistically significant differences in baseline serum 25(OH)D levels between races, with non-white athletes demonstrating hypovitaminosis D more frequently than white athletes. Athletes of certain specialties may be at an increased risk for poor vitamin D status [29,30,33,48]. Thus, correcting hypovitaminosis D can improve bone health and may reduce skeletal overuse injuries like stress fractures.

Multiple studies found vitamin D3 supplementation significantly increased 25(OH)D levels in athletes, while levels in nonsupplemented groups tended to decline [18,49,50]. Current research conducted by Willians et al. (2020) [20] in athletes proved of the Vitamin D deficient performed by Vitamin D3 supplementation throughout the winter months, compared with the summer, demonstrated a statistically significant decrease stress fracture rate from 7.51% to 1.65%.

Reduced vitamin D status might therefore be linked to increased stress fracture risk. Evidence supports this supposition: stress fracture risk in athletes appears inversely related to serum 25OHD status up to a concentration of 50 ng/ml (125 nmol/L) [51]. Similarly, female US Navy recruits with serum 25OHD concentrations of less than 20 ng/mL (50 nmol L^{-1}) had double the risk for tibia and fibula fracture compared with recruits whose circulating concentrations were at least 40 ng/mL (100 nmol/L) [52]. However, this relationship has not been demonstrated consistently, and a systematic review and meta-analysis of stress fractures in military recruits could only conclude that 'some association' appeared to exist between low vitamin D status and stress fracture risk [52]. To clarify the veracity of this association, a prospective study wa performed with Royal Marines (RM) recruits undertaking the 32-week RM training programme. Recruits with a baseline serum 25OHD status below 20 ng/mL (50 nmol/L) had a higher incidence of stress fracture than matched controls [53].

Second Chung et al. (2019) [6], Vitamin D deficiency and high level of activity in a young athlete may be the etiology to atypical multiple stress fractures. In athletes who may want to return to sport rapidly, early operative intervention and correction of vitamin D deficiency may be treatment options. In addition, athletes participated in moderate intensity sports without a significant change in activity was found to have a significant underlying vitamin D deficiency. According to literature the Vitamin D deficiency has been reported in lower extremity stress fractures and should be evaluated if clinical concern warrants [54]. Diet, genetics, and participation in weight-bearing activities influence bone mass accrual in the pediatric athletic population, with about 90% of adult bone mass being acquired during phase of adolescence in young athletes [55,56]. Diet and nutrition are important considerations for bone health and fracture prevention. Increased consumption of calcium, vitamin D, and protein may play a preventative role against stress fracture development in athletes young [59-61]. Prospective studies including only females showed that increased intake of calcium and vitamin D supplements, dietary calcium, or dairy products (calcium, vitamin D, and protein) were associated with decreased incidence of stress fractures [54,57,58] . The supplementation of combined vitamin D and calcium with 12 weeks follow-up for a sustainable increase in 25(OH)D concentrations from higher doses (2000 IU/d) in military atheletes resulted decreased fracture rates. Second study performed by Lappe et al. [42], the authors found a significant decrease in stress fractures from 800 IU/d vitamin D with 2000 mg/d calcium supplementation in 5000 Navy recruits.

It is hoped that this Rapid Communication will aid to raise the awareness of the current trends of Vitamin D deficiency can improve athletic muscle strength and prevent stress fracture in athletes. Health professionals working with athletes should constantly monitor the concentration of vitamin D, especially vitamin D3, regardless of the training load of the athletes be with more emphase indoor or outdoor. We hope that the updates of the studies presented in this editorial letter can encourage research and clinical trials this theme, which are still scarce in the literature, with dose-effective parameters for supplementation of vitamin D in the muscle strength and prevention stress fractures in athletes.

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