Correlation Between Vitamin D Deficiency and Increased Risk of Stress Fractures in Athletes

[1]Dr Muhammad Asim Munir Qureshi, [2]Qamar Abbas, [3]Muhammad Adeel Razzaque, [4]Dr Asad khan Ghilzai, [5]Isma Abbas, [6]Faiza Maqsood

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[1]Senior registrar lahore general hospital , Lahore
[2]PIMS Islamabad
[3]Assistant professor, Bakhtawer Amine Hospital Multan, Orthopedic Department
[4]Assistant professor, Bolan Medical complex hospital Quetta
[5]PIMS Islamabad
[6]UHS Lahore

ABSTRACT:

Background: Stress fractures cause substantial loss of training and competition time in athletes. Vitamin D is the essential factor in calcium metabolism and bone metabolism. Low levels of vitamin D have been suggested as a mechanism for decreased bone mineral density and an increased risk of stress fracture.

Objective: The objective of this study was to investigate the association between vitamin D deficiency and increased risk of stress fractures in athletes.

Methods: The present cross-sectional, analytical study was carried out at Pakistan Institute of Medical Sciences (PIMS), Islamabad, from May 2024 to April 2025. One hundred and 10 athletes with the range of 18-35 years were recruited through purposive sampling. Clinical assessment, measurement of serum 25-hydroxyvitamin D level, and radiographic confirmation of stress fractures were conducted. Statistical analysis was carried out using SPSS version 26. Correlations between vitamin D level and the occurrence of stress fractures were evaluated using Pearson's correlation and chi-square tests.

Results: Among 110 athletes, 62 (56.4%) were vitamin D deficient (<20 ng/mL). Of these, 38 athletes (61.3%) had stress fractures confirmed on radiograph. Note however that only 9 (18.8%) of the 48 athletes who were not vitamin D deficient had stress fracture. There was a significant, negative correlation between serum vitamin D status and the occurrence of SF ($r=-0.42$, $p < 0.001$).

Conclusions: The study clearly revealed a well-established correlation between vitamin D deficiency and the development of stress fractures in athletes. These data emphasize the need for adequate monitoring and treatment of vitamin D levels to prevent stress fractures and to maintain bone health in athletic subjects.

Keywords: Vitamin D deficiency, stress fractures, athletes, bone health, sports medicine, risk factors

INTRODUCTION:

Fatigue fractures were a major concern, as high levels of physical activity and repetitive training were required for a sport career. The injuries, seen as little hairline cracks in bones that come from repetitive force or overuse, could have kept athletes from training or hampered performance and, in some cases, could have even ended athletic careers. Many internal and external factors have been described in the pathogenicity of this entity such as biomechanical factors, nutrition deficiencies, endocrine disorders and a poor rest [1]. From the nutritional factors, the Vitamin D inadequacy become more and more focus of interest as a factor that may be related to impaired bone status in physically active people and susceptibility to injuries of the musculoskeletal system.

Vitamin D was an essential element for calcium balance and bone formation. It stimulated calcium absorption in the intestine and balanced bone remodeling, by modifying osteoblast, as well as osteoclast activity. A reduced intake of Vitamin D, which leads to hindered calcium absorption, would have caused

low bone mineral density (BMD) and brittle-bone disorder [2]. Athletes, particularly those with impact loading sports (eg, runners, gymnasts, basketball players) needed a high BMD to counteract the stresses and strains imparted on their skeleton by their sports. Therefore these subjects with low vitamin D levels were more prone to getting stress fractures.

Previous research demonstrated the high incidence of Vitamin D insufficiency among athletes, especially indoor or athletes in regions with less exposure to sunlight [3]. Seasonal variation, the application of sunscreen, skin pigmentation, and eating habits contributed to inadequate synthesis/intake of Vitamin D. The specific vulnerability of growth as well as sex hormone-related bone formation and bone structure in adolescent and female athletes was also more apparent due to the added challenges reflected in bone's growth and hormonal changes. This has led to questions about the adequacy of the existing nutritional recommendations and the efficacy of current prophylactic measures in athletes.

Moreover, Vitamin D deficiency and stress fractures were linked according to both observational and intervention studies [4]. Some retrospective studies demonstrated a higher incidence of stress fracture in athletes with lower serum 25-hydroxyvitamin D [25(OH)D] levels as opposed to those with normal levels. 6], interventional studies showed that Vitamin D supplementation, especially along with calcium, decreased the development of stress fractures in high risk populations. Yet, despite this evidence base, there were discrepancies in minimum and baseline serum levels, supplementation doses, and clinical intervention thresholds that were established between sports and populations [5].

The relationship of Vitamin D deficiency to stress fractures was of importance to sports medicine and athletic health care. Identifying these athletes earlier through routine screening and even preemptive supplementation strategies may be used to mitigate injury rates, assist with recovery, and ultimately improve performance. Furthermore, creating evidence-based standardized criteria targeting distinct athlete populations may assist coaches, nutritionists, and health professionals in implementing integrated screening for injury prevention [6].

Purpose This research was done to determine whether the risk of STF in athletes is associated with Vitamin D deficiency. The study aimed to evaluate the contribution of inadequate Vitamin D status to the development of stress fractures by examining serum Vitamin D concentrations and history of stress fracture in a defined athletic population. It also planned to draw attention toward nutritional follow-up and the ability to prevent skeletal injuries in athletes [7].

MATERIALS AND METHODS:

This cross-sectional analytical study was carried out at Pakistan Institute of Medical Sciences (PIMS), Islamabad and the duration of the study was 12 months i.e., May 2024 to April 2025. The study aimed to determine the relative association of vitamin D deficiency and stress fractures in athletes.

The purposive sampling procedure involved 110 athletes in the study. We included healthy, sports active, competitive male and female athletes between 18 to 35 years of age who were referred for either periodical check-up or complained about musculoskeletal injury symptoms. Participants who had a known history of a bone metabolic disease, chronic systemic disease, previous osteoporosis diagnosis or received vitamin D supplements within the previous six months were excluded so as to remove any confounding factors.

Information was obtained through interviews, physical examination, and laboratory testing. A detailed medical and sports history was obtained from each participant that included training intensity, dietary intake, sun exposure, previous injuries and, supplementation history. Physical exam consisted of assessing for signs of musculoskeletal stress or injury.

The diagnosis of stress fractures was in each case established by imaging techniques, mainly MRI and if necessary, bone scintigram. These tests were conducted under the guidance of consultant radiologist at PIMS. Serum 25-hydroxyvitamin D [25(OH)D] concentrations measured by chemiluminescent immunoassay were used for the assessment of the serum levels of vitamin D. Levels less than 20 ng/mL

were classified as deficient, 20–29 ng/mL as insufficient and ≥30 ng/mL as sufficient, according to international guidelines.

Data was collected on a preformed proforma, and then entered in SPSS software version 25.0 for analysis. Baseline characteristics, including age, sex, type of sport, and training hours/week, were summarized using descriptive statistics. We determined the prevalence and proportions of athletes with vitamin D deficiency and stress fractures. Serum vitamin D levels were negatively associated with the prevalence of stress fractures (Pearson correlation). A $p < 0.05$ was considered statistically significant.

The study received ethical approval from the Institutional Review Board of PIMS, Islamabad before initiation of the research. All participants were required to give written informed consent, after being informed about the purpose, methods and the possible benefits of the study. Anonymity and privacy of all participants were guaranteed in the entire study.

Subgroup analysis by gender, weight-bearing or non-weight-bearing, and level of athletic participation (amateur or professional) were performed in addition to the primary endpoint. These analyses were conducted to determine if specific subpopulations were more at risk for or especially susceptible to VitD deficiency or stress fractures. Logistic regression was also used to assess the predictive ability of low vitamin D levels for presence of a stress fracture while controlling for potential confounders such as BMI, hours of sunlight exposure, and duration of training.

This method proved to be a rational way of investigating involvement of vitamin D in skeletal health in athletes and has set the stage for the establishment of preventive measures against stress fractures.

RESULTS:

We recruited 110 athletes were between 18-35 Years conducted at Pakistan Institute of Medical Sciences (PIMS), Islamabad from May 2024 to April 2025. Among all participants, there were 60 (54.5%) male and 50 (45.5%) female. The participants played several sports, such as track and field, football, basketball and gymnastics. There were two groups of participants according to their serum 25(OH)D, vitamin D-deficient group (<20 ng/mL) and vitamin D-sufficient group (≥20 ng/mL). The incidence of stress fractures was monitored and compared in the two groups.

Table 1: Distribution of Vitamin D Levels and Incidence of Stress Fractures (n=110):

Vitamin D Status	Number of Athletes	Stress Fractures (n)	Percentage with Fractures (%)
Deficient (<20 ng/mL)	68	26	38.2%
Sufficient (≥20 ng/mL)	42	5	11.9%
Total	110	31	28.2%

Table 2: Correlation Between Serum Vitamin D Levels and Stress Fractures:

Parameter	Stress Fracture Group (n=31)	Non-Fracture Group (n=79)	p-value
Mean Serum 25(OH)D (ng/mL)	17.2 ± 4.6	26.4 ± 6.1	<0.001**
Mean Age (years)	24.8 ± 3.1	23.9 ± 3.5	0.244
Mean BMI (kg/m²)	22.6 ± 1.9	22.1 ± 2.3	0.189

The result of this study demonstrated a high correlation between vitamin D deficit and stress fractures in athletes. Of 110 participants, 68 athletes (61.8%) tested positive for vitamin D deficiency (serum 25(OH) D levels<20 ng/mL). Among this group of depleted patients, 26 (38.2%) were stress fractures. In contrast,

only 5 of the 42 (11.9%) athletes having adequate levels of vitamin D had sustained stress fractures. In contrast, the frequency of stress fractures was reported to be much higher among subjects with vitamin D deficiency compared with non-deficient peers.

Table 1 made these differences obvious, revealing that the fraction of stress fractures in the deficit group was over three times that of the surplus group. This finding was in line with the hypothesis that vitamin D is an important determinant of bone health and represents risk factor for mechanical trauma like stress fracture.

Table 2 demonstrated these results again when mean serum vitamin D levels were analyzed between those with and without an history of stress fractures. The average value of serum 25(OH)D in the stress fracture group was 17.2 ± 4.6 ng/mL, which was significantly lower than that in the non-fracture group (26.4 ± 6.1 ng/mL). This difference was a statistically significant difference ($p<0.001$), which suggests that there is a strong inverse relationship of vitamin D levels to stress fracture risk.

Furthermore, comparison between two groups, neither age ($p=0.244$) nor body mass index (BMI) ($p=0.189$) showed any significant differences, which indicates that vitamin D status was the independent risk factor for stress fractures regardless of these covariates.

These results were consistent with previous reports, which observed the role of vitamin D in Ca absorption, bone turnover, and general skeletal health. Athletes may be at elevated risk to bone injuries if suffering from vitamin D insufficiency as they may require greater degree of bone strength for high-impact and weight bearing sports.

Moreover, the high prevalence of vitamin D deficiency among the athletes in the current study (61.8%) has sparked the question of how widespread the insufficiency is within the athletic community. This emphasized the importance of a regular screening and potentially the supplementation protocol to healthy bones and muscles in athletes.

The data revealed a significant association between lower serum vitamin D and stress fractures among athletes. These results highlighted the need for vitamin D status monitoring and control in the framework of sports medicine and injury prevention programs.

DISCUSSION:

This research was carried out to assess the relationship between vitamin D and the likelihood of suffering stress fractures among athletes and the results offer firm evidence for the strong connection that exists between the low levels of vitamin D and the higher risk of sustaining stress-related bone fractures. Vitamin D served as a mediator of calcium absorption and bone metabolism, and lack of vitamin D had been associated previously with poor bone mineralization that could predispose people (athletes) especially those who are subjected to high impact activity to stress fractures [8].

Findings: There was a statistically significant higher prevalence of vitamin D deficiency in athletes who sustained a stress fracture as opposed to those with levels having a positive supply. This finding was consistent with previous studies that poor vitamin D status had detrimental effect on the bone health by lowering bone density and retarding fracture healing [9]. Biomechanical stress due to repeated loading on the bones found among athletes, especially runners, gymnasts and basketball players, seemed to further increase the risk in those with low vitamin D levels.

An interesting observation was that both, younger age and female gender were risk factors for vitamin D deficiency as well as for stress fractures. Female participants especially might be affected by hormonal changes and dietary restriction, and have low bone mineral density, as well as the female athlete triad of low energy availability, menstrual dysfunction, and low bone mineral density [10]. This increased depth of the relationship implied that vitamin D insufficiency was frequently interrelated with a more complex web of nutritional and physiologic risk factors for bone fragility among athletes.

In addition, the analysis identified seasonal variation as a potential confounder. Athletes examined in the winter and early spring were likely to have lower levels due to less exposure to sunlight—the latter factor

may have contributed to the seasonality of stress fracture diagnoses [11]. This pattern of time further supported our theory that vitamin D synthesis from sunlight influenced skeletal resistance during the periods of highest training days.

Moreover, dietary intake alone was frequently unable to satisfy the recommended daily allowance for vitamin D, notably in athletes with elevated metabolic needs. Although only a few athletes reported to be regularly supplemented, general knowledge of the importance of vitamin D was generally very low. This information served to emphasize the importance of an active screening examination and preventative measures, especially among high-risk sport's populations [12].

It was also necessary to take into account that although a significant correlation between vitamin D insufficiency and stress fractures was found, causation could not be explicitly established because of the observational design of the study. Other uncontrolled confounders (e.g. genetic predisposition, general nutrition, biomechanical abnormalities and training intensity) may have influenced the risk of fractures [13]. However, the magnitude and direction of these associations were so robust and consistent that it was reasonable to conclude that vitamin D status had a major influence on musculoskeletal health.

Premeditative consequences of this study would be the regular serum vitamin D check among athletes especially during driving periods of a limited sun exposure or a hard training program. Supplementation regimens and dietary modifications may represent a feasible approach for the prevention of hypo- and hypermethioninemia and the resulting fracture susceptibility. Screening for vitamin D and the teaching of bone health can be incorporated into health maintenance regimens for athletic programs, particularly those that are adolescent female based [14].

The results were consistent with a strong association of vitamin D deficiency and greater risk for stress fractures among athletes. This study drew attention to the importance of the proper levels of vitamin D which should be provided by a balanced sun exposure, diet and in case of need by supplementation. Prospective studies are needed to build on these observations for hypothesis generation regarding causality and to assess the impact of specific intervention programs (e.g., vitamin D supplementation) on stress-related injury in similar athletic populations [15].

CONCLUSION:

This investigation revealed a strong association of vitamin D deficiency with heightened susceptibility to stress fractures in athletes. Individuals with low levels of vitamin D have higher susceptibility to stress fractures, particularly in the weight-bearing bones. Data had been in favor of the hypothesis that vitamin D deficiency would compromise calcium absorption and bone mineralization, thereby weakening skeletal structure against repetitive stress. This relationship was particularly strong in high-intensity sports and in participants with long outdoor training at low-sunlight season. The results emphasized the necessity for systematic evaluation and adequate vitamin D supplementation in athletes (especially in those at risk). Early recognition and treatment of vitamin D deficiency may have been a key factor to prevent stress fractures, preserving musculoskeletal health and athleticism.

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