



Vitamin D Inadequacy and Musculoskeletal Symptoms in Elite Albanian Athletes

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Abstract

Symptoms such as fatigue, muscle cramps, and pain are widespread among athletes and may be associated with nutritional factors, particularly vitamin D status. The present study aimed to evaluate the association between serum 25(OH)D concentration and musculoskeletal symptoms among athletes, as well as to examine serum calcium levels in relation to vitamin D status. A total of 102 athletes were included in this cross-sectional study conducted from October to December 2025. Serum 25(OH)D and calcium concentrations were measured, and vitamin D status was classified according to predefined laboratory thresholds. Vitamin D inadequacy occurred in 50% of the subjects, whereas serum calcium levels were within the normal range in the majority of participants. Subjects experiencing musculoskeletal symptoms demonstrated significantly higher frequencies of vitamin D inadequacy compared with those without symptoms (59.4% vs 34.2%, $p = 0.024$). In a multivariable analysis, musculoskeletal symptoms were associated with vitamin D inadequacy. No strong association was observed between serum 25(OH)D and calcium concentrations. The frequency of vitamin D inadequacy among athletes was high and was significantly associated with musculoskeletal symptoms, after considering age group, sex, and body mass index (BMI). Normal calcium levels should not be interpreted as evidence of adequate vitamin D status.

Keywords: vitamin D inadequacy, musculoskeletal symptoms, fatigue, muscle pain, clinical screening

1. Introduction

Vitamin D is fundamental to calcium-phosphorus homeostasis, bone mineralization, and neuromuscular function. In addition to its well-established importance for skeletal health, vitamin D has gained increasing attention in sports medicine due to its involvement in muscle physiology. The presence of vitamin D receptors in skeletal muscle tissue suggests that vitamin D may directly influence muscle strength, neuromuscular coordination, and post-exercise recovery. (Holick et al., 2011) (Larson-Meyer & Willis, 2010) (Ogan & Pritchett, 2013) (Constantini, Arieli, Chodick, & Dubnov-Raz, 2010) (Owens, Fraser, & Close, 2015) (Yoon, Kwon, & Kim, 2021). Consequently, maintaining adequate vitamin D levels is considered important not only for bone integrity but also for optimal physical performance and injury prevention in athletes. (Constantini, Arieli, Chodick, & Dubnov-Raz, 2010) (Owens, Fraser, & Close, 2015) (Yoon, Kwon, & Kim, 2021)

In athletic populations, musculoskeletal function is critical for performance, training adaptation, and recovery. However, a wide range of non-specific symptoms, including fatigue, muscle weakness, muscle cramps, and musculoskeletal pain, are commonly reported by athletes, particularly during periods of intense training or competition. These symptoms are often attributed to mechanical overload, insufficient recovery, or training-related stress. They may also be associated with underlying metabolic or nutritional imbalances, including suboptimal vitamin D status (Yoon, Kwon, & Kim, 2021) (Mehran, Schulz, Neri, Robertson, & Limpisvasti, 2016) (Valtueña, Dominguez, Til, González-Gross, & Drobnic, 2014) Emerging evidence suggests that vitamin D inadequacy may impair muscle function, reduce exercise capacity, and negatively influence athletic performance. (Sale & Elliott-Sale, 2019)

Despite the assumption that athletes are less likely to have vitamin D deficiency due to regular physical activity and greater outdoor exposure, numerous studies have indicated that vitamin D insufficiency remains highly prevalent across different sports disciplines and geographic regions. Factors such as indoor training, seasonal variation, use of protective clothing, skin pigmentation, and inadequate dietary intake may all contribute to reduced vitamin D synthesis and availability, even among otherwise healthy and active individuals. These findings challenge the notion that athletic status alone ensures adequate vitamin D levels. (Holick M. F., 2010) (Alkoot, Boland, Brugha, & Biesma, 2019) (Harju, Gray, Mavroedi, Farooq, & Reilly, 2022) (Willis, Smith, Broughton, & Larson-Meyer, 2012) (Geiker et al., 2017) (Hoxha, Bozo, Krasniqi, & Bozo, 2024) (Bozo, Pojani, Hoxha, Lami, & Bozo, 2026)

Calcium, which is closely linked to vitamin D metabolism, plays a key role in neuromuscular transmission, muscle contraction, and bone health. However, serum calcium levels are tightly regulated by hormonal mechanisms, including parathyroid hormone and renal calcium handling, and are maintained within a narrow physiological range. (Most et al., 2021) (Farrokhyar et al., 2015) As a result, normal calcium concentrations do not necessarily indicate adequate vitamin D status. This physiological dissociation limits the usefulness of calcium as a standalone marker for identifying vitamin D insufficiency in clinical or sports settings. (Chiang, Ismaeel, Griffis, & Weems, 2017) (Han, Li, Tan, Shao, & Yi, 2019)

Although the relationship between vitamin D status and athletic performance has been widely studied, much of the existing literature focuses on prevalence estimates or performance-related outcomes. In contrast, fewer studies have examined the clinical relevance of vitamin D in relation to symptom burden in athletes. Understanding whether commonly reported musculoskeletal symptoms are associated with vitamin D inadequacy is particularly important, as these symptoms are often non-specific and may go unrecognized or be attributed solely to training factors. Identifying a possible association between vitamin D status and symptom presentation could have important implications for targeted screening, early detection, and individualized management strategies in athletic populations. (Jastrzębska, Kaczmarczyk, & Jastrzębski, 2016) (Sodero et al., 2025)

Furthermore, athletes experiencing persistent or unexplained symptoms such as fatigue or musculoskeletal pain may represent a subgroup for whom biochemical evaluation is particularly relevant. Therefore, evaluating vitamin D status may provide additional insight beyond routine clinical assessment and may help guide preventive or therapeutic strategies.

Accordingly, this research sought to examine the relationship between serum concentrations of

25-hydroxyvitamin D [25(OH)D] and musculoskeletal symptoms among athletes, while also examining whether serum calcium levels reflect vitamin D status. By focusing on symptom-related outcomes, this study is designed to contribute to the clinical understanding of the relevance of vitamin D inadequacy in athletic populations.

2. Materials and Methods

2.1 Study design and setting

The present cross-sectional study took place in October to December 2025 (to ensure a clearly defined period of biochemical assessment) using clinical and laboratory evaluations performed on athletes in a laboratory accredited according to ISO 9001-2015 standards located in an urban region of Albania. In particular, the research sought to explore the correlation between vitamin D levels and the development of musculoskeletal symptoms in athletes.

The sample size was determined based on the availability of participants who met the eligibility criteria during the study period.

2.2 Study population

The study participants were selected from organized sports clubs at the national level and comprised elite athletes aged 18-30 years from diverse sports disciplines (athletics, basketball, volleyball, boxing, fitness football, shot put/discus throw, kick boxing, wrestling, swimming, weightlifting, and ping-pong), including both individual and team sports, who were assessed during the study period. For the purpose of this study, elite athletes were considered as athletes affiliated with sports clubs at the national, superior, or Olympic level and engaged in structured and regular training during the study period. (McKay et al., 2022) Overall, 102 athletes fulfilled the eligibility criteria and were included in the final analysis. Inclusion required the availability of both serum 25(OH)D and total calcium measurements, and the sample collection season was recorded because 25(OH)D concentrations may be influenced by sunlight exposure. Athletes with missing laboratory data for either parameter were excluded from the analysis.

2.3 Data collection and study variables

Data were extracted from the study database using a standardized structured data collection form. Lifestyle-related, sport-related, and biochemical information were collected from each participant at the time of data collection. Daily sun exposure was self-reported and expressed in minutes per day. Participants were classified according to sunlight exposure as follows: less than or equal to 30 minutes per day, more than 31 but less than 60 minutes per day, and more than 60 minutes per day. Sport discipline was recorded for characterization purposes. Musculoskeletal symptoms were assessed through self-report and included fatigue, muscle cramps, back pain, and leg pain. For analytical purposes, a composite binary variable was created to indicate the presence of at least one of these symptoms.

Participants were asked about current vitamin D supplementation, and none reported taking vitamin D supplements during the study period. Participants with chronic diseases or chronic diarrhea were excluded from the study.

2.4 Laboratory measurements

Serum 25(OH)D and calcium concentrations were assessed using blood samples drawn from the cubital vein. After centrifugation, the resulting serum was analyzed using absorbance photometry with the automated COBAS INTEGRA® 400 plus for calcium measurement, and electrochemiluminescence (ECL) with the automated COBAS® E 411 system for measuring 25(OH)D levels.

The primary biochemical variables of interest were serum 25(OH)D concentration (ng/mL) and total serum calcium concentration (mg/dL). Serum 25(OH)D was used as the indicator of vitamin D status (Bikle, Bouillon, Thadhani, & Schoenmakers, 2017), while total calcium was used as the indicator reflecting aspects of musculoskeletal functions. These biochemical parameters were interpreted together with lifestyle-related factors, including daily sun exposure, sports discipline, and the absence of reported chronic diseases or current vitamin D supplementation. Serum 25(OH)D and calcium concentrations were quantified using standardized automated laboratory techniques in accordance with the manufacturer's protocols. (Bozo, Pojani, Hoxha, Lami, & Bozo, 2026) Laboratory reference ranges were applied according to the standards of the performing laboratory. Laboratory analyses were performed at an accredited and ISO-certified 9001-2015 medical laboratory located in Albania, using standardized procedures.

2.5 Operational definitions

Vitamin D status was classified based on serum 25(OH)D concentrations as deficiency (<20 ng/mL), insufficiency (20–29.9 ng/mL), and sufficiency ($\geq$ 30 ng/mL). (Holick et al., 2011) For additional analyses, vitamin D inadequacy was defined as serum 25(OH)D levels below 30 ng/mL. Calcium status was categorized as low (<8.5 mg/dL), normal (8.5–10.5 mg/dL), and high (>10.5 mg/dL). (Rifai, 2018) The composite symptom variable was operationalized as the presence of at least one self-reported musculoskeletal symptom, including fatigue, muscle cramps, back pain, or lower limb pain.

2.6 Statistical analysis

All statistical **analyses** were conducted using IBM SPSS Statistics for Windows (version 30.0; IBM Corp., Armonk, NY, USA). Categorical variables are expressed as numbers (n) and percentages (%). Quantitative variables were presented as mean $\pm$ standard deviation (SD) or median (interquartile range [IQR]), depending on their distribution. (Sodero et al., 2025) (Jiao et al., 2025)

The normality of quantitative variables was assessed using the Shapiro–Wilk test. Because serum 25(OH)D and calcium were not normally distributed, non-parametric tests were applied. (Sodero et al., 2025)

Correlations between quantitative variables were assessed using Spearman's rank correlation coefficient. Two independent samples were compared using the Mann–Whitney U test, whereas comparisons among more than two groups were made using the Kruskal–Wallis test. Associations between categorical variables were analyzed using the chi-square test or Fisher's exact test, where applicable. (Sodero et al., 2025) (Jiao et al., 2025)

To examine factors independently associated with vitamin D inadequacy (<30 ng/mL), a multiple logistic regression model was created. Age, sex, BMI, and the composite symptom variable were included as independent variables. Results were expressed as adjusted odds ratios (aORs) with 95% confidence intervals (95% CIs).

All statistical tests were two-sided, and a p-value <0.05 was considered statistically significant.

2.7 Ethical considerations

All study procedures conformed to the Declaration of Helsinki guidelines. The project received clearance from the Ethics Committee for Scientific Research at the University of Sports of Tirana, Albania, on 02/10/2024 (protocol number Prot.N.2602/2).

All subjects signed written consent before being included in the current research. Data confidentiality and subject anonymity were assured, and all statistical analyses were performed using anonymized data.

3. Results

3.1 Characteristics of the study population

A total of 102 athletes were included in the analysis, of whom 55 (53.9%) were male, and 47 (46.1%) were female. The median age was 21.5 years (IQR 18.0–26.8).

Anthropometric characteristics showed a median body weight of 70.0 kg (IQR 63.0–80.0), median height of 178.0 cm (IQR 170.0–183.8), and median BMI of 22.1 kg/m² (IQR 21.0–24.3).

Athletes reported a median training volume of 14.0 hours per week (IQR 10.0–18.0) and a median training frequency of 5 sessions per week (IQR 3–5). Median daily sun exposure was 30 minutes (IQR 30–60).

Additional baseline characteristics are summarized in Table 1.

Table 1. Baseline characteristics of the study population (N = 102)

Characteristic	Value
Male sex, n (%)	55 (53.9)
Female sex, n (%)	47 (46.1)
Age, median (IQR), years	21.5 (18.0–26.8)
Weight, median (IQR), kg	70.0 (63.0–80.0)
Height, median (IQR), cm	178.0 (170.0–183.8)
BMI, median (IQR), kg/m ²	22.1 (21.0–24.3)
Training hours/week, median (IQR)	14.0 (10.0–18.0)
Training frequency/week, median (IQR), sessions	5.0 (3.0–5.0)
Sun exposure, median (IQR), minutes/day	30.0 (30.0–60.0)
25(OH)D, median (IQR), ng/mL	29.95 (25.95–32.38)
Calcium, median (IQR), mg/dL	9.57 (9.34–9.85)

3.2 Vitamin D and calcium status

Median serum 25(OH)D concentration was 29.95 ng/mL (IQR 25.95–32.38), while median calcium was 9.57 mg/dL (IQR 9.34–9.85).

Vitamin D inadequacy (<30 ng/mL) was present in 50.0% of athletes. Calcium levels were predominantly within the normal range.

Detailed distributions are shown in Table 2.

Table 2. Distribution of vitamin D and calcium status

Variable	N	%
Vitamin D deficiency (<20 ng/mL)	5	4.9
Vitamin D insufficiency (20–29.9 ng/mL)	46	45.1
Vitamin D sufficiency (≥30 ng/mL)	51	50.0
Vitamin D inadequacy (<30 ng/mL)	51	50.0
Low calcium (<8.5 mg/dL)	0	0.0
Normal calcium (8.5–10.5 mg/dL)	97	95.1
High calcium (>10.5 mg/dL)	5	4.9

No participants presented with hypocalcemia.

3.3 Association between musculoskeletal symptoms and biomarker levels

Athletes reporting musculoskeletal symptoms (fatigue, muscle cramps, back pain, or leg pain) had lower vitamin D levels compared with asymptomatic athletes.

Median 25(OH)D levels were 28.30 ng/mL in symptomatic athletes versus 30.90 ng/mL in asymptomatic athletes, although this difference did not reach statistical significance ($p = 0.0687$). No statistically significant differences in calcium levels were observed between groups. These results are presented in Table 3.

Table 3. Biomarker levels according to musculoskeletal symptoms and sex

Group	25(OH)D, median (IQR), ng/mL	Calcium, median (IQR), mg/dL
Male	30.10 (26.35–32.40)	9.69 (9.48–9.98)
Female	28.90 (25.70–32.05)	9.46 (9.26–9.61)
Symptoms present	28.30 (25.30–32.42)	9.55 (9.31–9.81)
Symptoms absent	30.90 (27.88–32.27)	9.61 (9.38–9.97)

Calcium levels were significantly higher in males compared to females ($p = 0.0006$), whereas no significant difference was observed for vitamin D levels ($p = 0.4361$). Vitamin D inadequacy (<30 ng/mL) was significantly more frequent among symptomatic athletes compared with asymptomatic athletes (59.4% vs 34.2%, $p = 0.024$).

3.4 Correlation analysis

Spearman correlation analysis showed a weak inverse correlation between serum 25(OH)D levels and age ($\rho = -0.267$, $p = 0.0066$).

No significant correlations were found between 25(OH)D and calcium levels ($\rho = 0.032$, $p = 0.7480$), body weight, height, BMI, training hours, training frequency, or sun exposure.

Serum calcium showed a weak positive correlation with BMI ($\rho = 0.224$, $p = 0.0237$). No other significant correlations were observed between calcium and the remaining variables. The remaining correlations were weak and not statistically significant.

3.5 Multivariable analysis

Multivariable logistic regression analysis identified musculoskeletal symptoms as an independent predictor of vitamin D inadequacy (<30 ng/mL).

Athletes with symptoms had significantly higher odds of vitamin D inadequacy (aOR 2.50, 95% CI 1.03–6.06, $p = 0.043$).

Results are presented in Table 4.

Table 4. Multivariable logistic regression for vitamin D inadequacy (<30 ng/mL)

Variable	Adjusted OR	95% CI	P
Age (per 1 year)	1.07	0.98–1.18	0.146
Male sex	0.63	0.25–1.59	0.326
BMI (per 1 kg/m ²)	1.17	0.99–1.38	0.059
Musculoskeletal symptoms	2.50	1.03–6.06	0.043

4. Discussion

This study evaluated serum 25-hydroxyvitamin D [25(OH)D] and calcium status in a cohort of athletes and examined their associations with demographic, anthropometric, and clinical variables, with a particular focus on musculoskeletal symptoms. The principal findings of the present study were that vitamin D inadequacy was common, affecting approximately half of the athletes, while calcium levels remained largely within the normal range; athletes reporting musculoskeletal symptoms had a significantly higher prevalence of vitamin D inadequacy; and musculoskeletal symptoms were independently associated with vitamin D inadequacy in multivariable analysis. In contrast, serum

calcium levels showed limited variation and were not notably associated with vitamin D status. These findings highlight the potential clinical relevance of vitamin D assessment in symptomatic athletes and underscore the limited utility of calcium as a surrogate marker for vitamin D status (Holick et al., 2011) (Larson-Meyer & Willis, 2010) (Ogan & Pritchett, 2013) (Lambert et al., 2014) (Constantini, Arieli, Chodick, & Dubnov-Raz, 2010) (Owens, Fraser, & Close, 2015) (Yoon, Kwon, & Kim, 2021) (Farrokhyar et al., 2015) (Harju, Gray, Mavroedi, Farooq, & Reilly, 2022)

One of the most important findings of this study is the high prevalence of vitamin D inadequacy, observed in 50% of the athletes. These findings are consistent with the growing evidence indicating that vitamin D insufficiency remains prevalent even among physically active individuals and athletic populations. Despite the common assumption that athletes may be less susceptible to vitamin D deficiency due to increased outdoor activity, previous studies have demonstrated that suboptimal vitamin D status persists across various sporting disciplines and geographic regions. (Holick M. F., 2010) This apparent paradox may be partly explained by multiple potential factors, including indoor training environments, seasonal variation, the timing of training sessions, the use of protective clothing, and insufficient dietary vitamin D intake. (Larson-Meyer & Willis, 2010) (Harju, Gray, Mavroedi, Farooq, & Reilly, 2022) (Farrokhyar et al., 2015) (Ip, Fu, Ong, & Yung, 2022) (Ribbans, Aujla, Dalton, & Nunley, 2021) Therefore, the present findings reinforce the concept that athletic status alone does not guarantee optimal vitamin D levels.

Vitamin D insufficiency in this group of athletes must be considered in light of the multiple factors that control serum 25(OH)D levels. The current investigation includes serum 25(OH)D and serum calcium, along with daily sun exposure, vitamin D supplementation, type of sport practiced, and pertinent clinical details. No athlete was taking vitamin D supplementation, and none had a history of chronic diseases or chronic diarrhea, which would affect vitamin D metabolism and absorption. While sun exposure plays a major role in endogenous vitamin D production, serum 25(OH)D levels can also be affected by dietary intake, seasons, training conditions, body constitution, and other individual variables. Vitamin D insufficiency must therefore not be attributed solely to sun exposure or any single variable.

A central aspect of this study is the observed association between vitamin D status and musculoskeletal symptoms. Athletes reporting symptoms such as fatigue, muscle cramps, back pain, or leg pain were significantly more likely to have vitamin D inadequacy compared to asymptomatic athletes. The association remained significant even after adjustment for age, sex, and BMI in multivariate analysis, thus suggesting that the connection does not depend on the above-listed confounders. These findings are consistent with previous studies suggesting a potential relationship between vitamin D inadequacy and musculoskeletal symptoms in physically active populations (Sodero et al., 2025) (Channarong & Phongamwong, 2023)

The biological rationale for this association is supported by the recognized role of vitamin D in muscle function and neuromuscular coordination, as well as the presence of vitamin D receptors in skeletal muscle tissue. Previous research has linked vitamin D deficiency with impaired muscle strength, reduced functional performance, and increased risk of muscle pain and injury. In athletes exposed to repetitive mechanical stress and high training loads, these effects may contribute to symptom development. (Constantini, Arieli, Chodick, & Dubnov-Raz, 2010) (Owens, Fraser, & Close, 2015) (Yoon, Kwon, & Kim, 2021) (Ip, Fu, Ong, & Yung, 2022) (Ribbans, Aujla, Dalton, & Nunley, 2021) (Goolsby & Boniquit, 2017) (Sale & Elliott-Sale, 2019) Nevertheless, musculoskeletal symptoms in athletes are multifactorial and may also reflect training-related, biomechanical, recovery-related, or other nutritional factors. Therefore, vitamin D inadequacy should be considered as one potential contributing factor rather than a direct cause of these symptoms. Although causal conclusions cannot be established due to the cross-sectional design, the persistence of the association in adjusted analysis suggests that vitamin D status may warrant consideration in athletes presenting with unexplained musculoskeletal complaints. Another key finding of the present study is the lack of a significant relationship between serum 25(OH)D and calcium levels. Although vitamin D plays an important role in calcium absorption and metabolism, serum calcium concentrations are maintained within a narrow physiological range through homeostatic mechanisms involving parathyroid hormone, renal regulation,

and bone turnover. Consequently, calcium levels may remain normal even in the presence of vitamin D insufficiency, which may explain the lack of correlation observed in the present study. (Holick M. F., 2010) (Holick et al., 2011) (Goolsby & Boniquit, 2017) (Sale & Elliott-Sale, 2019) (Ayaz, Zaman, Radák, & Gu, 2024)

From a clinical perspective, these findings suggest that normal calcium concentrations should not be interpreted as evidence of adequate vitamin D status. Since calcium is commonly included in routine laboratory panels, reliance on calcium values alone may contribute to underrecognition of vitamin D inadequacy, particularly in athletes presenting with unexplained musculoskeletal symptoms. Therefore, direct assessment of serum 25(OH)D may be more informative when vitamin D status is clinically relevant. (Holick et al., 2011) (Goolsby & Boniquit, 2017) (Sale & Elliott-Sale, 2019)

The study also identified a weak inverse correlation between vitamin D levels and age, indicating that older athletes in the sample tended to have lower 25(OH)D concentrations. Although the magnitude of this association was relatively small, it may reflect differences in lifestyle habits, outdoor exposure, or training patterns across age groups. However, given the relatively narrow age range of the study population, this finding should be interpreted cautiously. (Constantini, Arieli, Chodick, & Dubnov-Raz, 2010) (Farrokhyar et al., 2015) (Harju, Gray, Mavroedi, Farooq, & Reilly, 2022)

Calcium levels were found to be significantly higher in male athletes compared to females, although the differences were small and remained within the normal range. This observation may reflect physiological differences related to body composition, hormonal factors, or dietary intake. Nevertheless, the clinical relevance of this finding is likely limited, given that calcium values remained within normal limits in nearly all participants.

Interestingly, no significant associations were observed between vitamin D levels and variables such as training volume, training frequency, or reported sun exposure. Although sunlight exposure is a major determinant of vitamin D synthesis, self-reported measures may not accurately capture relevant factors such as season, ultraviolet intensity, clothing coverage, or time of day. Similarly, training-related variables may not adequately distinguish between indoor and outdoor activity. Therefore, the absence of significant associations should be interpreted cautiously and may partly reflect limitations in measurement precision. (Holick M. F., 2010) (Larson-Meyer & Willis, 2010) (Alkoot, Boland, Brugha, & Biesma, 2019) (Harju, Gray, Mavroedi, Farooq, & Reilly, 2022) (Ip, Fu, Ong, & Yung, 2022) (Ribbans, Aujla, Dalton, & Nunley, 2021)

The clinical implications of the present findings are noteworthy. First, the high prevalence of vitamin D inadequacy suggests that routine monitoring of vitamin D status may be relevant in athletic populations, particularly in the presence of potential risk factors for insufficiency. Second, the observed association between vitamin D inadequacy and musculoskeletal symptoms supports the potential value of targeted assessment in symptomatic athletes. Although causality cannot be established, evaluation of vitamin D status may be useful in athletes presenting with unexplained fatigue or musculoskeletal complaints. Third, the lack of association between calcium and vitamin D status emphasizes the importance of direct measurement of 25(OH)D rather than relying solely on indirect biochemical markers. (Yoon, Kwon, & Kim, 2021) (Ip, Fu, Ong, & Yung, 2022) (Goolsby & Boniquit, 2017) (Ribbans, Aujla, Dalton, & Nunley, 2021) (Sale & Elliott-Sale, 2019)

From a sports medicine perspective, these findings may have practical relevance for routine clinical assessment. Evaluation of vitamin D status may be considered in athletes presenting with unexplained fatigue or musculoskeletal complaints, particularly when symptoms persist without an evident cause.

5. Strengths and Limitations

The present study has several strengths, including the comprehensive assessment of vitamin D and calcium status in athletes through the integration of biochemical measurements with clinically relevant variables, including musculoskeletal symptoms. In addition, the use of multivariable analysis strengthened the evaluation of the observed associations by accounting for potential confounding factors. To our knowledge, data evaluating the association between vitamin D status and

musculoskeletal symptoms among athletes in Albania remains very limited, and the present study contributes novel evidence in this population. However, some limitations should also be acknowledged. The cross-sectional design does not allow causal conclusions to be established, and daily exposure to sunlight, vitamin D supplementation status, and musculoskeletal symptoms were self-reported, which may have introduced bias or subjective interpretation. There is no quantifiable measure of the ratio of indoor versus outdoor practice. Although the sample size was sufficient for the primary analyses, it may have limited the ability to detect weaker associations. Furthermore, the study relied on a single measurement of vitamin D and calcium without accounting for seasonal variation or longitudinal changes over time. Additional biomarkers related to calcium metabolism, such as parathyroid hormone or ionized calcium, were also not available, limiting the depth of physiological interpretation. (Ip, Fu, Ong, & Yung, 2022) (Yoon, Kwon, & Kim, 2021) (Goolsby & Boniquit, 2017) (Ribbans, Aujla, Dalton, & Nunley, 2021) (Sale & Elliott-Sale, 2019) (Sodero et al., 2025). Overall, the findings contribute to growing evidence that vitamin D inadequacy is common in athletes and may be associated with musculoskeletal symptoms. Future longitudinal and interventional studies are needed to further clarify these relationships and to evaluate whether correcting vitamin D inadequacy is associated with improvements in symptoms and performance-related outcomes.

6. Conclusions

Vitamin D inadequacy appears to be common among athletes, whereas calcium levels generally remain within normal ranges and may not reliably reflect vitamin D status. Athletes presenting with fatigue or musculoskeletal complaints were more likely to exhibit vitamin D inadequacy, suggesting a potential association between vitamin D status and non-specific musculoskeletal symptoms. However, given the cross-sectional design of the study, causal conclusions cannot be established.

Overall, the findings support the potential relevance of vitamin D assessment in athletic populations, particularly in symptomatic individuals, as part of a comprehensive approach to musculoskeletal health and clinical evaluation. Further longitudinal and interventional studies are needed to better clarify these relationships and their possible implications for athlete health and performance.

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