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Article

Evaluating the Role of Vitamin D Supplementation in Enhancing Muscle Strength Among Athletes

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ABSTRACT
Background: Vitamin D is essential for musculoskeletal health, and a deficiency can affect muscle performance. Athletes, especially those training indoors or in areas with limited sunlight, may lack sufficient vitamin D.
Objectives: This review examines how vitamin D supplements affect muscle strength in athletes across different sports.
Method: A comprehensive literature search was conducted across PubMed, Scopus, and Science Direct for randomized controlled trials (RCTs) published between 2014-2024. Studies examining vitamin D supplementation in athletes and its impact on muscle strength outcomes were included. Data on dosage, duration, baseline vitamin D levels, and muscle strength assessments were extracted and analyzed.
Results: Four RCTs were identified, with supplementation doses from 600 IU to 5000 IU daily. The results indicate that vitamin D supplements significantly improve lower limb strength, power, and recovery in athletes with initial vitamin D insufficiency (levels below 30 ng/mL). For athletes with sufficient vitamin D levels, supplements had little to no impact. Factors such as the length of the intervention and initial vitamin D levels were important in determining the outcomes.
Conclusion: Vitamin D supplements can benefit athletes with a deficiency, enhancing muscle strength. However, they show limited effects on those with adequate vitamin D. Future research should focus on determining the ideal dosing and examining the long-term impact of supplements on athletic performance.

Keywords: Vitamin D, Muscle strength, Athletes, Supplementation

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INTRODUCTION

Muscle strength is necessary for athletic performance, influencing endurance, power, and overall physical capacity (Wang et al., 2024). Among various nutritional factors contributing to muscle function, vitamin D [25(OH)D] has gained increasing attention due to its potential role in skeletal muscle metabolism and strength enhancement (Savolainen et al., 2024).

An optimal concentration of plasma 25-hydroxyvitamin D [25(OH)D] plays a crucial role in supporting the muscular system both during and after physical activity. It helps regulate the balance of pro- and anti-inflammatory cytokines, particularly tumor necrosis factor-alpha (TNF-α) and interleukin-10, thereby reducing inflammatory responses (Pilch et al., 2020). Vitamin D also facilitates muscle cell protein synthesis by activating intracellular receptors, contributing to enhanced physical performance, muscle strength, mass, and endurance by sustaining adequate ATP levels. Additionally, it helps minimize Delayed Onset Muscle

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Soreness (DOMS), protects fast-twitch (type-II) muscle fibers, and accelerates post-exercise recovery (Mateen & Moin, 2017). Conversely, vitamin D deficiency has been linked to impaired motor coordination, reduced muscle strength and endurance, and an increased risk of muscle damage. However, these parameters tend to improve as blood 25(OH)D levels return to their optimal range (Pennisi et al., 2019).

Correcting low serum vitamin D levels has been shown to lower the risk of stress fractures, which are particularly common in sports such as basketball, baseball, athletics, rowing, soccer, aerobics, and classical ballet (Ip et al., 2022; Millward et al., 2020). Recent studies indicate that daily supplementation with 800 IU of vitamin D and 2000 mg of calcium reduces the prevalence of stress fractures among athletes (Ip et al., 2022; Knechtle et al., 2021). Additionally, high-risk collegiate athletes experienced a significant reduction in stress fracture incidence, dropping from 7.51% to 1.65% with vitamin D_3 supplementation (Ip et al., 2022; Williams et al., 2020).

Vitamin D supplementation may also contribute to preventing skeletal muscle injuries, particularly those resulting from eccentric muscle contractions (Ip et al., 2022). Research by Żebrowska et al. (2020) demonstrated that three weeks of vitamin D supplementation led to increased serum 25(OH)D levels and a substantial decrease in post-exercise biomarkers such as troponin, myoglobin, creatine kinase, and lactate dehydrogenase in ultra-marathon runners (Żebrowska et al., 2020). However, a recent meta-analysis reviewing the impact of vitamin D on muscle strength and power in athletes found that supplementation significantly improved lower body muscle strength, with no notable effects were observed on upper body muscle strength or overall muscle power. The underlying cause of this discrepancy remains uncertain (Sist et al., 2023; Zhang et al., 2019). Another meta-analysis examining the effects of vitamin D_3 on serum 25-hydroxyvitamin D [25(OH)D] levels and muscle strength in athletes found no statistically significant impact of supplementation on overall muscle strength (Farrokhyar et al., 2017; Han et al., 2019). Despite these findings, vitamin D supplementation is still believed to contribute to the prevention of skeletal muscle injuries. Given these findings, this study was conducted to examine how vitamin D supplementation influences the muscle strength in athletes and various exercise.

METHODS

Eligibility Criteria

The PICO framework was used to formulate the research question as follow (Table 1): The Population (P) consisted of male and female athletes under the age of 35 years, with no restrictions on sport type or competitive level. The Intervention (I) involved the oral administration of vitamin D2 or D3, without limitations on dosage or duration. The Comparison (C) was either intervention and placebo. The Outcomes (O) measured were maximal strength and power. Moreover, only published randomized controlled trials (RCTs) involving athletes were included. Studies were excluded if they were non-randomized, unrelated to athletes, involved athletes with chronic illness, injury or impairment, did not assess muscle strength

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using 1 RM tests or muscle power by jump tests, or if intervention included additional components. In addition, the eligibility criteria also use articles published in 2015-2025, including national and international journals.

Information Sources and Searching Strategy

Literature searches were carried out during January-March 2025, utilizing secondary data from previous research on both national and international journals. The databases used included PubMed, Science Direct, and Google Scholar. The search strategy involved the use of keywords and filters, incorporating MeSH (Medical Subject Headings) and text words to facilitate the identification of relevant studies. The filters applied focused on Vitamin D2/D3 and muscle strength in athletes.

Search string that included controlled vocabulary and free-text terms related to vitamin D were also utilized, such as “vitamin D2”, “vitamin D3”, “cholecalciferol”, “ergocalciferol”, “oral supplementation”. These terms were combined with keywords related to muscle strength in athletes, including “muscle strength”, “muscle power”, and “muscles of athletes”, using the Boolean operators “OR” and “AND”.

Table 1. Criteria for the PICOS framework for a systematic review of vitamin D supplementation on muscle strength among athletes

PICOS *framework*	Inclusion Criteria	Exclusion Criteria
Population	Studies using male and female athletes under the age of 45 years, with no restrictions on sport type or competitive level.	Studies among non-athletes population, as well as athletes with either chronic illness, injury, or impairment.
Intervention	Studies evaluating treatment interventions in the form of oral administration of vitamin D2 or D3, without limitations on dosage or duration.	Studies involved additional components beyond vitamin D2 or D3 supplementation, such as medications affecting muscle function or metabolism, hormonal treatments (e.g., growth hormone, testosterone), or any other nutritional supplements (e.g., creatine).
Control	The control intervention group used was placebo therapy.	There were no exclusion criteria.
Outcome	Studies that observed maximal strength or power of muscle.	Studies that do not address the maximal strength or muscle power to be observed.
Study design	Randomized control trial, cross sectional, original research.	Literature review, meta-analysis.

Study Selection

A total of 129 articles were identified through database searches using the predefined search strategy. After removing duplicates and screening based on titles and abstracts, a subset of articles remained for full-text evaluation according to the inclusion and exclusion criteria. The final articles that met all eligibility requirements were included in the analysis. The PRISMA flowchart illustrating this selection process is shown in Figure 1.

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Data Collection Process

The researchers utilized the checklist sheet obtained from PRISMA to evaluate the literature and collect data from relevant articles, which were then organized according to systematic recovery guidelines. The data collection process involved several key steps. First, guidelines from the Center for Review and Dissemination, the Joanna Briggs Institute, and the PRISMA Checklist were followed. Second, keywords and filters in the form of MeSH terms were used to search for literature across various databases. The databases selected for this research included PubMed, Science Direct, and Google Scholar. Eligibility criteria were determined using the PICOS framework, applying specific inclusion and exclusion criteria. The study selection process involved thoroughly reading and assessing each article in accordance with the PRISMA flow diagram. To address potential biases in the results, the articles were analyzed and synthesized based on the JBI Critical Appraisal Checklist as part of this systematic review.

All four studies underwent methodological quality assessment using the Joanna Briggs Institute (JBI) critical appraisal tool. Each study met at least 50% of the JBI criteria, indicating moderate to high methodological quality. Specific strengths included appropriate randomization and clear definition of outcome measures, while common limitations involved small sample sizes and incomplete reporting of blinding procedures.

Types of Data and Variables

Based on the topics covered in this systematic review, data were collected on several variables. These include research characteristics such as the author, research design used, year of the study, and key findings. Additionally, information was gathered regarding the oral interventions employed, specifically whether vitamin D2 or vitamin D3 supplementation was used. Lastly, the review also documented the limitations faced by researchers during the analysis or research process.

Quality Assessment

Risk assessment can be carried out using the JBI Critical Appraisal in analyzing the methodology used by the studies that will be used in the preparation of this systematic review. A critical assessment (CA) was conducted to assess a study as having a score of at least 50% meeting the criteria for CA.

Risk of Bias

The risk of bias in this systematic review was assessed using a research evaluation method applied to each study. This evaluation consisted of four criteria: First, the theory criterion examines whether the explanations presented are appropriate, current, and credible; explanations that are outdated or lack credibility were considered problematic. Second, the design and research instruments criterion assesses whether the study's design aligns with its objectives and whether the instruments used are valid and reliable. Third, the variable criterion evaluates whether the research variables are appropriate and accurately reflect the characteristics being observed. Lastly, the analysis criterion reviews whether the types of analysis employed are suitable and in accordance with established standards.

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Summary Measures

Interventions provided regarding the effect of oral Vitamin D2/D3 supplementation towards muscle strength in athletes were the main variables evaluated in this systematic review. The results of the literature search used are based on JBI CA and PRISMA.

Synthesis of Result

The synthesis of the results used in this systematic review is a descriptive method, that provides a narrative description to describe the obtained results. The narrative explanation used aims to gather evidence about the effect of oral Vitamin D2/D3 supplementation towards muscle strength in athletes and develop a coherent and systematic textual narrative.

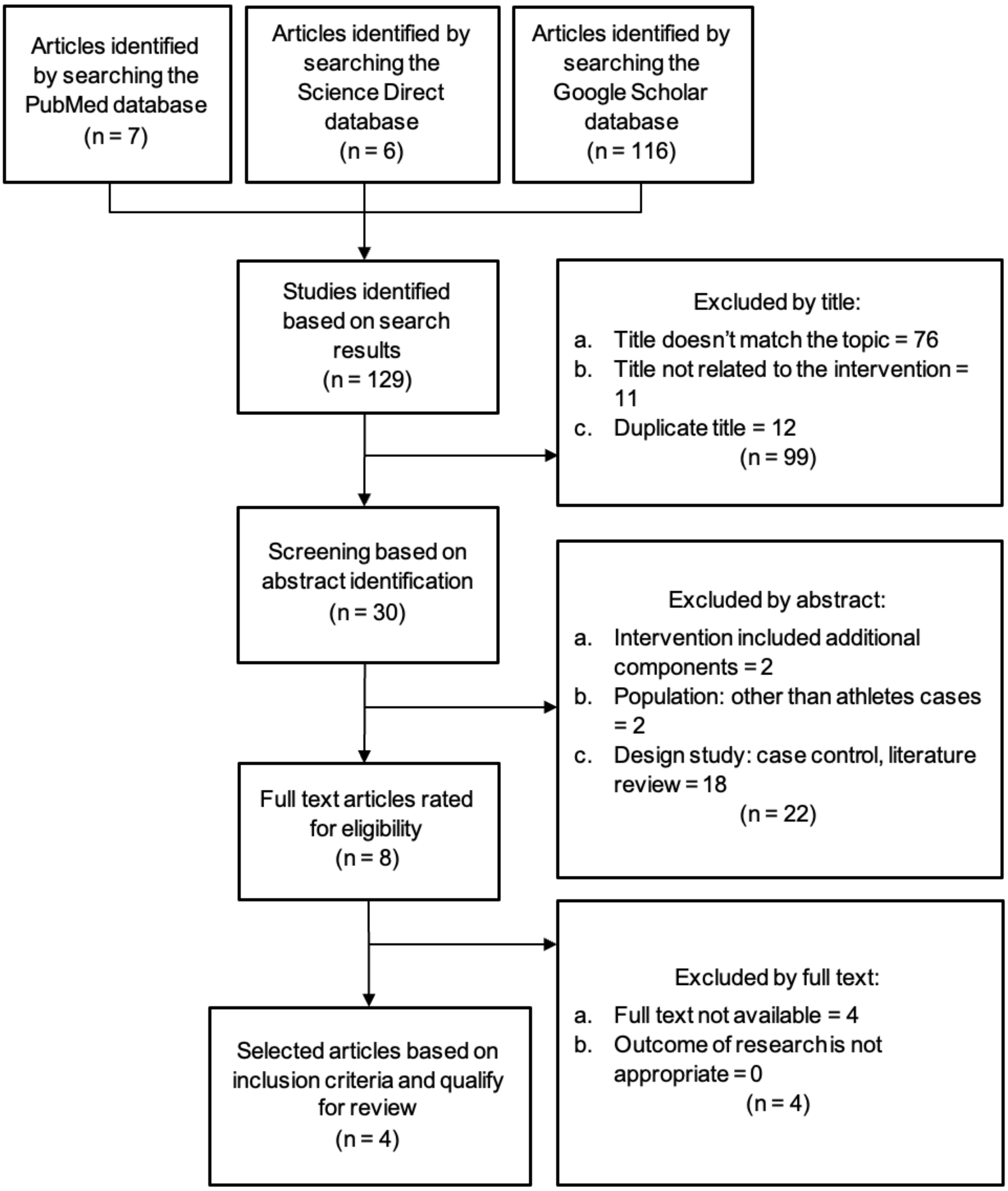

Figure 1. Data collecting process

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RESULTS

A total of 129 articles were identified through database searches using the predefined search strategy. After removing duplicates and screening based on titles and abstracts, 18 articles remained for full-text evaluation. After applying inclusion and exclusion criteria, 4 articles met all eligibility requirements and were included in the final analysis. The PRISMA flowchart illustrating this selection process is shown in **Figure 1**.

Characteristics of Included Studies

The four included studies investigated the effects of oral vitamin D supplementation (either D2 or D3) on muscle strength in athletes from diverse sports including rugby, taekwondo, student athletics, and judo. The dosage and duration of supplementation varied across studies, ranging from 600 IU daily for six weeks to a high-dose of 150,000 IU over eight days. Participant baseline serum 25(OH)D levels also varied, influencing the outcomes.

Effects of Supplementation on Muscle Strength

The reviewed studies presented mixed findings regarding the efficacy of vitamin D supplementation on muscle strength outcomes in athletes. Fairbairn et al. (2018) conducted a placebo-controlled trial involving 57 professional rugby players who received 50,000 IU of vitamin D3 biweekly for 11 to 12 weeks. Although the supplementation significantly increased serum 25(OH)D levels, there was no notable improvement in sprint performance or bench press strength. However, a selective enhancement in weighted reverse-grip chin-up performance was observed, suggesting that the effects of supplementation may be limited to certain muscle groups or exercise modalities.

Similarly, Jung et al. (2018) investigated the effects of daily supplementation with 5000 IU of vitamin D3 for four weeks among 35 taekwondo athletes aged 19–22 years who had low baseline vitamin D levels. The intervention led to significant improvements in peak power and knee extension strength, particularly in lower limbs, but failed to produce observable changes in overall field performance. This indicates that vitamin D supplementation may offer specific strength benefits in vitamin D-deficient individuals, though its impact on comprehensive athletic performance remains inconclusive.

In contrast, Shanely et al. (2015) studied 50 male student athletes with serum 25(OH)D levels below 30 ng/mL who received 600 IU/day of vitamin D2 over six weeks. Despite an increase in serum levels, the supplementation did not enhance muscle function or protect against muscle damage. These findings raise concerns about the relative effectiveness of vitamin D2 compared to D3 in influencing muscle strength.

Notably, Wyon et al. (2024) reported positive outcomes in a study involving 22 male judoka athletes who received a high-dose of 150,000 IU vitamin D3 over just eight days. The participants experienced a 34% increase in serum 25(OH)D and a corresponding 13% increase in muscle strength, suggesting that acute high-dose vitamin D3 supplementation may yield rapid and substantial improvements in muscle performance.

Methodological Quality and Bias Risk

All four studies underwent methodological quality assessment using the Joanna Briggs Institute (JBI) critical appraisal tool. Each study met at least 50% of the JBI criteria, indicating moderate to high methodological quality. Specific strengths included appropriate randomization and clear definition of outcome measures, while common limitations involved small sample sizes and incomplete reporting of blinding procedures.

Table 2. Summary of studies about the effect of oral Vitamin D2/D3 supplementation towards muscle strength in athletes

No	Author	Year	Design Study	Findings
1	Fairbairn, et al.	2018	Placebo-controlled cross-sectional study	This study involved 57 professional rugby players from New Zealand to explore the impact of Vitamin D3 supplementation (50,000 IU biweekly) over 11-12 weeks. Results showed an increase in serum 25(OH)D levels without significant improvement in 30m sprint, 10m sprint, Yoyo intermittent recovery, or bench press. However, there was a notable improvement in weighted reverse-grip chin-up (5.5 kg increase) in the Vitamin D group compared to placebo. It was revealed that while Vitamin D supplementation is effective in increasing serum levels, it does not translate to enhanced sprint performance among professional rugby players.
2	Jung, et al.	2018	Placebo-controlled cross-sectional study	35 male and female taekwondo athletes (aged 19-22 years) were given 5000 IU vitamin D daily for 4 weeks. They were previously had a low baseline serum 25(OH)D concentrations. Although the result demonstrates positive associations between serum 25(OH)D levels and improvements in peak power and knee extension strength, it showed no enhancement in overall field performance.
3	Shanely, et al.	2015	Placebo-controlled cross-sectional study	The study involved 50 male student athletes with serum 25(OH)D < 30 ng/mL, undergoing 6 weeks of 600 IU vitamin D2 supplement (experiment) and placebo (control). It was revealed that while vitamin D2 supplement raised serum level, it did not influence muscle function or mitigate muscle damage in deficient adolescents.
4	Wyon, et al.	2024	Placebo-controlled cross-sectional study	The study investigated the acute effects of 8 days 150,000 IU Vitamin D3 supplementation on muscle strength in 22 male judoka athletes. It appears that the treatment group saw a 34% increase in serum 25(OH)D with 13% increase in muscle strength, indicating a significant interaction observed for treatment and time regarding muscle strength and beneficial impact of the supplementation.

DISCUSSION

Vitamin D has been increasingly recognized for its role in musculoskeletal health, particularly in enhancing muscle strength and overall athletic performance (Savolainen et al., 2024). Given its influence on muscle protein synthesis, inflammation regulation, and recovery, researchers have explored its potential benefits in improving sports performance. However, the impact of vitamin D supplementation on muscle strength remains a topic of debate, with mixed findings across different studies. Some research suggests that adequate serum 25(OH)D levels are essential for optimal muscle function (Wyon et al., 2016), while others indicate that supplementation may not yield significant improvements in strength or power, especially in well-nourished athletes (Fairbairn et al., 2018; Jung et al., 2018; Shanely et al., 2014).

In addition to the subsequent discussion, the review found mixed results regarding the effectiveness of vitamin D supplementation on muscle strength, with more pronounced benefits observed in athletes with deficient baseline vitamin D levels and those receiving higher or acute dosages of vitamin D3. These findings underline the potential influence of baseline serum levels, type of vitamin D, and dosing regimen on muscle performance outcomes.

The studies summarized in Table 2 demonstrate a range of effects of vitamin D2 and D3 supplementation on muscle strength in athletes. Fairbairn et al. (2018) observed that while biweekly vitamin D3 supplementation increased serum 25(OH)D levels in professional rugby players, it did not significantly enhance sprint performance or most strength parameters, except for a notable improvement in weighted reverse-grip chin-up strength. Similarly, Jung et al. (2018) found that daily vitamin D supplementation for four weeks improved peak power and knee extension strength in taekwondo athletes with low baseline serum 25(OH)D levels but did not translate into overall field performance improvements.

In contrast, Shanely et al. (2015) reported that vitamin D2 supplementation in student athletes raised serum levels but failed to improve muscle function or mitigate muscle damage. This suggests that the type of vitamin D (D2 vs. D3) may influence outcomes, with D3 potentially being more effective in muscle strength improvements. Wyon et al. (2024), however, demonstrated a significant increase in muscle strength (13%) following eight days of high-dose vitamin D3 supplementation in judoka athletes, suggesting that acute high-dose supplementation may yield more immediate benefits in strength gains.

Han et al. (2024) suggest that vitamin D3 supplementation can enhance quadriceps strength when administered with an appropriate dosage and duration. This supports the hypothesis that elevating serum 25(OH)D concentrations can lead to muscle strength improvements. However, the study's limitations, such as small sample sizes and variability in baseline vitamin D levels, may affect the generalizability of these results. Similarly, Wyatt et al. (2024) concluded that vitamin D supplementation positively impacts aerobic endurance, anaerobic power, and muscle strength, reinforcing the potential benefits of maintaining adequate vitamin D levels in athletes. Conversely, a meta-analysis by Sist et al. (2023) found no strong evidence supporting the effect of vitamin D supplementation on improving maximal strength and power among athletic populations. Furthermore, Shanely et al. (2014) demonstrated that while vitamin D2 supplementation increased serum vitamin D levels in adolescent athletes with deficiency, it did not improve muscle function or prevent muscle damage, suggesting that the type of vitamin D (D2 vs. D3) may also influence outcomes.

The variations in findings highlight the complexity of vitamin D's role in muscle physiology. One key factor contributing to these discrepancies is the baseline vitamin D status of participants. Studies involving athletes with initially low serum 25(OH)D levels (Jung et al., 2018; Wyon et al., 2024) showed more pronounced improvements in muscle strength, whereas those with adequate levels at baseline (Fairbairn et al., 2018) exhibited minimal to no additional benefits. This supports the notion that vitamin D supplementation may be most beneficial for individuals with pre-existing deficiencies rather than those with already sufficient levels.

Another critical factor is the variation in supplementation protocols. While Wyon et al. (2024) administered a high-dose regimen over a short period, Jung et al. (2018) and Shanely et al. (2015) utilized more prolonged but lower-dose interventions. These differences in dosage and duration may have influenced the observed outcomes, emphasizing the need for standardized supplementation strategies tailored to athletic populations.

Like many systematic reviews, some inherent limitations must be acknowledged. The availability of data for specific assessment criteria, such as vitamin D doses and muscle strength differences in each study, remains limited. It is also important to recognize that this study includes a variety of supplementation dosages, outcome measures, sports disciplines, and training regimens, which may contribute to potential confounding factors and increased heterogeneity. There were some inherent limitations that must be acknowledged between each meta-analysis or studies that were included in this systematic review. For instance, athletes participating in indoor sports such as Judo and Taekwondo may experience significantly lower serum 25(OH)D levels compared to those engaged in outdoor sports due to reduced sun exposure. Additionally, the importance of muscle strength varies across different sports, with disciplines like Judo and Taekwondo placing greater emphasis on strength development compared to sports such as soccer. These differences add complexity and potential variability to the findings.

Another challenge arises from the limited number of randomized controlled trials (RCTs) investigating the impact of vitamin D3 supplementation on muscle strength, making it difficult to fully account for all variables that could influence outcomes. The small number of available RCTs restricts the ability to perform more comprehensive analyses that consider various confounding factors. These factors include seasonal variations in measurements, athlete-specific characteristics, sunlight exposure levels, demographic differences such as age and gender, and dietary habits (e.g., Mediterranean diet, vegan diet, or ketogenic diet). The interplay of these variables makes it challenging to control for all potential confounders in this study.

These discrepancies underscore the need for further research to determine optimal vitamin D dosing strategies linked to athletic populations. The variations in study designs, supplementation protocols, and outcome measures highlight the necessity of standardized methodologies in future trials. Additionally, the widespread prevalence of vitamin D deficiency among athletes, as reported by Wyatt et al. (2024), indicates the importance of monitoring vitamin D status and addressing deficiencies to potentially enhance athletic performance and reduce injury risks.

CONCLUSION

While some evidence suggests a beneficial role of vitamin D supplementation in muscle strength enhancement, conflicting findings indicate that further large-scale, well-controlled studies are required. Establishing optimal dosage, duration, and target populations for vitamin D supplementation will be crucial in determining its practical application in sports nutrition and performance enhancement.

CONFLICT OF INTEREST

The authors stated there is no conflict of interest in this study.

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