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Review Article

Vitamin D - A Probable Performance Boosting Mediator in Athletes

Abstract

Vitamin D positively influences athletic performance by improving strength, power, speed, cardio respiratory fitness, reaction time, coordination, and body composition. Debatable opinion exists regarding the exact role of Vitamin-D (Vit-D) which is supplemented in the form of Vit-D₃ to improve sports performance. Proper dose of Vit-D₃ supplementation among athletes has been recommended since lower Vit-D level is a common feature in athletes. Direct association of Vit-D level and athletic performance has not yet been confirmed. The present attempt was aimed to review the concept of Vit-D induced improvement in athletic performance and also to explore the guidelines of Vit-D₃ supplementation improve health and performance in adolescent athletes.

Methods or strategy adopted to search literatures: A systematic analysis of the scientific literature was undertaken to find as many studies as possible that reported the information related to Vit-D. Studies published during 1975 to 2013 were searched. The key words used in this search procedure were Vit-D supplementation, athletes, dose of Vit-D, mechanism of action of Vit-D and synthesis of Vit-D. Only published, full-text manuscripts written in the English language were included. A systematic literature search has been followed in different internet databases, viz., google, MEDLINE, Scopus, Web of Science and Researchgate. Various hard copies of text books and journals were also consulted from different institutional libraries to ensure exhaustive literature search. This entire search procedure fetched 439 articles which underwent initial screening process. Reference lists of the initially screened articles were also screened and relevant articles were again considered and further screened for the purpose of this review. All the abstracts were thoroughly read to judge its suitability. When the title and abstract provided insufficient data to ensure an article's eligibility, the full text paper was retrieved and analysed. After that the article was consulted if it provided explicitly any new information, otherwise it was excluded or used as a supportive reference. The article which was found irrelevant in the context of the objective of the present review was also excluded.

Introduction

Vit-D₃ supplementation may play a crucial role for optimal performance in athletes as Vit-D deficiency has become worldwide epidemic among children, adolescents and adults [1-10]. Calcitriol, the activated form of Vit-D is a pluripotent pleiotropic secosteroid hormone which regulates more than thousands of genes in human involving cellular growth, cell turnover and regeneration, immune function, protein synthesis, hormone synthesis [11-13].

The key function of Vit-D is to maintain physiological homeostasis of calcium and phosphorus under the patronage of intestine, kidney, parathyroid gland, bone and skeletal muscle [14]. Deficiency of Vit-D may affect skeletal health involving bone and muscle [15,16], as well as may be correlated to chronic diseases like cancer, infectious diseases, diabetes, hypertension, cardio-vascular diseases, inflammatory bowel

disease, depression, osteoarthritis, autoimmune diseases like rheumatoid arthritis, etc [17,18].

The discovery of Vit-D receptor in muscle cells signifies its important role in muscle tissue function, and could also have impact on athletic performance and injury like stress fractures [12] But less is known about the status of Vit-D in adolescent athletes. Emerging evidences suggest that Vit-D is imperative to maintain and improve muscle protein synthesis, muscle strength, muscle size, reaction time, posture and balance, coordination, endurance, inflammation, bone health, immune function, and inflammatory responses which are essential component for building optimal performance level [11,19-22].

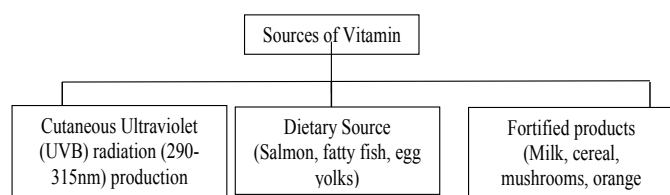
However, definite information about the exact role played by Vit-D following its supplementation in improving athletic performance has not yet been clearly discussed. Specific requirement of Vit-D, i.e., the dose of Vit-D for athletes is not exactly known [35].

The present review has been focused to investigate the probable underlying mechanisms about the potential association between Vit-D concentration and athletic performance as well as to summarize the current recommendations regarding Vit-D₃ supplementation to improve the general health and athletic performance in adolescent athletes.

Is there any disparity between Vit-D deficiency, insufficiency, sufficiency?

The best indicator of Vit-D status is the concentration of serum 25(OH)D [17,20,23], However, optimal serum 25(OH)D concentrations is debatable and have yet to be defined but proposed to fall in the range of 40–70 ng/ml [20,28] (Table 1).

Sources of Vit-D in athletes [20–22]



Pathway of Vit-D derivative synthesis

On exposure of skin to UVB radiation 7-dehydrocholesterol which is present in the plasma membrane of epidermis and dermis is converted to previtamin D₃ (precholecalciferol). This previtamin D₃ isomerizes to vitamin D₃ (cholecalciferol) within two to three days [30]. Vit-D then binds with Vit-D binding protein (VDBP) and migrates into the capillary bed of dermis and into circulation and is consequently hydroxylated in the liver by enzymes of the cytochrome P-450 system to 25(OH)D [16,17]. Further hydroxylation in kidney tubules to the hormonally active form, 1,25(OH)₂D, is driven by parathyroid hormone (PTH) when serum calcium and phosphate concentrations fall below the physiological range [16–18] (In addition to this, many extra-renal cells (and tissues), including macrophages, brain, colon, breast, and others, have the enzymatic machinery (1- α -hydroxylase) to produce 1,25(OH)₂D locally [16,20,31].

Etiology of Vit-D deficiency

The etiology of Vit-D deficiency is multifactorial. In spite of adequate dietary intake of Vit-D it may be deficient due to its malabsorption in the intestine [14,32]. Other causative factors include geographical location that limits the availability of UVB rays, climate and different seasons e.g., summer, winter, spring, etc., clothing, skin pigmentation, age, indoor practice, higher adiposity, strict vegan or vegetarian dietary nature, etc.. [17,20,33–37]. Hence supplementation of Vit-D₃ is necessary and has already been widely accepted along with higher dietary intake and UVB exposure to maintain the normal level of Vit-D in human body [20,23,25,38,39].

Physiological Requirement of Vit-D

According to the National Institute of Health [40] and other guidelines [41] the healthy requirement of Vit-D is as follows: (Tables 2,3).

Dietary intake recommendation for Vit-D increases with age, pregnancy and lactation [12]. There is a controversy between the Recommended Dietary Allowance (RDA) of Vit-D among experts [16,25,34,38].

The optimal Sports health benefits threshold of Vit-D is still unknown, however, 25(OH)D levels of 50ng/ml and above is sufficient for peak neuromuscular performance [19,24,25]. It is also important to recognize the threshold requirement of Vit-D sine it is highly individualized due to the variations of individual diet, endogenous synthesis and storage capacity [35].

Supplementation protocol of Vitamin D3 for athletes

Athletes having 25(OH)D level < 30ng/ml is Vit-D deficient. Now-a-days Vit-D₃ supplementation is accepted widely, hence according to the supplementation protocol a Vit-D deficient athlete should receive a short-term high dose “loading dose” 50,000 IU of Vitamin per week for 8 weeks [17] to replenish stores more rapidly. After about 90 days of supplementation a steady state level of 25(OH)D is reached and retesting is required at this level [43]. If results are still < 30ng/ml, repetition of the same supplementation protocol is necessary, and the serum level of 25(OH)D should be tested again [17]. Once the sufficient level reached, a maintenance level of supplementation of 1000–5000 IU per day as required should be continued as directed by The National Academy of Science [44].

According to The National Academy of Science the upper levels of intake of Vit-D₃ and calcium for adolescents and adults is 4000 IU per day and it is unnecessary to exceed this level if sufficient Vit-D is present in serum [18,44–48]. There is another advantage of Sun exposure over Vit-D₃ supplementation because cutaneous synthesis has a negative feedback loop preventing Vit-D accumulation and toxicity [49,50]. Oral

Table 1: Blood levels of 25(OH)D in different conditions.

	Deficiency	Insufficiency	Optimal level
Serum 25(OH)D concentration	<20 ng/mL (50 nmol/L)	20-32ng/mL (50-80 nmol/L)	>40 ng/mL (100 nmol/L)

Table 2: Requirements of Vit-D in human body.

Age	Male	Female	Pregnancy	Lactation
0–12 months*	400 IU (10 mcg)	400 IU (10 mcg)		
1–13 years	600 IU (15 mcg)	600 IU (15 mcg)		
14–18 years	600 IU (15 mcg)	600 IU (15 mcg)	600 IU (15 mcg)	600 IU (15 mcg)
19–50 years	600 IU (15 mcg)	600 IU (15 mcg)	600 IU (15 mcg)	600 IU (15 mcg)
51–70 years	600 IU (15 mcg)	600 IU (15 mcg)		
>70 years	800 IU (20 mcg)	800 IU (20 mcg)		

Table 3: Recommendations of the Endocrine Society for dietary intake of Vit-D in addition to sensible sun exposure⁴²

For infants	400–1000 IU/day
For children (1–18 years)	600–1000 IU/day
For adults	1500–2000 IU/day

dosing with 10 000 IU per day is the tolerable upper-intake level without toxicity [46,51-53]. But it is not recommended to take 10000 IU per day with incremental increases in 25(OH) D by 70 ng/ml, well over the amount of 50ng/ml is needed for optimal sports health benefits [46]. Alternatively long-term Vit-D sufficiency can be maintained easily by taking 50 000 IU of Vit-D₃ once or twice a month [9].

Physiological effects of Vit-D

A strong correlation between Vit-D sufficiency and optimal muscle function has been widely reported [16,22,54-57] with the fact that Vit-D exerts its physiological action in autocrine and endocrine mode [12]. The autocrine pathway appears to be essential for skeletal muscle function [25,58], through which more than 80% of Vit-D is utilized in the body [58]. Receptor mediated Vit-D action in the cells has been established that regulates hundreds of gene expression especially within the muscle cells where it not only promotes muscle hypertrophy but also modifies the transportation of calcium in the sarcoplasmic reticulum, but this mechanism is yet to be proved in human studies [11,15,17,19,54,58,60-64,68]. Physical performance changed proportionately with the dose of 25(OH)D [19,69,71-79]. Correlations were stronger for reaction time, balance, and timed tests of physical performance. Direct relationship of Vit D with strength, power and athletic performance indicated that Vit D has an influential role to develop muscle power and force which in turn improve the athletic performance [90]. Maintaining adequate Vit-D status is important to improve strength, power, and speed performance by facilitating the genomic and non-genomic actions of Vit-D in skeletal muscle [11].

Vit-D is essential for maintaining bone density, bone growth and bone remodeling [85,88]. Calcium absorption and osteoclast activity in the bone are also influenced by Vit-D via its endocrine activity mediated via Parathyroid and Thyroid glands [35].

Significant positive correlations have also been reported between Vit-D concentration and cardiorespiratory fitness expressed in terms of VO_{2max} [91-93]. Significantly higher values of VO_{2max} in athletes and non-athletes during summer than in the winter was also attributed to the fact of higher Vit - D synthesis in summer [94,95]. Vit-D was also linked with UVB radiation to improve cardio-respiratory fitness [11]. These studies concluded that athletes have better cardiorespiratory endurance when they are able to maintain an adequate Vit-D status.

Insufficient Vit-D concentrations are associated with an unfavorable body composition in otherwise healthy individuals [102]. Vit-D concentrations were inversely correlated with percent body fat and suppressing parathyroid hormone levels by attaining an adequate Vit-D status may reduce adiposity in non-athletes and athletes alike and help them to achieve their ideal body composition [103].

Vit-D status among athletes

There are several studies that documented a high incidence

of Vit-D insufficiency and deficiency in the general population worldwide, only a handful of studies have focused on athletes listed in Table 1.

Though the findings varies mainly due to the lack of sun exposure and to a less extent due to geographical location (latitude) and gender, major risk factors for Vit-D insufficiency occurs to the indoor athletes and those who avoid peak daylight hours, despite of latitudinal location [46,47,89,105-108].

Conclusion

The review summarizes and supports the hypothesis that Vit-D may have some impact on physiological system to improve the athletic performance. Exposure to UV-B radiation seems to improve various measurements of athletic performance, but adequate randomized controlled trials are essential to land to a specific conclusion. During summer greater sun exposure may facilitate cutaneous Vit-D synthesis and consequent reflection in athletic performance is speculated. However, other factors like indoor practicing has secondary influence on Vit-D production. It is also evident that Vit-D₃ supplementation reverses hypertrophy and hyperplasia of Type II muscle fibers in Vitamin D deficient individuals. Several large community-based cross-sectional studies of neuromuscular functioning and serum Vit-D found positive associations, but prospective cohort studies are conflicting, raising the possibility of reverse causation.

From the above evidences it may be concluded that adequate Vit-D₃ supplementation may improve athletic performance in Vit-D deficient athletes. If such a treatment effect exists, the largest improvements in performance will probably occur in those with the lowest levels; that is, a significant improvement in athletic performance may occur when levels increase from 15-30 ng/mL, but less improvement will occur when levels increase from 30-50 ng/mL. However, an ideal Vit-D level is needed for peak athletic performance that needs confirmation through well designed experimental interventions explaining the magnitude, type of athletic performance variables (reaction time, muscle strength, balance, coordination, or endurance) that is improved the most.

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