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Special Article - Vitamin D Deficiency

Vitamin D and Muscle Function and Performance – A Perspective

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Introduction

Research into the substance we now call vitamin D was motivated by the search for a cure for rickets [1], which is characterized by the softening and weakening of bone in children. Vitamin D was discovered and named in the early 1920's. Unsurprisingly, the first research interest of vitamin D was its role in bone health [1,2]. However, as soon as in the 1930's and '40's, systematic research was conducted on the role of vitamin D in athletic performance [3].

Today we know that vitamin D plays a role in every organ system in the body and adequate vitamin D levels can help in the prevention of autoimmune diseases including type I diabetes [4], multiple sclerosis [5-7] rheumatoid arthritis [8]; cardiac disease; colon, prostate and breast cancer mortality and morbidity and even depression [9] and inflammation.

Less than adequate vitamin D levels are extremely common, with as much as 77% of the general population being estimated to be affected by it [10]. Certain features increase the risk for deficient or insufficient vitamin D levels, such as having high skin melamine content (dark skin), and limiting UV-B radiation (sun) exposure due to sun block, long-sleeve clothing, not spending much time outside and living in northern latitudes (>35º). Although there is no universally agreed upon categorization on what constitutes an adequate level of vitamin D as measured by blood serum level of 25-hydroxyvitamin D (25(OH)D), a scientifically supported and commonly used categorization defines adequate vitamin D levels as >32ng/ml [11,12], vitamin D insufficiency as 25(OH)D levels between 20-32 ng/ml and vitamin D deficiency as 25(OH)D levels <20 ng/ml.

While adequate vitamin D levels are important for everyone, its musculoskeletal health and athletic performance association makes vitamin D of particular importance to athletes. In recent years, there has been a research effort to better understand if and how vitamin D is associated with or affects performance. However, our understanding of the mechanism as well as evidence from clinical research is limited. Amongst athletes, professional American football players, who regularly endure high impact hits and put great demand on their musculoskeletal system have only recently received research attention.

Mechanism

The effect of vitamin D on athletic performance is hypothesized to be mediated by its role in muscle health and muscle performance. Yet, the underlying mechanism of how vitamin D affects skeletal muscle performance is not well understood [13], but several pathways seem to play a role. Multiple studies showed that low vitamin D negatively affects handling, binding and storage of calcium in the muscle sarcoplasmic reticulum. Hence, one proposed role of vitamin D is to increase calcium accumulation in the sarcoplasmic reticulum. Furthermore, phosphate imbalance, as induced by low vitamin D was shown to cause muscle weakness which can be reversed with vitamin D supplementation. Lastly, there is a direct effect of vitamin D on the muscle cells via the vitamin D receptor which induces new protein synthesis [13].

Vitamin D and muscle function and performance in athletes

The early studies from the 1930's and '40's typically used an UV lamp to elevate serum vitamin D levels and evaluated effects on 100 meter sprint times, bike ergometer performance and general cardiovascular fitness [3]. All studies showed benefits on performance from UV lamp radiation exposure; yet, sample sizes were very small and studies not always well controlled.

More recently, Ward et al. [14] investigated the relationship between serum vitamin D levels and muscle power and force using jumping mechanography (n=99 females, age 12-14 years) and found a positive relationship between vitamin D levels and muscle power and force. Close et al. [15] conducted a randomized placebo controlled study in 61 professional male athletes (of which 62% deficient in vitamin D at baseline) and 30 age-matched non-athletes as controls. They found that vitamin D supplementation significantly increased total serum 25(OH)D and significantly improved performance levels, including sprints and vertical jump, when compared with their own baseline measures and with the placebo control group. However, in a different but similar study amongst 30 young athletes, Close et al. [16] failed to find improvements in muscle performance after 12 weeks of supplementation. The authors hypothesized that higher serum vitamin D levels may be necessary to see improvement.

Two recent studies have been conducted in players of the National Football League (NFL). In a published abstract, Shindle et al. measured serum vitamin D levels of all 89 players of a single NFL team, and assessed if vitamin D levels were associated to occurrence of muscle injury [17]. They found that only 19.1% of the players had adequate vitamin D levels, 50.6% had insufficient levels of vitamin D and 30.3% had deficient levels. In addition, they found that players who had at least one muscle injury (defined as strain, tear of pull that led to at least one missed practice or game) throughout the prior season had significantly lower vitamin D levels than players with no muscle injury during the same time frame (19.9ng/ml vs 24.7ng/ml, $p < 0.05$).

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We recently published a study on vitamin D levels in a different team of N=80 NFL players (mean age 26.5±3.7) in which we measured serum vitamin D levels during the 2011 off-season and evaluated, amongst other things, the ability to obtain contracted employment, which may be a proxy for performance. This study showed that only 31.3% of the players had adequate vitamin D levels, 42.5% had insufficient levels of vitamin D and 26.3% had deficient levels. Furthermore, we found that players who were released during the pre-season had significantly lower vitamin D levels than players who played in the regular season ($F(1,64)=27.60$, $p<.001$) [18].

Implications and future directions

Like in the general population, we found that vitamin D deficiency and insufficiency is very common in athletes. The extent of the research on vitamin D and its role in muscle health and athletic performance is still rather limited and especially the early studies suffer from small sample sizes, limiting their reliability. The most prominent limitation in research on vitamin D levels and performance, however, concerns the definition of the concepts assessed. The field still lacks unanimously accepted criteria of what constitutes adequate, insufficient and deficient serum vitamin D levels – and why. These inconsistencies make it difficult to compare findings between studies and can hinder interpretation of findings.

For example, Ward et al. [14] raised vitamin D levels through supplementation to (almost) adequate levels but still hypothesized that the lack of effect they found on performance was due to the fact that still higher levels may be required for an effect on performance. However, other studies suggest that supplementing above adequate levels has no further benefit [3]. Similar problems occur in the assessment of athletic performance. Studies have used 100 meter sprints, bike ergometer or jumping mechanography to measure athletic performance. In our study, we used an even more indirect measure, i.e. being released during footballs pre-season and hence not making the team, which may be a proxy for athletic performance (we did not control for potential confounding variables or moderators of this association and other explanations for this finding are possible). To advance the understanding of the relation between vitamin D and athletic peformance, more fundamental research into the physiology of the effect of vitamin D on muscle tissue is needed. This will benefit the streamlining effort to establish unanimously accepted vitamin D categorization criteria and will help us understand what types of athletic performance and muscle function can benefit from adequate vitamin D levels.

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