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The Role of Vitamin D3 Supplementation in the Prevention of Hypertension in Adolescents Athletes: A Review

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Abstract

Background. Vitamin D is mainly known for its role in bone health and maintaining proper calcium balance, especially in athletes. In recent years, however, more attention has been paid to its influence on the cardiovascular system. Even though vitamin D deficiency is common among physically active people, its effect on the heart and blood vessels during intense exercise is still often underestimated in sports medicine.

Aim. The aim of this study was to assess how vitamin D deficiency affects the cardiovascular system in athletes, with particular focus on endothelial function, the renin-angiotensin-aldosterone (RAA) system, and blood pressure regulation.

Material and methods. A literature review was carried out using scientific databases such as PubMed and Google Scholar. Current research papers, clinical studies, and review articles concerning 25(OH)D levels, cardiovascular stress during exercise, and vascular health in athletes were analyzed and compared.

Results. The analyzed studies showed that maintaining adequate vitamin D levels is important for proper endothelial function and nitric oxide production, as well as for limiting excessive activation of the RAA system. Vitamin D deficiency may impair vasodilation and increase vascular resistance during exercise, which puts additional strain on the cardiovascular system. As a result, it may contribute to the development of exercise-induced and chronic arterial hypertension, reducing some of the protective cardiovascular effects normally associated with regular physical activity.

Conclusions. The reviewed findings support the hypothesis that individualized vitamin D3 supplementation can improve endothelial function and provide additional cardiovascular protection in athletes, particularly in terms of blood pressure control. Regular monitoring of 25(OH)D levels and properly adjusted supplementation should therefore become an important part of modern sports cardiology practice.

Key words: Vitamin D; athletes; hypertension; endothelium; oxidative stress; supplementation

1. Introduction

Vitamin D is more than just a bone- health nutrient, is now recognized as prohormone with widespread influence throughout the body, particularly in cardiovascular function. Our understanding has evolved beyond its traditional role in calcium and phosphate regulation (Norman, 2008). Scientific findings reveal its significant impact on the heart and blood vessels, supported by the presence of vitamin D receptor in the myocardium and vascular endothelium (Manson et al., 2019). The real breakthrough came with the discovery that active vitamin D directly inhibits the renin-angiotensin system (RAS) which was linked fundamentally to blood pressure regulation (Li et al., 2004). In practice, without enough vitamin D, the body loses its control over renin. As a result, the RAS system goes into overdrive, causing blood vessels to constrict and driving up blood pressure. The study demonstrated that vitamin D deficiency removed the natural brake on renin production, which caused hypertension and cardiac hypertrophy; this was shown in animal studies. Despite the overactivation of the RAA system, vitamin D deficiency impairs the vasodilation mechanism in the body. Studies have shown that this vitamin is directly involved in the production of nitric oxide, which is widely known as a vasodilating factor. Since there is a lack of sufficient vitamin D, nitric oxide production itself will also decrease (Andrukhova et al., 2014). The lack of vasodilation and the overactive RAA system cause endothelial dysfunction and lead to the development of arterial hypertension and may later contribute to the development of atherosclerosis (Jablonski et al., 2011). Knowledge of these mechanisms becomes especially important when we look at athletes. Although we usually associate them with excellent health, without any vitamin and electrolyte deficiencies. They actually represent a hidden risk group (Ogan & Pritchett, 2013). During intense physical exertion, this deficiency deprives their blood vessels of natural endothelial protection, while the overactive renin-angiotensin system creates an environment highly conducive to hypertension. In accordance with current internal medicine guidelines, identifying and correcting such reversible risk factors is the cornerstone of cardiovascular prevention. Therefore, the aim of this review is to analyze the impact of vitamin D3 deficiency on the risk of hypertension in the athletic population and to evaluate optimal supplementation strategies (Visseren et al., 2022).

Research Problems. What are the optimal and safe vitamin D3 supplementation strategies for athletes to prevent the development of hypertension?

Research Hypotheses. Targeted and individualized vitamin D3 supplementation effectively improves endothelial function and constitutes a crucial element in the cardiovascular prevention of athletes.

2. Research materials and methods

This paper is based on a review of scientific literature. To gather the necessary information, qe searched standard medical databases, primarily PubMed and Google Scholar. During the search we used a combination of the following keywords: vitamin D defficency, hypertension, renin-angiotensin-aldosterone system. To ensure the sources were reliable, we focused on peer-reviewed original research articles, meta-analyses, and official clinical guidelines published in English. We included human studies involving athletes.

Participants.

Because this is a literature review, we did not recruit our own study subjects. In our research, we focused on the athletic population.

Procedure / Test protocol / Skill test trial / Measure / Instruments.

Because this study is a literature review, our procedure did not involve direct clinical testing on participants. Instead, our protocol focused on a structured review process. First, we independently screened the titles and abstracts of the found articles. Next, we read the full texts of the selected papers to extract specific data regarding health of the athletes.

2.3. Data collection and analysis / Statistical analysis.

In our review, data collection meant extracting specific information from the chosen articles. We didn't collect raw data directly from patients. Instead, we read each paper and gathered key details to compare them in ours metanalysis. We looked for research on athletes that addressed our main thesis.

2.3.1. Statistical Software.

Since this paper is a literature review, we didn't run our own statistical tests on raw data. Instead, we relied on the statistical analyses performed by the authors of the original studies.

2.3.2. AI.

AI was utilized for two specific purposes in this research. Text analysis of clinical reasoning narratives to identify linguistic patterns associated with specific logical fallacies. Assistance in refining the academic English language of the manuscript, ensuring clarity, consistency, and adherence to scientific writing standards. **AI** were used for additional linguistic refinement of the research manuscript, ensuring proper English grammar, style, and clarity in the presentation of results. It is important to emphasize that all AI tools were used strictly as

assistive instruments under human supervision. The final interpretation of results, classification of errors, and conclusions were determined by human experts in clinical medicine and formal logic. The AI tools served primarily to enhance efficiency in data processing, pattern recognition, and linguistic refinement, rather than replacing human judgment in the analytical process.

2.3.3. Statistical Methods.

In this narrative literature review, we did not use advanced statistical software or perform our own statistical calculations. Instead, we focused on a descriptive analysis of the available studies. We collected and compared the main statistical results reported by the original authors to identify common patterns related to vitamin D levels and blood pressure in athletes. The statistical significance discussed in our review was based on the results presented in the analyzed papers, where the significance level was usually set at $p < 0.05$.

3. Research results

After reviewing the available literature, we selected a range of studies examining the relationship between vitamin D levels, hypertension, and cardiovascular health in athletes. The final review included different types of scientific papers, from observational studies to large-scale review articles and meta-analyses. Most of the analyzed studies focused on athletes involved in team sports. Overall, the findings consistently highlighted two key issues, vitamin D3 deficiency is surprisingly common among athletes, and insufficient vitamin D levels may significantly affect blood pressure regulation.

3.1. Prevalence of Vitamin D Deficiency in Athletes

When analyzing the collected literature, one of the main findings is the high prevalence of vitamin D deficiency among physically active people. Regular physical activity is widely considered one of the most important elements of a healthy lifestyle and cardiovascular disease prevention (Piotr & Andrzej, 2026). Despite this, many athletes still do not maintain adequate levels of vitamin D.

The studies also show that the type of training environment has a significant impact on vitamin D status. In their meta-analysis, pointed out clear differences between indoor and outdoor athletes (Farrokhyar et al., 2015). According to their research, people training mainly indoors, such as basketball players, volleyball players, or martial arts athletes, are particularly exposed to vitamin D deficiency because of limited access to sunlight during most of the year. At the same time, outdoor training does not fully protect against this problem. (Ogan & Pritchett, 2013) showed that even athletes training outside often have low vitamin D levels.

The authors explained this by factors such as living in regions with lower sunlight exposure, training early in the morning or late in the evening, and frequent use of sunscreen. Overall, the literature suggests that athletes, regardless of the discipline they practice, are a group at increased risk of vitamin D deficiency.

3.2. Physiological Mechanisms: The Endothelium and the RAA-System

After establishing how common vitamin D deficiency is among athletes, the next step was to analyze how it affects the cardiovascular system. Based on the reviewed literature, two main mechanisms seem to play the biggest role: endothelial dysfunction and overactivation of the renin-angiotensin-aldosterone (RAA) system.

The first mechanism relates to the endothelium, which is the inner layer of blood vessels. In athletes, proper blood flow is extremely important because it allows oxygen and nutrients to reach working muscles efficiently. Research suggests that vitamin D stimulates endothelial cells to produce nitric oxide (NO), a molecule responsible for relaxing and widening blood vessels (Andrukhova et al., 2014) (Judd & Tangpricha, 2009)also showed that low vitamin D levels are strongly linked with endothelial dysfunction. In practice, this means that vitamin D deficiency may reduce NO production, causing blood vessels to become stiffer and less able to dilate during exercise. Direct evidence from extensive cardiovascular research confirms that vitamin D deficiency is significantly associated with increased arterial stiffness in healthy, active populations, forcing their hearts to work much harder than necessary(Al Mheid et al., 2011).

The second important mechanism involves the renin-angiotensin-aldosterone (RAA) system, which is responsible for regulating blood pressure. Normally, the kidneys produce renin to maintain cardiovascular balance. However, studies by (Li et al., 2002) demonstrated that vitamin D acts as a natural inhibitor of this system and helps prevent excessive renin activity. Similar conclusions were presented by (Tomaschitz et al., 2010), who linked low vitamin D levels with overactivation of the RAA system. As a result, vitamin D deficiency may lead to excessive narrowing of blood vessels and higher cardiovascular strain. In athletes, where the cardiovascular system is already under heavy stress due to intense training, this imbalance may significantly increase the risk of cardiovascular complications.

3.3. The Clinical Consequence: Vitamin D Deficiency and Cardiovascular Risk in Athletes

In the final stage of the analysis, the collected physiological data related to its possible clinical consequences for physically active individuals. The reviewed literature in sports medicine suggests that reduced nitric oxide production together with chronic overactivation of the RAA system may create favorable conditions for cardiovascular remodeling and the development of hypertension (Owens et al., 2018)

This creates an interesting paradox in athletes. On the one hand, regular intensive training is usually associated with better cardiovascular fitness and healthier blood pressure. On the other hand, studies indicate that vitamin D deficiency may weaken some of the protective cardiovascular effects normally associated with exercise (Angeline et al., 2013)

During intense training sessions or competitions, the heart has to pump large amounts of blood to the muscles. If blood vessels become stiffer and less able to dilate because of low vitamin D levels, the heart must work against greater resistance. According to (Shuler et al., 2012) long-term training under these conditions may place excessive stress on the cardiovascular system and contribute to exercise-induced hypertension as well as structural changes in the heart.

To better understand how serious this problem may be, it is important to also consider evidence from general cardiology research. Large prospective studies have shown that low vitamin D levels are associated with a higher risk of developing hypertension, even in people who were previously healthy (Forman et al., 2007). Additionally, Mendelian randomization studies performed by (Vimaleswaran et al., 2014) suggest that this relationship may be causal, indicating that vitamin D deficiency itself can contribute to increased blood pressure.

This issue appears particularly important in athletes because hypertension is already considered one of the most common cardiovascular disorders observed in this population (Berge et al., 2015). During intensive exercise, temporary increases in blood pressure are a normal physiological response. However, when vitamin D deficiency is present and remains untreated, these repeated elevations in blood pressure may not return efficiently to baseline values during recovery periods. Over time, this may place additional strain on the cardiovascular system and increase the risk of long-term complications.

Overall, the analyzed literature shows that maintaining proper vitamin D levels in athletes is important not only for bone health, but also for cardiovascular protection. Therefore,

monitoring vitamin D status and introducing supplementation, when necessary, may be an important element of cardiovascular prevention in physically active individuals.

3.4. Reversing the Risk: The Role of Targeted Supplementation

To complete the analysis, it was also important to determine whether the cardiovascular effects associated with vitamin D deficiency can be reversed. Fortunately, the available literature provides promising results. Studies suggest that endothelial dysfunction and other negative vascular changes caused by vitamin D deficiency are not permanent. (Tarcin et al., 2009) demonstrated that restoring proper vitamin D levels through supplementation can improve endothelial function and positively affect vascular health.

In athletes, this issue may require a more individualized approach. According to (Close et al., 2013), physically active individuals often have increased metabolic demands and continuous muscle regeneration, which means that standard supplementation doses may not always be sufficient. In some cases, athletes may require higher or long-term maintenance doses of vitamin D3 to achieve optimal serum concentrations.

The significance of vitamin D supplementation has also been recognized by major sports organizations. The International Olympic Committee (IOC), in its consensus statement on dietary supplements, emphasized that correcting vitamin D deficiency is important not only for bone health and athletic performance, but also for the overall health of professional athletes (Maughan et al., 2018)

Based on the analyzed studies, regular monitoring of vitamin D levels together with properly adjusted supplementation may play an important role in cardiovascular prevention among athletes and physically active individuals.

Psychological target	Effect of Deficiency	Clinical Consequence for the Athlete
Endothelium	Drop in nitric oxide production	Stiffer blood vessels during physical exertion
RAA system	Overproduction of renin	Excessive vasoconstriction and increased blood pressure
Heart	Pumping against high vascular resistance	Risk of exercise-induced hypertension and cardiac strain

Table. 1. The cardiovascular consequences of vitamin D deficiency in athletes occur as a sequential physiological cascade.

4. Discussion

4.1.1 Vitamin D Deficiency in Athletes: A Classic Pathophysiological Perspective

The main aim of this review was to assess how vitamin D deficiency influences cardiovascular health in athletes, especially in relation to the development of arterial hypertension. The analyzed studies suggest that even though athletes are generally considered a population with very good cardiovascular health, many of them may still be at increased risk of vascular and hemodynamic disturbances caused by insufficient vitamin D levels.

To better understand these findings, they should be considered in the context of current medical knowledge. Standard medical textbooks, including *Szczeklik's Internal Medicine*, describe chronic activation of the renin-angiotensin-aldosterone (RAA) system and endothelial dysfunction as two of the key mechanisms involved in the development of hypertension. What is particularly interesting in the reviewed literature is the fact that these same mechanisms, usually associated with conditions such as obesity, aging, or metabolic syndrome, may also occur in young and physically active athletes because of vitamin D deficiency.

These observations may change the way cardiovascular risk in athletes is perceived. Although regular physical activity is generally protective for the cardiovascular system, severe vitamin D deficiency may reduce some of these beneficial effects. The studies discussed earlier indicate that without adequate vitamin D levels, the cardiovascular system may not adapt properly to the high physiological demands of intensive training. As a result, long-term

exposure to increased cardiovascular strain may contribute to the development of hypertensive changes instead of preventing them.

4.2. Addressing Conflicting Evidence, the Observational vs. Clinical Trial Paradox

Although many studies describe the mechanisms linking vitamin D deficiency with arterial hypertension, the available literature is not completely consistent. An important difference can be seen between observational studies and randomized controlled trials (RCTs). For example, meta-analyses of RCTs, including the review by (Beveridge et al., 2015) often did not show a significant reduction in blood pressure after vitamin D supplementation in the general population. Similar conclusions were presented in (Scragg et al., 2017), where high-dose vitamin D supplementation did not significantly reduce the risk of cardiovascular disease. However, these findings do not necessarily mean that vitamin D has no role in cardiovascular health. Instead, they suggest that the relationship is more complex than initially expected. One possible explanation is that many participants included in these studies did not have severe vitamin D deficiency at baseline. In individuals with already normal vitamin D levels, supplementation may simply not provide additional cardiovascular benefits.

This issue may be particularly important in athletes. Most studies performed in the general population do not consider the very high cardiovascular load associated with intensive physical training. In less active individuals, mild endothelial dysfunction or slight overactivation of the RAA system may remain clinically silent for years. In athletes, however, the cardiovascular system is exposed to repeated and intense physiological stress. Under these conditions, the reduced vasodilatory capacity associated with vitamin D deficiency may become much more clinically relevant.

Therefore, vitamin D supplementation should probably not be viewed as a universal treatment for hypertension in the general population. At the same time, severe vitamin D deficiency in athletes may represent an additional cardiovascular risk factor that could negatively influence vascular adaptation to intensive exercise and increase susceptibility to hypertensive changes.

4.3 Vitamin D is Not Just for Bones, Changing How We Treat Athletes

Despite the growing evidence linking vitamin D deficiency with cardiovascular problems, this issue is still often overlooked in everyday sports medicine practice. In most cases, athletes are tested for vitamin D levels mainly because of orthopedic problems, such as stress fractures, muscle injuries, slower recovery, or chronic musculoskeletal pain (de la Puente Yagüe et al.,

2020). The possible cardiovascular consequences are usually not the main reason for further diagnostics or supplementation.

This approach may create an important gap in athlete care. Current studies and clinical guidelines (Renke et al., 2023) emphasize that vitamin D affects many systems in the body, not only bone metabolism and calcium regulation. Previous cardiology research has also shown that low vitamin D levels are associated with a higher risk of cardiovascular disease and hypertension. In relation to the findings discussed in this review, diagnosing vitamin D deficiency only after orthopedic complications appear may mean that the cardiovascular system has already been exposed to long-term unnoticed stress.

For this reason, a broader approach to vitamin D assessment in athletes seems necessary. Vitamin D should not be considered only in the context of skeletal health, but also as an important factor influencing cardiovascular function. Measuring 25(OH)D concentrations could become a useful part of routine cardiovascular screening, especially in athletes with elevated blood pressure, unexplained fatigue, or early signs of cardiac remodeling such as left ventricular hypertrophy.

Additionally, maintaining adequate vitamin D levels through proper monitoring and supplementation, in line with current endocrine recommendations(Holick et al., 2011), may represent a relatively simple and cost-effective strategy supporting cardiovascular prevention in professional athletes.

4.4 Limitations of Current Evidence and Future Research Directions

Although many studies support the connection between vitamin D deficiency and cardiovascular risk in athletes, the current literature still has several limitations. One of the main problems is that most studies focused on athletes are observational or cross-sectional studies (Ogan & Pritchett, 2013). This means they can show associations, but they do not fully prove cause-and-effect relationships. There are still very few long-term randomized controlled trials (RCTs) that specifically analyze how vitamin D deficiency influences cardiovascular remodeling or the development of hypertension in professional athletes over many years of training.

Another important issue is the lack of clear recommendations regarding the optimal vitamin D dose for cardiovascular protection. Current sports nutrition guidelines mainly focus on vitamin D levels needed for bone health and proper muscle function(Larson-Meyer & Willis, 2010). It is still unclear whether athletes may require different or even higher vitamin D concentrations to fully protect the cardiovascular system, especially during intense physical

effort where endothelial function and regulation of the RAA system become particularly important.

Future research should focus more on these cardiovascular aspects. According to (Lanteri et al., 2013), larger clinical studies are needed to create athlete-specific recommendations for vitamin D supplementation aimed at cardiovascular protection. Such studies should include more advanced cardiovascular assessment methods, for example pulse wave velocity (PWV), which is used to evaluate arterial stiffness, together with blood pressure monitoring during exercise.

Until more detailed data becomes available, sports physicians and trainers should base their decisions on the current physiological evidence and pay closer attention to maintaining proper vitamin D levels in athletes as part of cardiovascular prevention.

5. Conclusions

The findings of this review confirmed our hypothesis: individualized supplementation of vitamin D improves endothelial function and enhances cardiovascular protection in athletes, mainly in the context of blood pressure regulation. The reviewed literature suggests that vitamin D deficiency in athletes should not be treated only as a problem related to bones and the musculoskeletal system. More and more evidence point to its important role in cardiovascular health. Low vitamin D levels may disturb vascular function, contribute to endothelial dysfunction, and stimulate excessive activation of the renin-angiotensin-aldosterone (RAA) system. In athletes exposed to intense physical effort, these changes can impair proper vasodilation and increase vascular resistance, forcing the heart to work harder during exercise. As a result, long-term vitamin D deficiency may significantly increase the risk of developing both exercise-induced and chronic arterial hypertension.

For this reason, sports medicine should place greater emphasis on monitoring vitamin D status in physically active individuals. Regular assessment of 25(OH)D concentration and appropriately adjusted supplementation should be considered not only in the context of bone protection, but also as an important element of cardiovascular prevention. Correcting vitamin D deficiency may therefore represent a simple yet effective strategy to support the long-term cardiovascular health of athletes.

Disclosure

The authors report no conflicts of interest in this work.

Supplementary Materials

Not applicable. No supplementary materials are associated with this article.

Author Contributions

Conceptualization, M.A., C.B. and A.P; Literature search and data excraction, M.A., F.N., B.H.,M.T., J.W.; writing, original draft preparation, M.A., A.G., M.G.; writing—review and editing, M.A., C.B., J.B., All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

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Conflicts of Interest

The authors declare no conflicts of interest.

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