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# VITAMIN SUPPLEMENTATION IN ATHLETES: WHERE DO WE STAND IN THE MOMENT?

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*(Original scientific paper)*

**Sanja Mancevska[1], Jasmina Pluncevic Gligoroska[1], Lidija Todorovska[1], Lence Aleksovska Velickovska[2]**
[1]University "Ss. Cyril and Methodius", Faculty of Medicine, Institute of Physiology and Anthoroplogy, Skopje, North Macedonia
[2]University "Ss. Cyril and Methodius", Faculty of Physical Education, Sport and Health, Skopje, North Macedonia

***Abstract***

*Dietary supplements target different aspects of health and performance and their use is under influence of different personal, regional, cultural and economic factors. Vitamins are widely used by the general population worldwide. Additionally, along with other dietary supplements, their use is widespread at all levels of sport. Athletes use dietary supplements in order to manage micronutrient deficiencies, supply convenient forms of energy and macronutrients and to provide direct and indirect benefits to performance. The aim of this article is to summarize current standpoints in vitamin supplementation in athletes and to provide information for athletes and their support team to assist them to make informed decision. The issue of the effect of supplements on training and sport performance until now has not been sufficiently researched. Many of the available studies have used a variety of designs which have provided little sound evidence in favor of proclaimed performance enhancing effects of supplements. Moreover, the athlete's responses are affected by the scenario of use and may vary widely between individuals because of factors that include genetics, the microbiome and habitual diet. Therefore, a complete nutritional assessment should be mandatory before decisions regarding supplement use (including vitamins) are made by the athlete and their support team*

***Key words:***

## Introduction

Genetic predeterminations, anatomical, physiological, psychological and metabolic attributes which completely match the specific needs of the sports they are engaged, primarily define the athlete's ability to achieve supreme sport performance (Williams, 2004). Optimal training in order to enhance and maintain physical and mental strength is a contributing factor. Nutrition usually has a small, but potentially important role in this process. Dietary supplements can contribute very little in this effect. Nevertheless, supplements are used on every level of sport activity, mostly because modern athletes believe that nowadays the difference between winning and losing is so small and that the supplements can provide that difference. Nevertheless, some studies also show that many athletes do not meet micronutrient recommendations (Wardenaar et al, 2017).

On the other hand, half the adult population in the USA, of which a major part is sedentary, use some form of dietary supplements within their everyday nutrition. The prevalence is similar in other countries, although there are regional, cultural and economic differences (Maughan et al, 2018). Until now there is no published data on the use of dietary supplements among general population, nether among athletes in our country.

Athletes use supplements for a range of different reasons. They include the maintenance of good health by contributing to the required intake of the specific nutrients, the management of micronutrient deficiencies and the provision of energy and macronutrient needs that might be difficult to achieve through food intake alone. Other specific reasons for supplement use pointed out by athletes include direct performance enhancement or the indirect benefits that are apparent during hard training, the manipulation of the physique, the alleviation of musculoskeletal pain, rapid recovery from injury and enhancement of mood (Sekulic et al, 2019). Proper use of supplements can be very helpful to athletes. However, some

supplements can harm their health, their performance, their quality of life and their reputation (Jovanov et al, 2019). Therefore, it is most important that a complete professional evaluation of the nutritional status and nutritional needs of an athlete is made before any decision for supplement use is reached. The aim of this review is to summarize current standpoints in vitamin supplementation in athletes and to provide information for athletes and their support team (coach, trainer, nutritionist, and physician) to assist them to make an informed decision.

**Dietary supplements**

According to Maughan et al, 2018, there is no single definition either legal or within nutritional science, of what constitutes a dietary supplement. One of the existing definitions which was introduced in 1994, by the US Congress in their Dietary Supplement Health and Education Act (DSHEA; https://ods.od.nih.gov/About/DSHEA_Wording.aspx) and is still accepted by the FDA (Food and Drug administration) describes a dietary supplement as a product, other than tobacco, which is used in conjunction with a healthy diet and contains one or more of the following dietary ingredients: a vitamin, mineral, herb or other botanical, an amino acid, a dietary substance for use by man to supplement the diet by increasing the total daily intake, or a concentrate, metabolite, constituent, extract or combination of these ingredients. Maughan et al., consider this definition incomplete because it depends on whether or not "healthy diet "is consumed. In their article entitled "IOC Consensus statement: dietary supplements and high-performance athlete" they introduce the following definition of dietary supplement: a food, food component, nutrient, or non-food compound that is purposefully ingested in addition to the habitually consumed diet with the aim of achieving a specific health and /or performance benefit (Maughan et al, 2018). Dietary supplements come in different forms, including the following: functional foods, foods enriched with additional nutrients or components outside their typical nutrient composition (for example: mineral-fortified and vitamin fortified as well as nutrient-enriched foods), single nutrients and other components of foods or herbal products provided in isolated or concentrated forms and multi-ingredient products containing various combinations of those products described in the earlier groups that target similar outcomes.

**Evidence base for dietary supplements use**

Many surveys report high prevalence of dietary supplement use among athletes (over 37-98% of athletes) (Muwonge et al, 2017), which is in accordance with the widespread use in the general population. The proportion of supplement used in athletes depends on the type of the sport; it increases with the increased level of training and with the age of the athlete, and is under the influence of the cultural norms of the society. Male athletes tend to use more supplements that female athletes (Jovanov et al, 2019).

The question whether dietary supplements enhance the effect of the training and sports performance until now has been addressed by a growing body of research. However, it still remains insufficient, while the assessment of the evidence base for supplement use is difficult. Many studies have used a variety of designs which have provided little sound evidence in favor of proclaimed performance enhancing effects of supplements. Therefore it has been argued that the "gold standard" for scientific investigation of the effects of supplements on sports performance should be prospective, randomized, controlled double-blind scientific trials which follow with strict protocols within standardized conditions. They should include adequate sample size and appropriate participant characteristics and provide high reliability and validity of the results. The studies should mimic, as far as possible the conditions that exist in real-life competition. Performance change should be interpreted in light of what is meaningful to the outcomes of sporting competition (Burke & Peeling, 2018). Safety, quality and efficacy of the product should remain to be of highest importance for replicable clinical studies witch should apply rigorous designs, and should use only well-defined products, as well as for everyday use of these products in the training process. According to that, many publishers now require that submitted manuscripts comply with established guidelines for the reporting of clinical trial results (e.g., CONSORT guidelines), while funders require demonstration of product integrity by applicants (Dwyer et al, 2018).

Currently, the assessment of the effects of supplements on sport performance on individual level should also recognize that the effects of a supplement could be underpinned by a combination of genetic, environmental and epigenetic factors. For example, emerging evidence suggest that habitual diet can affect gene expression and microbiota, and that they all within their interplay could also affect athletic

performance (Clark & Mach, 2017). Therefore, it is important that a good or emerging evidence base is established to support situation-specific use of supplements by athletes.

In order to obtain compatibility between scientific evidence and the regulation practices, as well as institutions from other countries, such as USA and Canada, the Australian Institute of Sports (AIS) has successfully developed the ABCD Classification System which ranks sports foods and supplement ingredients according to the scientific evidence that they can safely and practically contribute to an athlete's performance goals. Table 1 shows the dietary supplements that are safe and permitted for use by athletes and those which are unsafe and pose risk.

Table 1. AIS ABCD Classification System

| Group | Evidence level/ Use within supplement programs | Sub-categories | Examples |
|---|---|---|---|
| A | Strong<br>Permitted | Sports foods<br>Medical supplements<br>Performance supplements | Sports drink, electrolyte supplement,<br>Fe, Ca supplement, Multivitamin supplement, Vitamin D, probiotics<br>Caffeine, Bicarbonate, B-alanine, Creatine, Glycerol |
| B | Deserving of further research<br>Provided for athletes within research or clinical monitoring situations | Food polyphenols<br>Other<br>Sick pack<br>Amino Acids<br>Antioxidants | Cherries, berries,<br><br>Carnitine, fish oil<br>Zinc lozenges and Vitamin C<br>Leucine, Tyrosine<br>Vitamin C &E, N-acetyl cysteine |
| C | Have little meaningful proof of beneficial effects<br>Not provided to athletes within supplement programs | | Category A and B products used outside approved protocols |
| D | Banned or at high risk of contamination with substances that could lead to positive drug test<br>Should not be used by athletes | Stimulants<br><br>Prohormones and hormone boosters<br>GH releasers and "peptides" | Ephedrine, Strychnine, Sibutramine, Metylhexanamine(DMAA)<br>Androstenedione and other testosterone boosters |

**Vitamins important to sports performance**

Vitamins are organic compounds, which are necessary for the metabolism in small amounts, but they cannot be produced by the cells of the human organism. Vitamins are essential nutrients with herbal origin or they can be synthetized by the bacteria in the gastrointestinal system of humans and some animals. They catalyze and regulate metabolism and influence many physiological processes which are also important for physical activity and sports. Specific metabolic deficits can occur when the habitual nutrition lacks vitamins.

Vitamins alone are incapable of enhancing performance; they do not have ergogenic capacities. However, they are essential to the process of energy production. For example, many of the B-complex vitamins are involved in the catabolism of carbohydrates and fats, which is important during the exercise with varying intensity (Kerkisick et al, 2018).

Other vitamins are involved in production of proteins that transport oxygen, in maintenance of the healthy bone tissue. They provide proper immune function and are involved in maintenance of the water and electrolyte balance in the organism. Vitamins are essential for the production and recovery of muscle tissue and they protect the body from oxidative stress.

There are numerous vitamins, of which groups B and D, as well as those of the antioxidant group (vitamin A, vitamin C, vitamin E) are significant for athletes.

Athletes show high intensity of energy metabolism and they need to maintain these high levels during a longer period of time. As a result, most often their needs for micronutrients are higher compared to non-athletes. Additionally, physical effort stresses the metabolic pathways in which vitamins and micronutrients are involved, which could lead to series of biochemical adaptations which will increase the needs for micronutrients. Regular physical effort can speed up the turnover of vitamins. On the other hand, the

absorption of vitamins from the gastrointestinal system is low without the presence of food. Certain vitamins in food are in a form that can be used immediately by the organism, while others are present in an inactive form like provitamins or precursors. They are transformed into an active form – vitamin, after absorption. All these condition could lead to certain vitamin deficiency.

There is solid evidence that supplementation or diet modification to improve vitamin status can consistently improve athlete's health and performance. Paschalis and colleagues supplemented individuals who were low in vitamin C for 30 days and reported these individuals had significantly lower VO2Max levels than a group of males who were high in vitamin C. Further, after 30 days of supplementation, VO2Max significantly improved in the low vitamin C cohort as did baseline levels of oxidative stress of oxidative stress (Paschalis et al, 2016). Alternatively, conflicting evidence has accumulated that ingesting high doses of Vitamins C and E may negatively impact intracellular adaptations seen in response to exercise training, which may consequently negatively impact an athlete's performance. Furthermore, while optimal levels of vitamin D have been linked to improved muscle health and strength in general populations, research studies conducted in athletes generally fail to report on the ergogenic impact of vitamin D in athletes (Kerkisick et al, 2018).

**Vitamin supplements**

Vitamin supplementation is widely used by athletes. According to several surveys, vitamin C is among five most frequently used dietary supplements by athletes (Sekulic et al, 2019). In order to answer the question concerning whether and how much additional quantities of vitamins and minerals are required for athletes, it is necessary to pay attention to the following terms:

Dietary Reference Intakes – DRI – are referential values, which are quantitative assessments of nutrient intake, used for planning and evaluation of nutrient intake in healthy people. They are determined by relative institutions. The values can vary by sex and age. They include:

a. Recommended Dietary Allowance – RDA- the allowed daily average intake of nutrient which is sufficient for satisfying the needs of almost all healthy people (97-98%)
b. Adequate Intake – AI – is an introduced term used when there is not enough proof to define RDA, and it displays values for which it is assumed that sufficient nutrient intake would be secured.
c. Tolerable Upper Intake level – UL – the largest quantity of daily intake of a nutrient which will not cause unwanted negative effects.

Recommended daily dose for the most important vitamins depends on the age, sex and the intensity of the individual's physical activity. The values of daily needs refer to the largest part of the population. However, an individual approach to the determination of the doses for each person is still necessary. Table 2 shows the most frequent vitamin supplements, their effects (both wanted and unwanted), the level of proof in terms of efficiency and safety of use and the RDA and UL doses.

Table 2. Most frequently used vitamin supplements by athletes

| Supplement | Use and effects | Side effects | Level of proof and status |
|---|---|---|---|
| Vitamin C<br>Vitamin E | Antioxidants<br>Protective role<br>Decrement of fatigue | Minimal<br>Higher risk for nephrolithiasis | B |
| Vitamins of B complex | Metabolic role | Minimal | A |
| Vitamin D | Prevention of osteomalacia<br>Muscle and general health protection | Nausea, vomiting, constipation, kidney damage | A |

Currently, there is no consensus on whether micronutrient requirements are different in athletes as compared to the general population. In practice, athletes are nowadays often advised to meet the general recommended dietary reference intakes (DRI) for all micronutrients by consuming a diverse diet to ensure nutrient adequacy, paying special attention to optimal intake of iron, vitamin D and calcium, and of antioxidants. In a study by Wardenaar and colleges (Wardenaar et al ,2017) micronutrient intakes of 553 Dutch (sub-) elite athletes were assessed and both users and non-users of nutritional supplements reported inadequate intake of micronutrients. Vitamin D intake was below the estimated average requirement (AR)

if supplements were not included in the analysis. Non-users of dietary supplements were particularly at risk for low intakes of vitamins B1, B2, B3 and vitamins A, C and selenium. A small prevalence of athletes using dietary supplements showed intakes of some micronutrients above the Upper Level. In addition, case reports have shown that some athletes consume very high doses of certain micronutrients exceeding the upper level (UL), possibly resulting in reduced health and performance in the long term. Examples of frequently reported highly dosed micronutrient supplements used by individual athletes are antioxidants (i.e., vitamin C and E), vitamin D, iron and magnesium. Further, practical experience and anecdotal reports suggest a substantial use of high doses of vitamin B6 among athletes (Knapik et al, 2015).

Some athletes are tempted to take mega-doses of vitamins and minerals because they believe doing so will provide improvement in their performance. These athletes need to know and follow the values for the tolerable upper intake level (UL). The overcoming of the UL values will not secure better results, but rather increase risk of the vitamin's toxicity, cause serious metabolic, biochemical and morphological disorders (especially for liposoluble vitmains such as vitamins A, E, D and K) in the body and it could hinder the absorption and effects of other micronutrients and drugs.

Table 3.

| Vitamin | RDA | Women | Kids | Adolescents | Athletes /(UL) | Food |
|---|---|---|---|---|---|---|
| A | 5000 IU | 2300 | 2000 | 3000 | 5000 -15000 IU | Carrot<br>Pumpkin, Liver,<br>Milk<br>Eggs |
| Thiamine (B1) | 1,5mg | 1,1mg | 0,9 mg | 1,2 mg | 30-200 mg | Grain,<br>Meet,<br>Liver, Leguminous plants |
| Riboflavin (B2) | 1,8 mg | 1,3 | 0,9 | 1,3 | 30-200 | Liver, bread, Almonds |
| Niacin (B3) | 20 mg | 16 | 14 | 16 | 20-100 | Meet, fish,<br>Leguminous plants, peanuts |
| Ascorbic acid (C) | 45 mg | 75 | 45 | 75 | 800-2000 | Citrus,<br>Green vegetables,<br>Tomato,<br>berries |
| D | 400 IU | | | | | |
| E | 15 IU | 15 | 11 | 15 | 200-1000 | Vegetable oils |
| K | 70 microgr | | | | | |
| Folic acid | 0,4 mg | 0,4 | 0,3 | 0,4 | 0,4-1 | Meet,<br>Leaf vegetables |
| B12 | 3 microgr | 3 | 1.8 | 3 | 12-200 | Meet, Liver, Fish, Milk |
| Pyridoxine (B6) | 2 mg | 1,3 | 1 | 1,2 | 20-100 | Meet, grains,<br>nuts, vegetables |
| Pantothenic acid | 5 mg | | | | | |

Table 3 shows the daily needs of vitamins (RDA) and UL doses which are most important to the health of the human body depending on the age, sex and physical activity. The table is made in accordance with the textbook for medical physiology Guyton and Hal, 2012, combined with recommendations for vitamin intakes in athletes from other sources, and should be used only after consultation with a medical doctor).

To ensure a harmonious intake of nutrients, it is necessary that the athlete knows how his choice of diet influences the intake of vitamins and microelements in their body. For that purpose, a tight cooperation between the athlete and their sports doctor, trainer and sports nutritionist is needed.

**Determining the nutritional status of the athlete**

Data in literature suggests that the determination of the nutritional status of the athlete, with special focus on determining their vitamin status, is the only correct approach to defining the need of vitamin supplementation and settling the daily dose and duration. The assessment of the nutritional status includes

protocols which secure, confirm and interpret proof of the existence of certain problems related to not only health, but their causes and their meaning. Ideally, a complete assessment of the nutritional status needs to include: collecting data for detailed medical and nutritional history, an evaluation of the diet, a clinical medical review, an anthropometric analysis and an analysis of the bodily composition and biochemical testing. With this approach, in opposition to taking supplements "with one's own judgment and blindly", athletes are allowed to identify the factors which could lead to certain dietary deficits, and with that – a future dietary plan is ensured to provide appropriate energy, macronutrient and micronutrient intake. Afterwards, certain nutritious deficits are prevented or corrected with appropriate supplementation (acute or chronic) which could be understood, accepted and practiced by the athlete. Appropriate supplementation, prescribed after an assessment of the nutritional status, protects the athlete from the occurrence of medical problems which could arise as a result of interaction between supplements and various drugs. Furthermore, the assessment represents an excellent base for further comparison and evaluation of progress in the athlete's diet.

According to the American dietetic association, the addition of vitamins in the diet of athletes is not necessary as long as they take enough vitamins and minerals through a well-balanced diet. Still, the use of certain vitamins and multivitamin products can be justified in the following situations: when the athlete has a special diet, like vegetarian diet, for example; when a reduced energy intake is caused in an effort to lose weight; if no opportunity for a diverse diet exists; when athletes go on long travels and intense competitions, where they have limited access to food; and in the case of injury recovery. According to certain authors, top athletes often fill one of the indicated criteria.

In practice, it is often the case that athletes practice inappropriate, uniform and imbalanced diets which, along with the increased turnover of nutrients, leads to danger of developing a clinical picture or subclinical deficit of certain vitamins. A number of reasons for vitamin deficiencies exist: inadequate intake, bad absorption (vitamins in the form of a tablet as opposed to vitamins in liquid form), bad usability, increased excretion and increased destruction of the vitamin in the body. When the depots are empty and there are no developed clinical symptoms of deficiencies, marginal nutrition is the matter at hand. In these situations, it is necessary to take the vitamin for a certain time. Athletes often have vitamin D, iron and calcium deficiencies.

**Examples of vitamin supplement application**

In recent times, special attention is given to the meaning of the optimal doses of vitamin D to the health of both the general population and athletes. In addition to the well-known role of vitamin D3 in the regulation of calcium and phosphorus, and with that – the maintenance of the skeletal system's "health", proofs of other vital functions exist, such as: a role in the regulation of the transcription of the genes in most tissues, a role in the synthesis of proteins, the synthesis of hormones, immunological answers and cellular regeneration (with anti-carcinogenic effects). The newest proofs are in reference to the vital role of this vitamin in the contraction of the skeletal muscles through its direct (by reacting with a specific core receptor) and indirect mechanism of effect (with the sarcoplasmic reticulum and calcium ions). Still, proof of its direct positive influence over physical performance is limited at this time. Additionally, there is no reference for the levels of the 25-hydroxyvitamin D in the serum for deficiencies, insufficiency, surplus, or a tolerable upper level. It is regarded that the supplementation of vitamin D needs to be conducted on the basis of exposure to UV rays, as well as the athlete's skin type. Athletes which train in closed spaces belong to the category in risk of developing a vitamin D deficiency. They need to have the vitamin D in their blood regularly checked. The recommendations of IOC (Maughan et al, 2018) even though there are still no unified recommendations for athletes, regarding the supplementation of vitamin D (according to the assessment of the vitamin status and when the levels of vitamin D in serum are lower than 75 nanomol/l) are:

- for maintenance of an optimal status for general population – supplementation with doses of 800 to 2000 IU/daily.
- Athletes with deficiencies should be carefully monitored and supplemented briefly with high doses of 50 000 units per week, in the course of 8 to 16 weeks or 10 000 units daily in the course of a few weeks.

**Nutritional interventions for athletes with a hindered vitamin status**

The approach for athletes with a hindered vitamin status (which show clinical deficiencies or a marginal deficiency of certain vitamins) needs to be individual and in accordance with the goals and strategies of achieving them. Most importantly, it is necessary that a compliance with the athlete to a long-term optimal diet, supported by appropriate supplementation, is determined and secured.

For all other athletes, it is necessary to get clear and precise answers to these questions before vitamin supplementation is practiced: Is the supplement safe? Is it legal? Is it efficient? The answers to these questions need to be acquired by the athlete in cooperation with their trainer and sport-medical team on the basis of objective assessments of the existing scientific proof and practical experience.

**Conclusion**

Although there are many unsolved issues regarding vitamin supplementation in athletes, current standpoints are that scientific evidence should support every situation-specific use of supplements in athletes with an aim to maintain their health and deliver supreme performance. A complete nutritional assessment should be mandatory before decisions regarding supplement use (including vitamins) are made by the athlete and their support team. Supplementation is justified on the condition that it would ensure an advantage which could not be acquired with another strategy.

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