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The role of vitamin D in health preservation and exertional capacity of athletes

Rola witaminy D w zachowaniu zdrowia i zdolnościach wysiłkowych sportowca

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Summary

Sports training causes an increased load on the musculoskeletal, hormonal and immune system, which makes maintaining homeostasis in the organism more difficult. Maintaining metabolic balance in the athlete's body is important due to the necessity to obtain high physical fitness. One factor that facilitates optimization of health and increased endurance is a balanced diet. Proper nutrition enables provision of energy-giving and body-building substances as well as bioelements and vitamins, which influence metabolic processes and play regulatory functions.

Vitamin D, also called calciferol, has an impact on maintaining effectiveness of the musculoskeletal system, on mineralization of bones and on increase of mass, strength and endurance of muscles. An association between vitamin D content in the organism and levels of anabolic hormones such as insulin and testosterone has been reported. A sufficient amount of calciferol is also necessary for effective functioning of the nervous system, including keeping balance and determining the reaction time. Maintaining an adequate vitamin D level in the athlete's body is also important due to its role in mobilizing the immune system and preventing infections, to which athletes are particularly prone.

The positive impact of vitamin D on physical fitness of athletes shows how important it is to maintain its adequate level in the organism. Numerous studies indicate widespread occurrence of vitamin D deficiency, including among athletes. Climatic conditions and training in halls lead to limited endogenous production of this vitamin, which shows the importance of diet as a source of vitamin D.

The aim of the study is to present the role of vitamin D in preservation of health, particularly endurance and physical fitness of athletes, on the basis of currently available scientific literature.

Key words: **vitamin D • sport • endurance • physical activity**

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Introduction

Vitamin D is a microcompound whose active form, 1,25-dihydroxycholecalciferol, due to the mechanism of action and structural similarity to steroid hormones, fulfills the role of a metabolism-regulating substance [16,22,35,37,45,52]. The presence of receptors for 1,25dihydroxycholecalciferol has been detected in many human tissues, which shows its various biological functions. Vitamin D has a significant impact on maintaining calcium and phosphorus homeostasis, on prevention of depression and chronic, autoimmune and neurodegenerative diseases [16]. The requirement for calciferol varies depending on the age and physical activity. The human body obtains vitamin D from dietary sources as well as forming it endogenously from 7-dehydrocholesterol, under the influence of sunlight [24].

Intense physical activity leads to changes in the body, which adapt it to the exercises. Diet quality, including the presence of all macro- and micronutrients, helps maintain the homeostasis in the body of the athlete. Providing an adequate amount of vitamin D in a diet is important for people practicing in halls due to the lack of endogenous synthesis of cholecalciferol, for which solar radiation is obligatory [24,52].

Numerous studies have confirmed that vitamin D supplementation contributes to an increase in muscle mass and strength, and also helps preserve a balance of steroid hormones, including the proper level of serum testosterone [40,44].

The aim of the study is to present the role of calciferol in health optimization, with particular emphasis on endurance and effectiveness of an athlete on the basis of currently available scientific literature.

Vitamin D in the human body

The structural basis of all forms of vitamin D is identical to the cholesterol and steroid hormones. A considerable part of vitamin D is formed in the skin in the reaction of conversion of 7-dehydrocholesterol (pro-vitamin D) into previtamin D under the influence of UVB radiation of the wavelength of 290-315 nm. In Poland, optimum insolation for endogenous production of vitamin D in the skin occurs in the period from June to September. Previtamin D is converted to active 25-hydroxycholecalciferol (calcidiol), from which, as a result of dehydroxylation, the strongest metabolically active form of vitamin D, 1,25dihydroxycholecalciferol, that is calcitriol, is formed. Calcitriol, by acting on the vitamin D receptor (VDR), influences the expression of specific genes in the target tissues [5,21,23,24].

Vitamin D deficiency, associated with latitude, skin pigmentation, weather, covering the skin with clothing and using sunscreens, is being observed more and more often. Especially exposed to deficiency are infants and elderly people, in whom formation disorders are combined with the aging process of the skin. Most studies of the elderly have demonstrated that supplementing the diet with vitamin D has a positive effect on halting the loss of muscle mass and strength, as well as on reducing the number of falls. It is suggested that this effect is achieved either by direct interaction of calcitriol with the VDR on the surface of muscle or through indirect mechanisms including regulation of calcium ion resources [5,8,49].

Moreover, deficiency of vitamin D production affects the obese, due to vitamin D deactivation and storage in adipose tissue [16,21,23,24].

The role of vitamin D in the athlete's body

Reduced levels of vitamin D have been observed in organisms of athletes, of various gender, age, and practiced discipline, inter alia among gymnasts (83%), basketball players (94%), dancers and long-distance runners. More frequent incidence of this vitamin deficiency was observed during the winter months, as well as among athletes who train indoors or after sunset [2,6,11,27,32,34]. On the basis of conducted research, Walker concluded that knowledge among athletes of various disciplines about vitamin D, its sources and the functions it performs in the body is limited [24]. This state of knowledge suggests that it is necessary to draw attention to providing adequate amounts of vitamin D in the diet, from fish, milk as well as from dietary supplements [4,16,21,23,24].

Due to the positive effects of vitamin D on the increase in bone density and on the gain in muscle mass and strength, as well as on the regulation of balance of a range of hormones, including steroid hormones, maintenance of its appropriate level is important for athletes [40,52].

Figure 1 shows the role of vitamin D in optimizing the fitness and endurance of the athlete.

In studies about dietary supplementation of young athletes with vitamin D_2, a positive influence of providing additional exogenous vitamin D has been observed only in people who had previously demonstrated a deficiency of this vitamin. Among physically active individuals with a normal serum concentration of vitamin D in the blood, there was no improvement in skeletal muscle function [1 ,8,12,18,26,29,33,38,42,50,56].

Vitamin D affects the regeneration of muscle fibers, in particular type II, which are responsible for fast contrac-

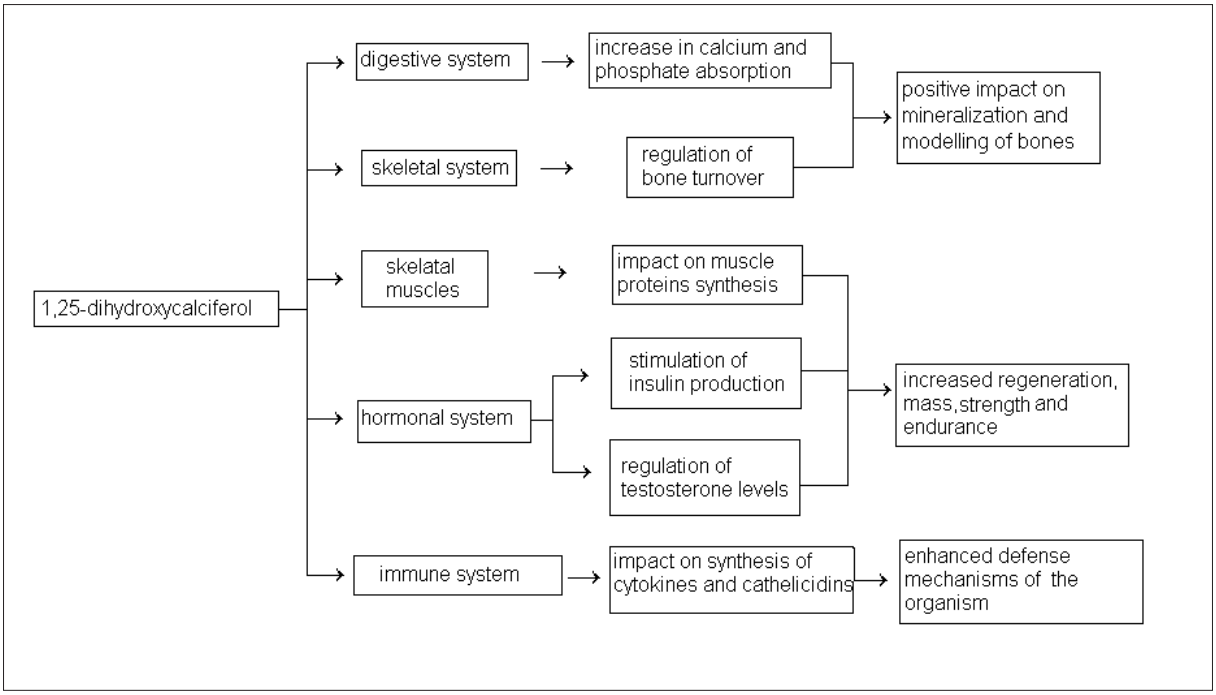

Fig. 1. Role of vitamin D in optimizing the efficiency and endurance of athletes. Own elaboration based on refs. 9,10,17,21,23,28,30,31,35,36,37,41,42,45,46,50,51,52

tions of muscles. Furthermore, it has an impact on the shortening of the relaxation time and on reduction of the risk of onset of skeletal muscle pain after exercise. It has been demonstrated that genes controlled by the active form of vitamin D influence protein synthesis, and thus the size, endurance and strength of the muscles [50].

Vitamin D can indirectly affect the recovery and construction of muscle tissue, by stimulating the production of insulin. It has been shown that 1,25-dihydroxyvitamin D_3 causes an increase in synthesis of this hormone [42].

The positive influence of vitamin D on calcium and phosphate homeostasis and on increase in density and mineralization of bone tissue is well known. It has been shown that the presence of vitamin D enhances the absorption of calcium and phosphorus in the gastrointestinal tract [22,35,45]. Numerous studies have demonstrated the positive effects of vitamin D on the bone mineralization process and remodeling. Such activity is explained by the impact of calcitriol on increasing the absorption of minerals and by its regulatory function on the parathyroid hormone and the C-terminal telopeptide contents [8,9,18,30,36,37,41].

Stein et al. and Chatterjee et al. found on the basis of research that 1,25-dihydroxyvitamin D, through the influence on the nervous system, determines the reaction time, balance and coordination of movement [37,46].

Deficiency of vitamin D is associated with reduced production of cytokines such as TNF-α (tumor necrosis factor-α), IL-1β (interleukin-1β) and IL-6 (interleukin-6) by monocytes as well as with the reduced concentration of IFN-γ (interferon-γ) secreted by lymphocytes. Vitamin D influences the regulation of immune function through its effect on the synthesis of cathelicidin, which protects against pathogenic agents, including *Mycobacterium tuberculosis*. Maintaining the optimum value of calcitriol in the body can improve the function of the immune system and reduce the amount of bacterial infections of the upper respiratory tract, which athletes, due to high loads, are more prone to than other groups of society [10,17,31,37].

The receptors of vitamin D and of the enzymes metabolizing it were also found within the male reproductive system, reproductive cells, sperm, Sertoli, Leydig, and in epithelial cells [44]. Numerous studies conducted in 2010-2012 among men aged 40 to 75 years found a positive effect of supplementation with vitamin D on the increase of testosterone levels [20,40,51]. Some researchers have reported a relationship between seasonal fluctuations of vitamin D concentrations and testosterone level [51,54]. In healthy young men, there was no such dependence, which is explained by a complicated, not completely understood mechanism of the effect of vitamin D on the level of testosterone in the blood. The relationship between serum vitamin D concentration and testosterone level is affected by, among other things, age, body fat content, glucose metabolism, and comorbid conditions. Bomberg Jensen in his work emphasizes that the correlation between the level of vitamin D and testosterone may be associated with calcium and phosphate metabolism, osteocalcin activity or concentration of steroid hormone-binding globulin (SHBG), which requires confirmation in further studies [14,44].

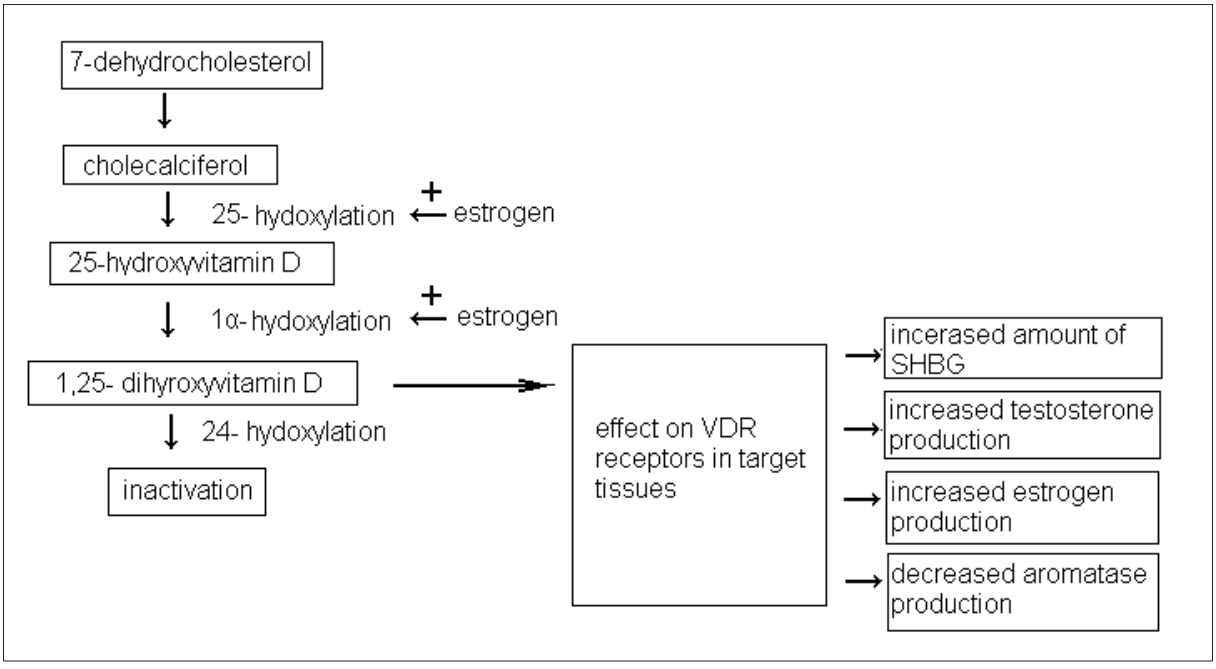

Fig. 2. Effect of vitamin D supplementation on steroid hormone homeostasis in physically active people. Own elaboration based on ref. 14

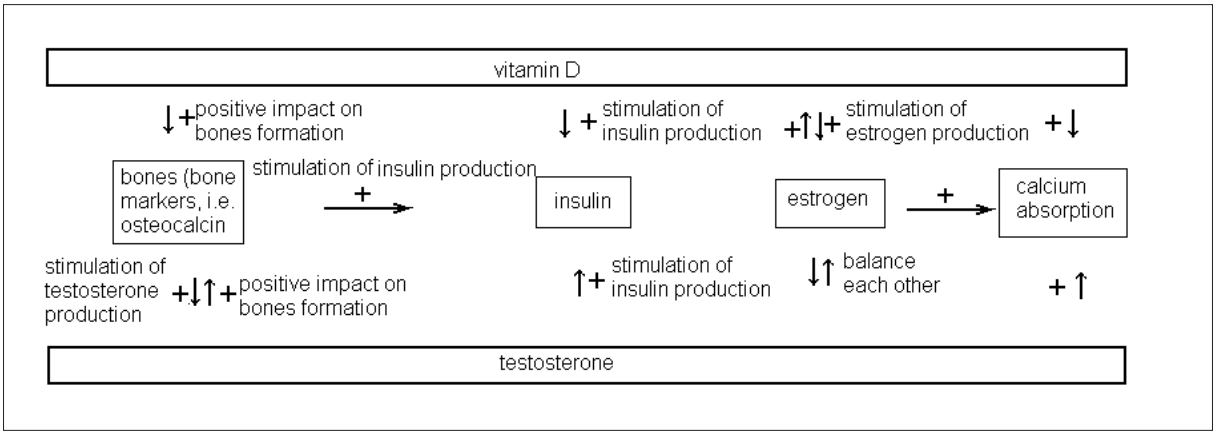

Fig. 3. Interactions of vitamin D, bone formation factors, insulin and sex hormones. Own elaboration based on ref. 14

Calcitriol influences the activity of the gene encoding aromatase (CYP19A1), an enzyme that converts androgens into estrogens. The CYP19A1 gene consists of 10 exons (I-X), of which the first is regulatory and has at least 10 different variants. It was observed that use of each variant is characteristic for the type of tissue. Adipose tissue, ovary, bone, endothelial cells, fetal cells and osteoblasts use promoters associated with variants I3 and I4, PII, I6, I7, I4 and PII, and I3 and I4, respectively [13,58].

It was observed that the activity of vitamin D in relation to the aromatase gene expression depends on the type of tissue. It was found that vitamin D alone does not influence aromatase expression in osteoblasts, but it strongly intensifies the enhancing effect of dexamethasone and other glucocorticoids [13,47,56]. Studies of Pino et al. demonstrated that vitamin D enhances aromatase activity during osteogenesis, but there is no such effect in the case of adipogenesis [39]. In breast cancer cells vitamin D inhibits aromatase expression, which is important in estrogen-dependent tumors. In glioma cells calcitriol increases expression of I3, I4 and I7, and arouses *de novo* expression of I6 [57].

In studies on elderly men there has been observed a negative correlation between serum estradiol and 25-hydroxyvitamin D levels [53], whereas in young healthy males there was no such correlation [15,19,55].

Figure 2 shows the effect of vitamin D supplementation on steroid hormone homeostasis in physically active people. Calcitriol increases the amount of SHBH (steroid hormo-

ne binding protein) and production of testosterone and estrogen, while estrogen influences conversion of cholecalciferol to active forms. It is important to maintain an adequate level of vitamin D in the organism to maintain the balance of steroid hormones [14].

The interactions between the various metabolites of vitamin D, steroid hormones, insulin and calcium ions are complex and require more detailed understanding (Fig. 3).

Vitamin D influences the increase of estrogen production, which stimulates the two-step conversion of cholecalciferol to an active form. Estrogen, like testosterone, increases the absorption of calcium from the small intestine, acting synergistically with vitamin D. Both vitamin D and testosterone positively influence bone turnover. In turn, osteocalcin enhances the production of testosterone and insulin, which have anabolic effects. The increase in insulin secretion is also affected by 1,25-dihydroxyvitamin D and testosterone [14].

Vitamin D influences sport performance indirectly, by affecting hormonal balance and controlling absorption of mineral compounds. Investigating the complicated system of dependences between the metabolism of cholecalciferol, steroid hormones, markers of bone turnover and insulin levels, results of research may be disturbed by serum calcium, phosphorus, parathyroid hormone, luteinizing hormone (LH), estrogen, osteocalcin and insulin-like growth factor 1 (IGF-1) in blood serum. Levels of all these hormones are controlled by many factors. It is hard to determine whether the change was caused by the vitamin D level or another agent [14].

The activity of calcitriol is also influenced by several other factors, e.g. age of the respondents, body fat, nutritional deficiencies and the type of tissue [14].

Conclusion

Vitamin D is a secosteroid compound that controls the expression of over 1000 genes and demonstrates non-genomic mechanisms of action. Receptors for the active form, 1,25dihydroxyvitamin D, have been detected in many cells, including intestinal epithelium, bone, muscle and reproductive cells. Analyzing the available studies, it can be argued that maintaining adequate levels of calcitriol in the blood contributes to the development of strength, muscle mass and endurance, as well as accelerating regeneration and reducing the pain caused by intensive training.

Practicing sports often involves performing complex tasks requiring the use of multiple muscle groups and connecting several types of movement. An adequate level of vitamin D influences the coordination and balance of the body. Vitamin D stimulates the secretion of insulin (anabolic hormone), contributing to the acceleration of regeneration and increase of muscle mass. Regulation of the calcium-phosphate levels affects the bone turnover, increasing mineralization and resistance of the skeleton to overload. An adequate concentration of vitamin D contributes to the preservation of homeostasis within the endocrine system, including steroid hormones, indirectly affecting other functions of the body.

In recent years, researchers who engage in nutrition in sport have drawn attention to the presence of cholecalciferol deficiency in the diet of athletes and their limited knowledge about the function of this vitamin and possible ways to deliver it to the body. Consequently, it is important to improve nutritional habits of athletes, so that they regain metabolic balance. Regular monitoring of the diet may lead to correction of nutritional mistakes and consequently to maintaining health and achieving better results in sports [4].

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