Original paper

Analysis of the dynamics of vitamin D status in the population of the Lodz region – a preliminary report

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Abstract

Introduction: Despite the ease of exposure to solar radiation, as well as oral supplementation with vitamin D, several findings still indicate the presence of the problem of insufficient supply of the organism with vitamin D in many populations.

Aim: To analyse the dynamics of changes of the vitamin D status in individuals of the population of the Lodz region depending on recreational exposure to solar radiation, and to determine the risk of vitamin D insufficiency.

Material and methods: Three measurements of the concentration of 25(OH)D_3 were performed: (1, baseline) within 2 weeks from the last exposure to solar radiation, (2) after 8 weeks, but not before September, (3) after 16 weeks. Measurements were performed with an automated method of the electrochemiluminescence assay under the DEQAS control system (vitamin D external quality assessment scheme).

Results: At baseline, the recommended vitamin D level was found in 36.67%, hypovitaminosis in 56.67%, and deficiency in 6.67% of individuals. After 8 weeks the recommended level was ascertained in 16.67%, hypovitaminosis in 63.33%, deficiency in 16.67%, and deficit in 3.33% of persons. After 16 weeks the recommended level was observed in 6.67%, hypovitaminosis in 36.67%, deficiency in 50.00%, and deficit in 3.33% of persons. The concentration of 25(OH)D_3 was significantly lower after 8 weeks in comparison to the baseline level ($p < 0.0001$). The decrease in the concentration after 16 weeks was significantly lower in comparison to the baseline value ($p < 0.0001$), as well as to those of the second measurement – after 8 weeks ($p < 0.0001$). The risk for low vitamin D level (< 30 ng/ml) after 16 weeks was more than twice as high as within the baseline period of exposure to solar radiation (OR = 2.79, $p < 0.01$).

Conclusions: The low concentration of vitamin D after 8 and 16 weeks after recreational exposure to solar radiation and the increased risk for vitamin D insufficiency underline the rationale of the use, especially in winter months, of oral vitamin D supplementation.

Key words: vitamin D, cholecalciferol, solar radiation.

Introduction

The relation between exposure to sunlight and prophylaxis of rickets was discovered by Jędrzej Śniadecki around 100 years ago [1]. Nowadays, it is known that this connection is a result of synthesis of vitamin D in the skin. However, the spectrum of biological activities of vitamin D is not limited only to the counteraction of rickets. Vitamin D also regulates the growth and differentiation of cells, and modulates various functions of the immune system [2, 3]. Several lines of evidence show the relationship between vitamin D deficiency and development of metabolic and autoimmune diseases and neoplasms [4]. The main source of vitamin D in the human organism is the synthesis in the skin, as a result of exposure to ultraviolet B radiation (UVB) (290-320 nm) that reaches the surface of the earth in the spectrum of sunlight [2]. Vitamin D is synthesized from 7-dehydrocholesterol (provitamin D_3), which is contained in cell membranes of keratinocytes. The exposure of the entire body to the dose of sunlight that equals one minimal erythema dose

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(1 MED) corresponds to intake of 10 000 IU of vitamin D *per os*. Therefore, the exposure of 6-10% of the body surface to 1 MED is the equivalent of the intake of 600-1000 IU of vitamin D *per os*. In other words, the exposure of the skin of hands, shoulders and face with the frequency of 2-3 times a week, to the dose of 1/3-1/2 MED, in spring, summer and autumn, seems to be sufficient for the adequate supply of vitamin D. In the case of skin phototype 2, this dose is the equivalent of 5 min sunbathing in July, at noon, in regions of the geographical latitude of Boston (42.2°N) [2]. Despite the ease of sunbathing, as well as oral supplementation with vitamin D, several studies indicate a problem of insufficient supply of vitamin D in many populations [5].

Aim

Therefore, the aim of the study was to investigate the dynamics of vitamin D status in the population of the Lodz region in relation to recreational exposure to sunlight, and to assess risk factors of vitamin D deficiency.

Material and methods

The study included a group of 30 individuals, with skin phototype 2 or 3, aged from 21 to 65, mean 46.89 ±12.81 years, inhabiting the Lodz region. Exclusion criteria were kidney or liver diseases, treatment with vitamin D or barbiturates, recreational sunbathing or the use of artificial sources of UV during the study period. The vitamin D status was estimated by measurements of serum concentration of calcidiol [25(OH)D_3], that is the main vitamin D metabolite in the circulation. Three measurements were performed: (1, baseline) – in a period not exceeding 2 weeks from the last recreational exposure to sunlight, usually recreational sunbathing during the summer vacation; (2) – after 8 weeks, but not earlier than in September; (3) – after 16 weeks. Serum concentration of 25(OH)D_3 was measured with reagents including calibrations and control sera obtained from Roche Diagnostic, Mannheim, Germany (Catalogue number: 11706802001, 11706799001, 11776576322, 10394246001, 03314847190) with electrochemiluminescence immunoassay (ECLIA) in the automated analyzer Elecsys 2010 (Roche Diagnostic, Mannheim, Germany). Both inter- and intra-assay variations were < 15%. 25(OH)D determinations were under international control of the Vitamin D External Quality Assessment Scheme (DEQAS) with Certificate of Proficiency [6]. Vitamin D status was based on the results of serum concentration of 25(OH)D_3 and defined as follows: deficiency < 10 ng/ml, insufficiency – 10-20 ng/ml, hypovitaminosis – 20-30 ng/ml, recommended range 30-80 ng/ml, and hypervitaminosis > 80 ng/ml.

In statistical analyses, the software Statistica version 9 was used. In order to assess differences in concentration of 25(OH)D_3 in the three successive measurements, the Wilcoxon test was applied. Logistic regression analysis with the estimation of odds ratio (OR) was performed in order to estimate the relation between the probability of decreased vitamin D status (deficiency or insufficiency or hypovitaminosis) and risk factors. Pearson's correlation coefficient was used to assess correlations between variables. In all calculations $p < 0.05$ was regarded as statistically significant.

Results

Results of serum concentrations of 25(OH)D_3 in the study group at three time points are shown in Table 1. The analysis of the baseline vitamin D status showed that the recommended level (30-80 ng/ml) was found in 36.67% of persons, hypovitaminosis (20-30 ng/ml) in 56.67%, and insufficiency (10-20 ng/ml) in 6.67%.

After 8 weeks serum concentration of vitamin D was significantly lowered in comparison to the baseline level ($p < 0.0001$). The decrease in 25(OH)D_3 level after 16 weeks was significantly lower than the baseline level ($p < 0.0001$), and lower than in the results after 8 weeks ($p < 0.0001$) (Fig. 1). After 8 weeks, results within the recommended range were ascertained in 16.67% of individuals, hypovitaminosis in 63.33%, insufficiency in 16.67%, and deficiency (< 10 ng/ml) in 3.33%.

After 16 weeks, the recommended level of vitamin D was found in 6.67% of persons, hypovitaminosis in 36.67%, insufficiency in 50.00%, and deficiency in 3.33%. The aforementioned data are shown in Figure 2.

The logistic regression analysis showed that the risk of the development of low vitamin D status after 16 weeks was 2.76-fold higher than at baseline (OR = 2.79, $p < 0.01$). No correlations between vitamin D level and age, body mass index or skin phototype were found.

Discussion

Risk factors of insufficient vitamin D status include decreased synthesis of cholecalciferol in the skin, low

Tab. 1. Serum concentration of 25(OH) vitamin D_3

Concentration	Mean [ng/ml]	Minimum [ng/ml]	Maximum [ng/ml]	Standard deviation [ng/ml]
Baseline level	30.46	13.78	54.52	9.85
After 8 weeks	23.3	8.19	41.98	6.18
After 16 weeks	19.28	4.01	30.97	6.2

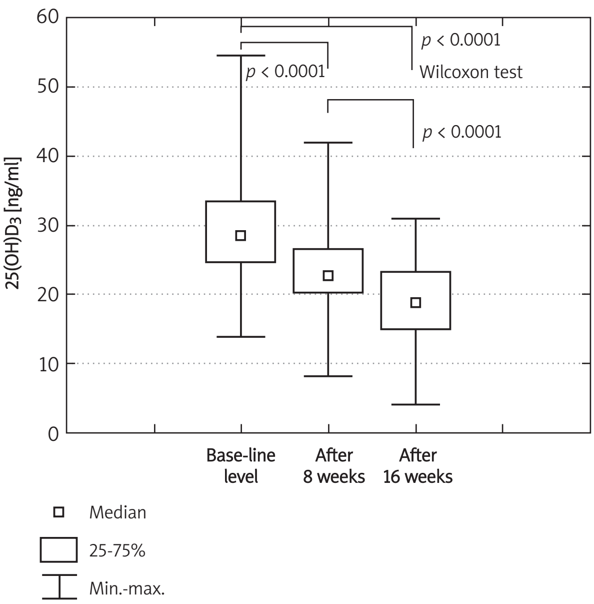

Fig. 1. Significant decrease in serum $25(OH)D_3$ concentration after 8 and 16 weeks

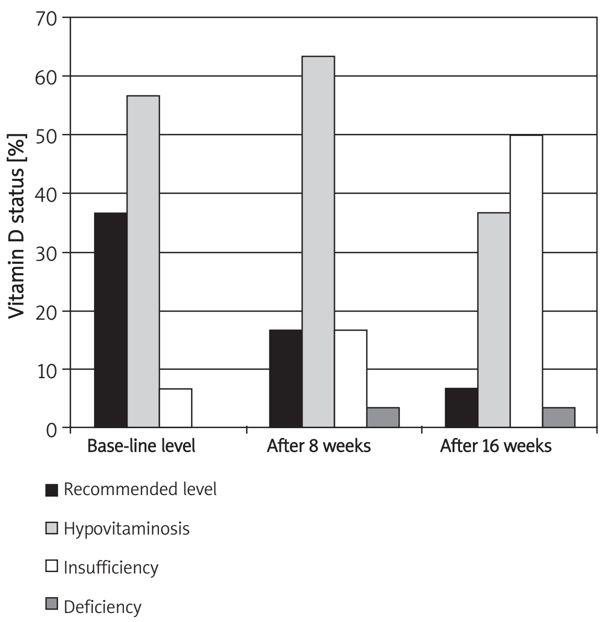

Fig. 2. Vitamin D status at the baseline level and after 8 and 16 weeks

bioavailability, increased loss of 25(OH)D in the urine, lowered synthesis of 25(OH)D, accelerated catabolism, chronic renal failure, and genetic disorders [3]. Decreased vitamin D with age follows diminutions of the content of 7-dehydrocholesterol in the epidermis [7]. In our study, we did not ascertain any correlation between age and 25(OH)D concentration. In the analysis of constitutional variables, height, body weight and body mass index (BMI) deserve special attention. In individuals with obesity vitamin D sequestration may occur in excessively developed adipose tissue [8]. On the other hand, obese persons may avoid exposure of the body surface, because of anticipated anxiety related to negative social perceptions, that may result in diminished exposure to sunlight and subsequent insufficient synthesis of vitamin D in the skin [8]. Despite the fact that in individuals with skin phototypes 2 and 3, both with BMI < 25 kg/m^2 as well as with BMI > 30 kg/m^2, vitamin D level was found to be increased, a negative correlation was revealed between body weight and UVB-induced maximum concentration of serum vitamin D [8]. Also, in obese persons lower concentration of 25(OH)D was observed after oral application with vitamin D in comparison to persons with normal body weight, regardless of the lack of essential differences in baseline levels of vitamin D_2 and D_3 [8]. In contrast, in our research no significant correlation between 25(OH)D concentration and BMI was found. These results are different from those of Botella-Carretero *et al.*, whose study conducted on 73 individuals revealed insufficient vitamin D status in 50.7% of patients with advanced obesity (BMI ≥ 40 kg/m^2) [9]. We did not find any significant correlation between skin phototype and insufficient status of vitamin D. A likely explanation could be the small range (2 and 3) of skin phototypes in our study group. One needs to take into account that although UVB contributes to increase of vitamin D level in the human organism, it has not been exactly established what dosage and frequency of application should be recommended in order to preserve or normalize physiological levels of biochemical parameters in individuals with certain pigmentation of the skin. Interesting results were obtained in the study of Armas *et al.*, who investigated UVB-induced serum concentration of 25(OH)D in relation to the degree of skin pigmentation. In the latter study, 72 volunteers were irradiated with a dose ranging 20-80 mJ/cm^2, 3 times a week, for 30 days. Ninety percent of the skin surface was exposed to UVB, and serum concentration of 25(OH)D was measured every 7 days. Armas *et al.* found that vitamin D level correlated positively with the UVB dose and negatively with skin phototype. However, essential changes in the concentration corresponded to changes in minimal tanning. Anyway, the 4-week period of exposures turned out to be too short to maintain the increase in concentration at a constant level [10]. In our study, a significant decrease in vitamin D developed with time. Thus a difference in proportions in the recommended range of vitamin D occurred and progressed after 8 and 16 weeks. At baseline recommended vitamin D status was ascertained in 36.67% of individuals, after 8 weeks in 16.67%, and after 16 weeks in 6.67%. In our study the possibility of out-of-protocol and unplanned synthesis of vitamin D in the skin was minimized, because the 2nd measurement, after 8 weeks, was performed not earlier than in September, and one of the exclusion criteria was recreational sunbathing or use of artificial sources of UV during the study. It should be emphasized that in the cold season of the year, in geographical latitudes above 35°N or below 35°S, the synthesis of vitamin D is insufficient [11]. The influence of the seasons, time of the day and geographical latitude on the synthesis of vitamin D results from the angle of solar beams that reach the surface of the earth or are absorbed in the atmosphere [1]. Our results confirm this observation, as the Lodz region is characterized by a geographical latitude within the range from 51.11°N to 52.23°N. In our studied population the risk of development of low vitamin D status (< 30 ng/ml) after 16 weeks was 2.76-fold higher than at baseline. Therefore an essential cause of low vitamin D level should be sought in insufficient synthesis in the skin. One of the consequences of vitamin D insufficiency and deficiency is a disadvantageous shift in equilibrium of bone mineralization, as the result of dominance of catabolism over anabolism of the extracellular matrix. Recent studies have underlined the problem of osteopenia and osteoporosis in many populations. In Poland, osteoporosis is estimated to affect about 7% of women aged 45-54 years, 25% aged 65-74 years, and nearly 50% aged 75-84 years [12, 13]. At present, osteoporosis is a worldwide problem that is constantly growing as the life expectancy of the human population is increasing. Several lines of evidence indicate an alarming relationship of insufficient vitamin D status with development of systemic diseases. Botella-Carretero *et al.* found that in individuals with advanced obesity (BMI ≥ 40 kg/m^2) a low vitamin D level (< 20 ng/ml) affected 50.7%, and especially those with metabolic syndrome compared with those who did not achieve the criteria for this syndrome (60.9% vs. 33.3%, respectively) [9]. These results of lowered concentration of 25(OH)D in patients with metabolic syndrome are in accordance with those of Ford *et al.*, obtained in an American population [14]. Besides obesity, other symptoms of metabolic syndrome are also associated with vitamin D. Auwerx *et al*. found a positive correlation between concentration of 25(OH)D_3 and concentration of apolipoprotein A-I and high-density lipoprotein cholesterol [15]. Chiu *et al*. found that 25(OH)D concentration was negatively correlated with total cholesterol and low-density lipoprotein cholesterol [16]. In the latter study, a positive correlation between 25(OH)D concentration and sensitivity to insulin was found, and low vitamin D level was found to be a risk factor of metabolic syndrome [16]. However, the aforementioned authors did not prove a relation between 25(OH)D and systolic or diastolic blood pressure [16]. In the study of Pfeifer *et al*., administration of calcium and vitamin D reduced systolic pressure in patients with arterial hypertension [17]. In research on mice with a switched off vitamin D receptor gene intense expression of renin in kidney and higher concentration of angiotensin II in plasma were found, which indicates a relationship between vitamin D and the renin-angiotensin-aldosterone system [18]. Cigolini *et al*. reported that in comparison to patients with diabetes type 2, without vitamin D deficiency, in patients with diabetes type 2 with insufficient vitamin D status, cardiovascular disorders and higher concentrations of fibrinogen and haemoglobin A_{1c} were more often found, and this group of patients more often required statins, aspirin and insulin therapy [19]. That is why there are suggestions that vitamin D deficiency is a risk factor of metabolic syndrome on the one hand, and on the other its axial symptom, that is obesity, predisposes to development of insufficient vitamin D status. In metabolic syndrome the risk of ischaemic heart disease is 3-fold higher and the mortality resulting from cardiovascular diseases is 5-fold higher [20]. These data show the importance of early detection of risk factors for civilization diseases in order to introduce prophylaxis. This needs to be emphasized when considering campaigns for avoidance of sun exposure and use of photoprotection. No extreme is advisable and too excessive avoidance of sunlight may paradoxically aggravate the risk of development of diseases instead of protect against them [1, 21, 22]. Also, it is important to remember about the efficiency, safety, accessibility and ease of use of oral supplementation with vitamin D in persons from risk populations of its insufficient status [23].

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