# Vitamin D status in Polish women with endocrine and osteoporotic disorders in relation to diet, supplement use and exposure to ultraviolet radiation

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## Abstract

**Background.** In Europe, the rate of 25(OH)D deficiency is considered high. Thus, it seems necessary to conduct population-based studies to fully assess vitamin D deficiency in various groups of patients.

**Objectives.** To evaluate serum 25(OH)D levels and the frequency of deficiency in women in Poland with endocrine and osteoporotic disorders. The influences of diet, use of vitamin/mineral supplementation and exposure to ultraviolet (UVB) radiation on vitamin D status in women with metabolic disorders were also examined.

**Materials and methods.** The patient group consisted of 223 women aged 19–81 years diagnosed with endocrine and/or osteoporotic disorders. The control group consisted of 108 clinically healthy women aged 26–72 years. Serum 25(OH)D concentration was assessed using a chemiluminescent immunoassay (CLIA). An ad hoc questionnaire was used to assess the participants' exposure to UVB radiation. Food intake was assessed using a three-day 24-hour questionnaire interview.

**Results.** The following groups showed significantly higher 25(OH)D levels: women taking vitamin D supplements compared to women not taking vitamin D supplements (29.3 ±3.2 compared to 19.5 ±3.7 ng/mL, $p = 0.0024$); premenopausal women compared to postmenopausal women (28.9 ±5.2 compared to 21.5 ±4.5 ng/mL, $p = 0.0021$); women who visited sunny countries in the last 6 months compared to women who did not (28.1 ±3.1 ng/mL compared to 24.5 ±5.3 ng/mL, $p = 0.0031$); and normal weight or overweight women (according to body mass index (BMI)) compared to obese women (27.4 ±4.5 ng/mL compared to 22.3 ±4.7 ng/mL, $p = 0.0431$). In addition, 25(OH)D concentration correlated with total dietary vitamin D intake in the patient group ($R = 0.17$, $p = 0.0021$). Of all examined food groups, fish consumption affected serum 25(OH)D levels in patients ($R = 0.20$, $p = 0.0421$) and controls ($R = 0.29$, $p = 0.0002$). Consumption of fish products contributed to statistical differences between the patient group ($R = 0.17$, $p = 0.0072$) and healthy subjects ($R = 0.19$, $p = 0.0032$).

**Conclusions.** The most crucial factors influencing vitamin D status in the studied women were regular fish consumption, spending holidays in sunny destinations and regular intake of vitamin D preparations.

**Key words:** diet, metabolic disorders, ultraviolet radiation, 25(OH)D, vitamin D status

# Background

In light of recent research, vitamin D is recognized as more than just a factor preventing rickets and osteoporosis. An increasing number of studies have confirmed its role in the proper functioning of the cardiovascular system and prevention of neoplastic and autoimmune diseases.[1–5] The presence of vitamin D receptors (VDR) in tissues that are not involved in maintaining calcium-phosphate homeostasis proves the multidirectional activity of calcitriol.3,6,7 Thus, vitamin D is thought to participate not only in bone metabolism, but also in cell proliferation and differentiation, as well as insulin secretion. Furthermore, it has pro- or anti-apoptogenic properties.[8–10] Until recently, vitamin D supplementation was recommended mainly for children. However, the need to introduce vitamin D supplementation in adults affected by various diseases, especially during the autumn-winter period, is increasingly discussed in the scientific literature.[9,11]

Both in Europe and worldwide, the rate of 25(OH)D deficiency is considered high.[8,10,11] This is caused by many factors including insufficient intake, insufficient exposure to sunlight, impaired cutaneous synthesis, and impaired formation of active metabolites in the liver and kidneys. Vitamin D regulates homeostasis of phosphate and calcium, and calcium intestinal absorption.[3,7] It also regulates blood pressure, and its concentration is inversely correlated with plasma renin activity.[12,13] Some studies have found that vitamin D may impact intracellular calcium concentration in pancreatic cells.[14,15] Since calcium stimulates insulin secretion, vitamin D deficiency may increase the risk of diabetes and other carbohydrate disorders. Vitamin D is also involved in lipid metabolism because its deficiency increases peripheral resistance to insulin, thereby worsening the lipid profile.[10,13,14] Moreover, studies have reported the decreased levels of 25(OH)D in obese patients resulting from sequestration of vitamin D in the overdeveloped adipose tissue.[2,3,5] Overall, vitamin D deficiency is associated with metabolic disorders and cardiovascular diseases, which are significant public health problems. However, whether vitamin D deficiency is a risk factor for cardiovascular and metabolic diseases, or if their existence predisposes an individual to deficiency, remains unclear. Thus, it seems necessary to conduct population-based studies in order to fully assess vitamin D deficiency in various groups of patients.

# Objectives

The aim of this study was to evaluate serum 25(OH)D levels and the frequency of deficiency in women with endocrine and osteoporotic disorders in Poland. Moreover, the influence of diet, use of vitamin/mineral supplementation and exposure to ultraviolet (UVB) radiation on vitamin D status in women with osteoporosis and endocrine disorders were examined.

# Materials and methods

## Patient and control groups

A total of 331 women living in the Łódź region of Poland participated in this study. The patient group consisted of 223 women aged 19–81 years (mean age: 64.6 ±12.8 years) diagnosed with endocrine and/or osteoporotic disorders, recruited from the Department of Endocrine Disorders and Bone Metabolism, Chair of Endocrinology, Medical University of Lodz, between 2017 and 2019. The control group consisted of 108 clinically healthy women aged 26–72 years (mean age 61.4 ±11.3 years) without the above disorders.

In the patient group, osteoporosis was found in 110 (49.3%) women, endocrine disorders (including hypothyroidism, Hashimoto inflammation and inactive nodules) were found in 53 (23.8%) women and both disorders were diagnosed in 60 (26.9%) women.

In the patient group, 26 (11.7%) women smoked cigarettes, and 173 (77.6%) took vitamin D supplements at a dose of 1000–2000 UI and a daily calcium dose of 500–600 mg for at least 3 months. In the control group, all women were non-smokers, and 31 (28.7%) took vitamin D at a dose of 1000–2000 UI without calcium for at least 3 months.

For both groups, women whose last menstrual period was at least 12 months prior to the commencement of the study were considered postmenopausal.

## Biochemical tests

Biochemical tests were performed by the hospital laboratory. Fasting blood was collected from the ulnar vein. The obtained blood samples were used to determine total 25(OH)D using a chemiluminescent immunoassay (CLIA). A serum 25(OH)D concentration of at least 30 ng/mL was considered normal, whereas a level below 30 ng/mL was considered insufficient (deficiency).[9] The 25(OH)D was assessed according to the season by dividing the year into quarters: I – January to March, II – April to June, III – July to September, and IV – October to December.

The collected blood samples were also used for the determination of total calcium concentration according to the Olympus Calcium Procedure (reaction of calcium ions $Ca^{2+}$ with Arsenazo III complex, corrected for albumin), and for the quantification of inorganic phosphorus using ultraviolet photometry.

## Assessment of exposure to UVB radiation

An ad hoc questionnaire developed by the authors of this study was used to assess participants' exposure to UVB radiation. The questionnaire estimated the time and the amount of sun exposure in all quarters of the year; the number of hours spent outdoors each week (8:00–16:00); and participants' preferences for being exclusively in the sun, both in the sun and shade, or only in the shade.

The questionnaire also assessed the frequency of solarium use (within the last 3 months), the frequency of visiting countries with high solar exposure (within the last 6 months), skin phototype (I – always burns, does not tan; II – burns easily, tans poorly; III – burns moderately, tans moderately; IV – burns minimally, tans easily; V – rarely burns, tans profusely; VI – never burns, never tans), and use of UVB protection agents (never, rarely, often, always).

## Anthropometry

All participants underwent standard anthropometric measurements. The waist-to-hip ratio (WHR) was determined by dividing the waist circumference by hip circumference. Body mass index (BMI) was determined by dividing participants' body weight (in kg) by height (in $m^2$).

## Nutrition assessment

Before the tests, food intake was assessed using a 24-hour questionnaire interview administered 3 times (2 weekdays and 1 weekend day) for each participant by a trained dietician. The "Album of photographs of food products and dishes" by the National Food and Nutrition Institute in Warszawa, Poland was used to determine the normal size of the consumed portions. The average energy intake, as well as the intake of particular nutrients, was assessed using Diet v. 5.0 software (license No. 52/PD/2013; Instytut Żywności i Żywienia, Warszawa, Poland).[16]

In order to assess vitamin D intake over the last month, a questionnaire on the frequency of consumption of selected dietary products that are sources of vitamin D was used. The products were divided into 7 groups depending on the content of vitamin D in a standard portion size. The number of portions consumed per week and per month was determined. The assessed food groups were: fresh and smoked fish (3–10 μg of vitamin D), fish products (10–12 μg of vitamin D), milk and milk products (0.07–0.3 μg of vitamin D), eggs (0.85 μg of vitamin D), meat and meat products (0.09–0.75 μg of vitamin D), cereals (0.06–0.25 μg of vitamin D), and fats (0.03–0.31 μg of vitamin D). The amount and type of supplement intake were also taken into account.

## Statistical analyses

Statistical analyses were performed using STATISTICA v. 13 software (StatSoft Inc., Tulsa, USA). Results are reported using descriptive statistics, including mean and standard deviation (SD). For variables with nominal scales, the rate of occurrence was computed. The normality of the distribution of the variables was determined using the Shapiro–Wilk test. All analyzed variables deviated significantly from the normal distribution. The means of 2 independent groups were compared using the Mann–Whitney U test for continuous and dichotomous variables. Spearman's rank order correlation was used to determine the correlation between variables. To assess the risk of vitamin D deficiency in patients with osteoporosis or endocrine disorders and in healthy subjects, receiver operating characteristic (ROC) classification models were used. A multivariate adaptive regression splines model was constructed to determine the relationship between the studied factors (vitamin D consumption, calcium and vitamin D supplement intake, consumption of fish, and normal weight/overweight/obese) and 25(OH)D concentrations. A value of $p < 0.05$ was considered statistically significant.[17]

## Ethics approval

This study was performed according to the Declaration of Helsinki and approved by the Bioethics Committee of the Medical University of Lodz, Poland (approval No. RNN/556/10/KB). All participants provided written informed consent before participating in this study.

# Results

There were no statistically significant differences regarding age, weight, waist circumference, BMI, or WHR between the study and control groups. Similarly, there was no difference regarding UVB exposure. However, patients with osteoporotic and endocrine disorders used vitamin and mineral supplementation significantly more often than healthy women. In both groups, 1/5 of women had spent a holiday in a country with high solar exposure in the last 6 months, and 2/3 claimed to have spent more than 7 h per week outdoors in spring and summer. With regard to skin phototype, nearly 60% of women claimed that their skin burns rarely or moderately and tans moderately or easily. A small percentage of participants reported that they always use UVB protective agents (Table 1).

The concentration of 25(OH)D was significantly lower in the group of women with osteoporosis and endocrine disorders compared to the control group (25.9 ±11.8 ng/mL compared to 28.1 ±9.1 ng/mL; Z = 2.1808, p = 0.0029). However, the prevalence of vitamin D deficiency was not significantly different between the 2 groups (Table 1). There were significantly higher 25(OH)D levels in the following groups: women taking vitamin D supplements compared to women not taking vitamin D supplements (29.3 ±3.2 ng/mL compared to 19.5 ±3.7 ng/mL, Z = 3.2056, p = 0.0024); premenopausal women compared to postmenopausal women (28.9 ±5.2 ng/mL compared to 21.5 ±4.5 ng/mL, Z = 2.9634, p = 0.0021); women who visited sunny countries in the last 6 months compared to women who did not (28.1 ±3.1 ng/mL compared to 24.5 ±5.3 ng/mL, Z = 2.9583, p = 0.0031); and normal-weight or overweight women (based on BMI) compared to obese women (27.4 ±4.5 ng/mL compared to 22.3 ±4.7 ng/mL, Z = 3.2845, p = 0.0431). In the control

**Table 1.** Characteristics of the study participants

| Characteristics | Patient group n = 223 | Control group n = 108 | Z, p-value Mann–Whitney test |
|---|---|---|---|
| | mean ±SD/n (%) | mean ±SD/n (%) | |
| Age [years] | 64.6 ±12.8 | 61.4 ±11.3 | 4.2306, 0.4673 |
| Weight [kg] | 71.5 ±14.7 | 73.5 ±7.9 | 1.1365, 0.6233 |
| Body mass index (BMI) [kg/m$^2$] | 27.8 ±5.5 | 26.1 ±5.8 | 1.4817, 0.7671 |
| Waist circumference [cm] | 88.8 ±12.9 | 87.2 ±7.2 | 1.1463, 0.5659 |
| Pre-menopausal women, n (%) | 84 (37.67) | 41 (37.96) | 1.0453, 0.7352 |
| Regular vitamin D supplements users, n (%) | 173 (77.6) | 31 (28.7) | 4.5638, <0.0001 |
| UVB exposure | | | |
| Sunny vacation during the previous 6 months, n (%) | 44 (19.73) | 20 (18.52) | 1.3482, 0.8671 |
| Outside during daylight >7 h/week, n (%) | 151 (67.71) | 79 (73.15) | 0.9834, 0.9654 |
| Summer | 136 (60.99) | 72 (66.67) | 1.7384, 0.7694 |
| Winter | 62 (27.80) | 25 (23.15) | 0.9954, 0.4739 |
| Preference, n (%) | | | |
| Sun avoiders | 49 (21.97) | 22 (20.37) | 1.2376, 0.9674 |
| Some exposure | 155 (69.51) | 74 (68.52) | 1.0674, 0.7698 |
| Frequent exposure | 19 (8.52) | 12 (11.11) | 1.1054, 0.8033 |
| Sunbathing during previous 3 months, n (%) | 5 (2.24) | 4 (3.70) | 0.8725, 0.6713 |
| Skin phototype, n (%) | | | |
| I–II | 39 (17.49) | 19 (17.59) | 1.1358, 0.7474 |
| III–IV | 132 (59.19) | 62 (57.41) | 1.0386, 0.6704 |
| V–VI | 52 (23.32) | 27 (25) | 1.1079, 0.8552 |
| Sun-protection products, n (%) | | | |
| Never | 70 (31.39) | 34 (31.48) | 1.1637, 0.8452 |
| Rarely | 59 (26.46) | 28 (25.93) | 0.9427, 0.7752 |
| Often | 65 (29.15) | 30 (27.78) | 1.0926, 0.8047 |
| Always | 29 (13.00) | 16 (14.81) | 0.9963, 0.9172 |
| Dietary intake | | | |
| Energy [kcal/day] | 1415.7 ±447.4 | 2127.2 ±1182.3 | 4.2349, <0.0001 |
| Fats [g/day] | 53.4 ±24.3 | 79.3 ±57.7 | 3.9465, <0.0001 |
| Proteins [g/day] | 57.9 ±19.5 | 99.6 ±45.8 | 2.9836, <0.0001 |
| Carbohydrates [g/day] | 189.0 ±61.0 | 268.8 ±139.8 | 6.4326, <0.0001 |
| Vitamin D (without supplements) [µg/day] | 3.7 ±2.3 | 7.4 ±5.6 | 2.9987, <0.0001 |
| Total vitamin D (including supplements) [µg/day] | 38.2 ±15.0 | 21.1 ±13.6 | 3.9075, 0.0028 |
| Calcium (without supplements) [mg/day] | 512.5 ±278.1 | 690.1 ±486.0 | 2.9967, <0.0001 |
| Total calcium (including supplements) [mg/day] | 713.4 ±419.3 | 690.1 ±486.0 | 3.0784, <0.0001 |
| Phosphorus [mg/day] | 921.3 ±318.7 | 1579.6 ±764.3 | 4.0237, <0.0001 |
| Groups of products | | | |
| Fresh and smoked fish [portions/week] | 1.2 ±0.7 | 2.4 ±1.1 | 4.2271, <0.0001 |
| Fresh and smoked fish [µg vitamin D/week] | 10.7 ±3.3 | 21.3 ±6.8 | 3.9566, <0.0001 |
| Fish products [portions/week] | 1.3 ±0.5 | 2.7 ±0.9 | 3.2874, <0.0001 |
| Fish products [µg vitamin D/week] | 13.8 ±2.9 | 26.8 ±5.6 | 4.0376, <0.0001 |
| Serum concentration | | | |
| 25(OH)D total [ng/mL] | 25.9 ±11.8 | 28.1 ±9.1 | 2.1808, 0.0029 |
| 25(OH)D deficiency, n (%) | 149 (66.8) | 68 (62.9) | 0.8725, 0.8043 |
| Parathormone [pg/mL] | 54.4 ±19.1 | 84.4 ±12.5 | 2.4381, 0.0068 |
| Calcium [mmol/L] | 2.4 ±0.6 | 2.4 ±0.2 | 0.5683, 0.9269 |
| Phosphorus [mmol/L] | 1.1 ±0.5 | 1.3 ±0.5 | 0.7856, 0.4738 |

UVB – ultraviolet radiation; SD – standard deviation.

group, higher 25(OH)D levels were observed in women taking vitamin D supplements compared to those who were not (32.58 ±3.2 ng/mL compared to 26.7 ±4.6 ng/mL, Z = 2.9743, p = 0.0492) and in normal-weight or overweight women (based on BMI) compared to obese women (35.3 ±4.7 ng/mL compared to 27.8 ±3.7 ng/mL, Z = 3.3124, p = 0.0476). The use of personal UVB protective agents, skin phototype, and time spent outdoors did not differentiate between 25(OH)D concentrations in the 2 groups. There was no seasonal variation in 25(OH)D concentration in the group of women with endocrine and osteoporotic disturbances or in the control group.

In the patient group, Spearman's rank order correlation analysis indicated significant correlations between 25(OH)D concentration and serum Ca (R = 0.50, p < 0.0001), phosphorus (R = 0.47, p < 0.0001), and parathormone (R = −0.65, p < 0.0001) levels. In the control group, the 25(OH)D concentration was only significantly correlated with the level of parathormone (R = −0.29, p < 0.0001).

In addition, Spearman's rank order correlation analysis detected a correlation between serum 25(OH)D concentration and the occurrence of osteoporosis (R = 0.21, p < 0.0001). Such a correlation was not found for thyroid diseases. Moreover, there was a correlation between serum 25(OH)D level and BMI in women with osteoporotic and endocrine disorders (R = −0.31, p = 0.0027) and in healthy women (R = −0.42, p < 0.0001). An inverse correlation between vitamin D level and waist circumference in the patient group (R = −0.27, p = 0.0413), an observation that was not confirmed in the control group, was also noted. Participants' age and vitamin D concentration were not correlated (Table 2).

According to Spearman's rank order correlation, 25(OH)D concentration correlated with the total dietary vitamin D intake in the patient group (R = 0.17, p = 0.0021) and in the control group (R = 0.43, p = 0.0000). Furthermore, 25(OH)D concentration positively correlated with total dietary calcium intake in the patient group (R = 0.22, p = 0.0041) and in the control group (R = 0.34, p < 0.0001). Of all food groups, fish consumption was correlated with serum 25(OH)D levels in the patient (R = 0.20, p = 0.0421) and control groups (R = 0.29, p = 0.0002). Consumption of fish products was also correlated with serum 25(OH)D levels in the patient (R = 0.17, p = 0.0072) and control groups (R = 0.19, p = 0.0032). No relationship was found between the intake of food from other groups and serum vitamin D levels in patient group or control group.

The multivariate adaptive regression splines model showed that there was a relationship between vitamin 25(OH)D serum level in all studied women and dietary intake, including intake of vitamin D and calcium supplements, consumption of 1 portion of fish per week, and a normal body weight, as measured with BMI (correlation coefficient R = 0.386, p < 0.0001; Fig. 1). Moreover, the risk of vitamin D deficiency in the 2 groups was determined.

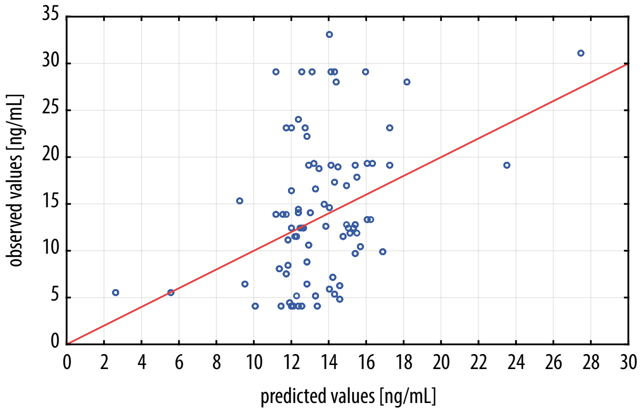


Fig. 1. Multivariate adaptive regression model for the serum level of 25(OH)D and its consumption with diet, accounting for intake of vitamin D and calcium supplements, consumption of fish, and normal body weight

The highest predictive quality was obtained for women with thyroid diseases and the lowest was obtained for healthy women (Fig. 2).

## Discussion

In our study, we found significantly lower serum 25(OH)D concentrations in women with metabolic disorders compared to healthy women. The prevalence of vitamin D deficiency in both groups was similar; more than 60% of studied women failed to demonstrate the recommended serum vitamin D concentration, despite the fact that about 77% of patients and nearly 30% of healthy women regularly took vitamin D supplements. In 2013, recommendations for supplemental prophylactic and therapeutic doses of vitamin D changed. Adults with normal 25(OH)D levels should take 800–2000 IU per day, while those with vitamin D deficiency should take up to 10,000 IU per day, but not more than 50,000 IU per week.[9] Compensation of vitamin D deficiency is particularly important among patients with bone metabolism disorders, and failure to achieve optimal 25(OH)D concentrations can make the anti-osteoporotic therapy less effective. Cutaneous synthesis is the main source of vitamin D. However, it is often insufficient to provide optimal concentrations of the vitamin even in spring and summer months, as confirmed in prior studies.[18–21] Thus, it is suggested that people over 65, obese people, and people who avoid the sun or use UV filters should also take vitamin D preparations in summer.[9] Such a high recommended dosage may raise doubts in patients, pharmacists and even doctors who are accustomed to the earlier recommendations. In our study, patients took low daily doses of supplementation, not exceeding 2000 IU. It was shown that in most cases, the recommended levels were achieved in neither sick nor healthy women. Similar results were obtained in other studies, in which supplementation used in different groups

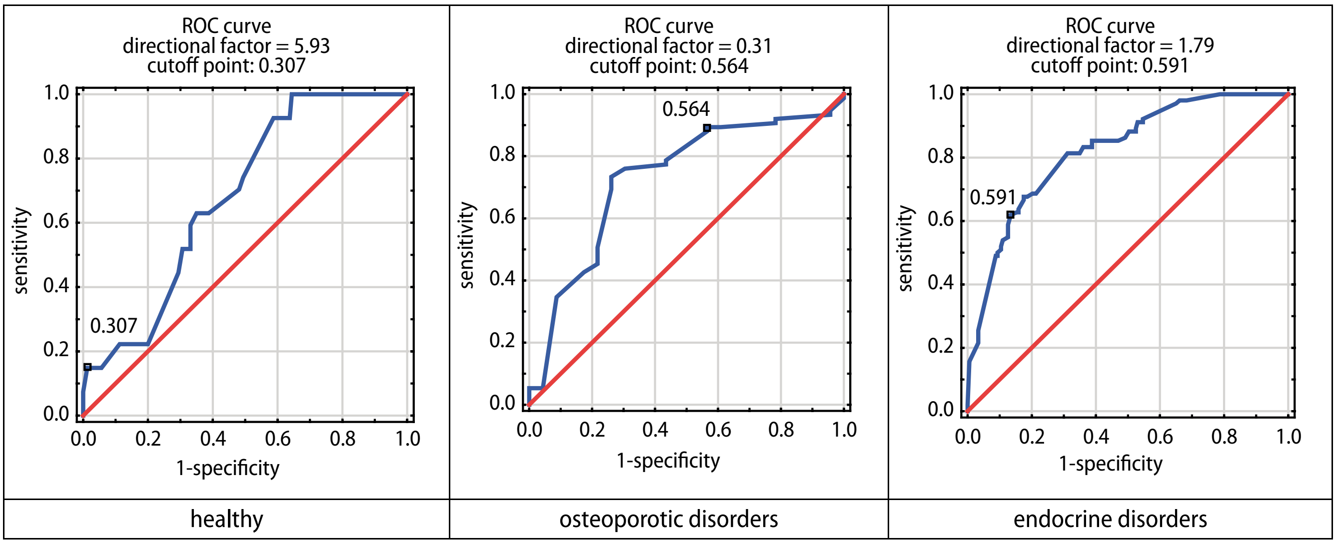


**Fig. 2.** Predicted prevalence of 25(OH)D deficiency in patients with different metabolic disorders

ROC – receiver operating characteristic.

**Table 2.** Multivariate adaptive regression model for the serum level of 25(OH)D and its consumption with diet, accounting for the intake of vitamin D and calcium supplements, consumption of fish, and normal body mass index (BMI)

| Vitamin D [ng/dL] | correlation coefficient | F-test | df | Standard error of estimate | p-value |
|---|---|---|---|---|---|
| | 0.386 | 10.883 | 3.186 | 7.234 | <0.0001 |
| Vitamin D and Ca supplements intake | 0.334 | | | | <0.0001 |
| Consumption of fish [1 portion/week] | 0.21 | | | | <0.0001 |
| Normal body weight [BMI < 25 kg/m$^2$] | 0.11 | | | | <0.0001 |

df – degrees of freedom.

of patients proved to be insufficient in normalizing serum 25(OH)D levels.[19,22,23]

This study demonstrated a significant effect of dietary vitamin D and calcium intake on serum 25(OH)D levels. Vitamin D intake without supplements in the patient group was 3.7 ±2.3 µg and in the control group was 7.4 ±5.6 µg, whereas the recommended intake is 15 µg. Low intake of vitamin D is common in European countries and ranges between 4 µg and 10 µg per day.[24–28] Hence, recommendations not just on possible need for supplementation, but concerning various doses of vitamin D administered to different age groups of patients with different disorders, are currently widely discussed. Insufficient intake of vitamin D may result from the fact that high doses of this vitamin can be found only in a few alimentary products. In countries where there is an obligation to fortify low-fat dairy products and margarines with vitamin D (Scandinavian countries), and in countries with a high intake of marine fish (Scandinavian and Mediterranean countries), vitamin D intake is higher than in central Europe.[29–32] In our study, we showed a significant increase in 25(OH)D concentrations in women consuming fish and fish products. These alimentary products are essential dietary components as they are the greatest source of vitamin D.

Cutaneous synthesis provides 90% of the body supply of vitamin D.[33,34] Due to a low exposure to sunlight in autumn and winter, supplementation is necessary to maintain optimal serum 25(OH)D concentrations. Thus, we also evaluated participants' exposure to ultraviolet radiation. We found that 25(OH)D concentrations did not show seasonal variation. Furthermore, factors such as time spent outdoors, use of UV protective agents and preference regarding exposure intensity did not significantly affect serum levels of 25(OH)D. In contrast, significantly higher 25(OH)D concentrations were observed in women who had spent holidays in countries with high solar exposure within the 6 months prior to the commencement of the study.

It is possible that brief but intense exposure of a large skin area to sunlight is a more effective method of supplying the body with vitamin D than supplementation. This possibility has been discussed in clinical studies evaluating the effects of sun exposure on vitamin D synthesis in the skin. However, the results were often contradictory. Some authors' results were consistent with ours, as they noted a significant increase in 25(OH)D concentration after strong exposure to sunlight during holidays.[33,35] Other studies failed to confirm this relationship.[8,11,36] Clinical studies on the efficiency of cutaneous vitamin D synthesis showed that a single erythemal dose leads to a large increase in 25(OH)D concentrations due to the release of about 30 μg D3 from 1 $m^2$ of body surface per day. The standard pre-exposure vitamin D concentration in healthy subjects was restored after several days. However, in patients with 25(OH)D deficiency, the increase in 25(OH)D concentration after sun exposure was observed for much longer,[37,38] which is consistent with the results of our study.

The effect of vitamin D concentration on calcium-phosphate metabolism is often discussed, as it is of particular importance for osteoporotic patients. This study revealed an inverse relationship between 25(OH)D and parathormone levels, and a positive relationship between calcium and phosphorus levels. Increased parathormone levels and decreased vitamin D blood levels result in rapid bone turnover and decreased bone mass, which promotes the development of osteomalacia and reduces muscle strength. Vitamin D, which contributes to the reabsorption of calcium from the gastrointestinal tract, enables maintenance of the calcium and phosphate balance. In addition, the gut is reported to be highly adaptive depending on the amount of dietary calcium intake.[8,9,11] When dietary calcium is low, the gut produces more calcium-binding protein, so calcium absorption is increased. Hypocalcemia in turn stimulates parathyroid gland production of parathormone, which stimulates renal 1α-hydroxylase to increase synthesis of $1,25(OH)_2D$. Once serum calcium levels are normalized, parathormone synthesis and calcium absorption in the gastrointestinal tract decrease. Despite insufficient dietary calcium intake, we observed normal mean concentrations in the patient and control groups, which confirms the mechanisms described above.

The factors influencing vitamin D nutritional status in patients with metabolic disorders are complex and require further research. Undoubtedly, the nutritional status and age of participants are variables that may influence the effect of sun exposure on cutaneous vitamin D synthesis. Many studies have reported lower 25(OH)D concentrations in obese subjects,[39–42] which were also demonstrated in this study. Other authors reported a decrease in 25(OH)D concentration that occurred with age,[20,21,25] which was not confirmed in our study. However, our study revealed an influence of menopause on vitamin D level, with a significantly lower concentration of 25(OH)D in postmenopausal women. Although similar relationships have been reported in other studies,[20,21] it is worth mentioning that this may be a result of less efficient dermal synthesis in older people and not necessarily a result of menopause.

Despite great knowledge about the factors influencing 25(OH)D concentration, the results of the present study and studies conducted by other authors confirm that the suggested amount and type of sun exposure, the amount of supplement intake and the need of vitamin D food fortification require further research, especially regarding patients with metabolic disorders.

## Limitations

Our study is subject to several limitations. Firstly, we could not evaluate the impact of cigarette smoking on 25(OH)D level due to the limited number of participants who were current smokers. Secondly, it was not possible to confirm the impact of calcium supplementation on 25(OH)D concentration in the control group, which may be important. Lastly, we were not able to assess seasonal changes in 25(OH)D because participants' blood samples were only taken once.

# Conclusions

The group of women with osteoporotic and endocrine disorders demonstrated vitamin D deficiency despite the intake, however insufficient, of supplements. The crucial factors determining vitamin D status in the patient group included regular fish consumption, spending holidays in sunny destinations and regular intake of vitamin D supplements.

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