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Vitamin D deficiency during winter months among an adult, predominantly urban, population in northern Poland

Niedobór witaminy D w przeważająco miejskiej populacji dorosłych z Województwa Pomorskiego w miesiącach zimowych

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Abstract

Introduction: Vitamin D is vital in the regulation of the calcium-phosphate metabolism, has a direct impact on the musculoskeletal system, and also affects numerous other systems. Widespread vitamin D deficiency and its detrimental effect on health have been reported globally. Data concerning vitamin D status in Polish adult population is scarce.

Material and methods: Ambulatory patients of an outpatient clinic in Gdańsk were included in the study. Serum concentrations of 25(OH)D, parathyroid hormone (PTH), alkaline phosphatase (ALP), calcium and phosphorus were determined. In a questionnaire declared UVB exposure, dietary vitamin D and calcium intake, and health status of the subjects were assessed. Non- and parametric tests, logistic regression and population attributable risk were applied in data analysis.

Results: 448 adults were examined from February to mid-April 2012, 305 women and 143 men, aged 19 to 86 (mean 46.3 ± 14.9 years). Mean 25-hydroxyvitamin D concentration was 14.3 ± 6.6 ng/mL. 84.4% of subjects were vitamin D deficient (25(OH)D < 20 ng/mL); 13.2% presented insufficient (20–30 ng/mL), and 2.5% (or 11 subjects) sufficient 25(OH)D concentrations.

Significantly higher 25(OH)D concentrations were found in subjects who reported more UVB exposure, supplemented vitamin D orally and those who declared more physical activity.

21% of subjects had elevated serum PTH concentration (i.e. > 62 pg/mL); mean parathormone was 48.6 ± 25.2 pg/mL. A linear correlation was found between the logarithm of PTH and logarithm of 25(OH)D concentrations ($r = -0.21$, $p < 0.001$).

Conclusions: Results obtained here demonstrate the necessity of implementing a monitoring and prophylaxis programme of vitamin D deficiency in Poland. **(Endokrynol Pol 2014; 65 (2): 105–113)**

Key words: *vitamin D deficiency; calcifediol; parathyroid hormone; sunlight; ultraviolet rays; overweight; adult*

Streszczenie

Wstęp: Witamina D pełni ważną funkcję w regulacji gospodarki wapniowo-fosforanowej, ma bezpośredni wpływ na układ mięśniowo-szkieletowy, a także oddziałuje na liczne, inne układy organizmu. Niedobór witaminy D i jego negatywny wpływ na stan zdrowia były i są wykazywane na całym świecie. Niewiele jest danych mówiących o stanie zaopatrzenia w witaminę D osób dorosłych z populacji polskiej.

Materiał i metody: Do badania zrekrutowano osoby korzystające z ambulatoryjnych usług zakładu opieki zdrowotnej w Gdańsku, u których oznaczono surowicze stężenia 25(OH)D, parathormonu (PTH), fosfatazy alkalicznej (ALP), wapnia i fosforu. W kwestionariuszu oceniono ekspozycję na UVB, nawyki dietetyczne w zakresie podaży witaminy D i wapnia oraz stan zdrowia. Dane przeanalizowano za pomocą parametrycznych i nieparametrycznych testów statystycznych, logistycznej regresji i ryzyka przypisanego populacji (*population attributable risk*).

Wyniki: Od lutego do połowy kwietnia 2012 roku przebadano 448 dorosłych: 305 kobiet i 143 mężczyzn w wieku 19–86 lat (średnia 46,3 ± 14,9 lat). Średnie stężenie 25-hydroksy-witaminy D wyniosło 14,3 ± 6,6 ng/ml; 84,4% badanych miało niedobór witaminy D (25(OH)D < 20 ng/ml); 13,2% niedostateczne stężenie (20–30 ng/ml), a 2,5% (tj. 11 probantów) prawidłowe stężenie 25(OH)D. Istotnie wyższe stężenia 25(OH)D wykazano dla uczestników, którzy: przyjmowali preparaty witaminy D, mieli większą ekspozycję na promieniowanie UVB (opalanie na słońcu lub w solarium), a także podawali większą aktywność fizyczną. 21% probantów miało podwyższone (> 62 pg/ml) stężenie PTH przy wartości średniej dla wszystkich badanych 48.6 ± 25.2 pg/ml. Stwierdzono liniową zależność między logarytmem parathormonu a logarytmem 25(OH)D ($r = -0.21$, $p < 0,001$).

Wnioski: Otrzymane wyniki wskazują na konieczność opracowania programu monitoringu i profilaktyki hipowitaminozy D w Polsce. **(Endokrynol Pol 2014; 65 (2): 105–113)**

Słowa kluczowe: *niedobór witaminy D; kalcyfediol; parathormon; światło słoneczne; promienie ultrafioletowe; nadwaga; dorosły*

Introduction

Vitamin D is classically recognised as a crucial hormone in the calcium-phosphate metabolism, vital in the formation and preservation of bone structure. However, evidence has been accumulating related to vitamin D's effects on muscle function as well as on numerous other organs, tissues and systems [1, 2].

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Insufficient levels of vitamin D have been observed in populations of many countries, mainly due to insufficient exposure to sunlight and inadequate supplementation [1, 3, 4, 6]. Associations have also been reported between low serum vitamin D concentrations and an increased risk of numerous diseases, ranging from autoimmune, infectious, cardio-metabolic to neoplasmatic [1, 2, 5–7]. Research concerning the effects of vitamin D on both skeletal and non-skeletal health is ongoing.

Vitamin D is a general name for several compounds categorised as secosteroids [8], however, two substances, cholecalciferol and ergocalciferol, are the specific compounds to which this term refers commonly [9]. The majority of vitamin D present in the human body is produced in the skin exposed to ultraviolet (type B, UVB) radiation (vitamin D3, cholecalciferol) while a smaller portion is obtained orally (vitamin D2, ergocalciferol) [9]. A number of factors influence the endogenous synthesis of vitamin D, among them (as in the review paper by Engelsen): solar zenith angle, ozone layer, altitude, time spent outdoors, body area exposed to sun, as well as clothing and use of sunscreens [10].

It is universally accepted that vitamin D status is reflected by the concentration of serum 25-hydroxyvitamin D, 25(OH)D, calcifediol, i.e. the most abundant circulating form of the vitamin [11]. There is, however, no consensus as to the reference values determining 25(OH)D deficiency and sufficiency, in particular considering vitamin D's nonskeletal effects [1, 2, 5, 13]. The proposed cut-off values — accepted by most authors - of sufficiency (25(OH)D > 30 ng/mL), insufficiency (20–30 ng/mL) and deficiency (< 20 ng/mL) have been applied in our study (Table I).

Data reflecting vitamin D status among Polish adults is insufficient. So far, the vast majority of studies have involved osteoporotic and elderly persons [14–17]. Also, to the best of our knowledge, the numbers studied in each study have not exceeded 300 subjects apart from the PolSenior project (and perhaps the study by Hoszowski et al.) [14, 15].

Table I. *Proposed 25(OH)D concentration ranges in adults*
Tabela I. *Proponowane zakresy stężeń 25(OH)D u dorosłych*

25(OH)D [ng/mL]	Clinical situation
≤ 10	Severe deficiency
10–20	Deficiency
20–30	Insufficiency
30–80	Sufficiency
≥ 150	Toxicity

In this study, we aimed at determining serum calcium-phosphate metabolism parameters, behavioural factors influencing vitamin D concentration, and health status of adults from the Pomeranian province during months of low UVB exposure.

Material and methods

The consent of the independent bioethics committee of the Medical University of Gdańsk was obtained to perform this study.

The project was performed from February to mid-April 2012 to ascertain the lack of effective skin vitamin D synthesis during these months.

Study participants

Persons aged 18 and older who agreed to participate in the study were recruited. The participants were individuals who presented for vocational medicine visits, physician's appointments and additional examinations in an outpatient clinic Endomed Medical Diagnostic Centre in Gdansk. There were no exclusion criteria. Each study participant received written information concerning the examinations and signed a consent form for them.

Questionnaire examination

Each study participant filled out a questionnaire concerning social characteristics, dietary habits related to vitamin D and calcium intake, exposure to UVB (from suntanning and sunbed tanning), health status, chronic medication and diseases. The questionnaire involved semi-quantitative and qualitative assessment of these factors.

In particular, the consumption frequency of vitamin D-rich foods was asked (fish, eggs); symptoms (muscle pain and weakness) and diseases associated with or leading to 25(OH)D deficiency were investigated.

Laboratory examinations

Blood was drawn from participants and spun for ten minutes at 3,500 g after which plasma was transferred to a separate tube and subsequently frozen at –20°C. After transport of tubes in dry ice to the Central Diagnostic Laboratory of the Medical University of Gdańsk, serum concentrations of 25-hydroxyvitamin D, 25(OH)D, and parathyroid hormone (PTH) were determined using a chemiluminescence method (CLIA) with dedicated assays in, respectively, a DiaSorin® Liaison® analyser ("25OH Vitamin D TOTAL" assay) and a Siemens IMMULITE® 1000 Immunoassay System. Alkaline phosphatase (ALP), calcium (Ca), phosphorus (P) concentrations were determined spectrophotometrically in an Abbott Architect® analyser.

Statistical analysis

Statistical evaluation was performed using STATISTICA 10, StatsDirect version 2.7.2 (StatsDirect Ltd), R (http://www.r-project.org/) and Stata (StataCorp LP) software.

25(OH)D concentration values did not follow a Gaussian distribution (as verified in Kolmogorov-Smirnov test with Lilliefors correction). Therefore, either a Box-Cox transformation was applied before performing comparisons with t-test, or non-parametric tests were used (depending on group size and expected values, chi-square with or without Yates correction, V-square or Fisher's exact test) as has been indicated in legends.

Uni- and multivariate analyses were performed to determine the probability of 25(OH)D concentration exceeding 20 ng/mL in the presence and/or absence of studied factor(s). Comparisons in univariate analysis for which the test power (1-β) exceeded 95% were considered significant. Multivariate analysis was performed by logistic regression (Quasi-Newton estimation). Confidence intervals (CI) for odds ratios were established at 95%. Population attributable risk (PAR) was calculated.

Significance level was set at 0.05.

Results

448 adults were examined from February to mid-April 2012, 305 women and 143 men, aged 19 to 86 (mean 46.3 ± 14.5 years) (Table II). The vast majority of participants inhabited a highly urbanised area of the Pomeranian province in the north of Poland, i.e. the Tri-city (Gdańsk, Sopot and Gdynia) and its suburbs.

Mean 25-hydroxyvitamin D concentration was 14.3 ± 6.6 ng/mL and median 12.9 ng/mL. 84.4% of subjects were vitamin D deficient (25(OH)D < 20 ng/mL) and 13.2% insufficient (20–30 ng/mL) (Fig. 1, Table II). Only 2.5% of subjects had 25(OH)D concentrations above 30 ng/mL (sufficiency).

According to the proposed 25(OH)D concentration ranges, four study participants subgroups were investigated. The vitamin D sufficiency (25(OH)D > 30 ng/mL) group (group 4) consisted solely of women with a median age of 38 years (mean 39.2) which was significantly lower than the age of participants from the three other groups (as demonstrated in Table II). Furthermore, the median BMI (23.44 kg/m^2) for these 11 women differed significantly from that of other groups.

Subjects were also divided into three age groups: 19–39, 40–59, and 60 years and older. Significant differences in 25-hydroxyvitamin D concentrations were found between:

— males and females aged 19-39 (mean concentrations: 15.3 *v.* 13.3 ng/mL, $p < 0.05$);
— males aged 19-39 and eldest (13.3 *v.* 15.9 ng/mL, $p < 0.05$);
— youngest and eldest females (15.3 *v.* 13 ng/mL, $p < 0.05$) as shown in Table III.

There was a highly significant difference in mean BMI values between genders in the under-40 and over-60 age group (22.4 *v.* 25.9, and 29.6 *v.* 25.6 kg/m^2 respectively) (Table III).

Further, significantly higher 25(OH)D concentrations were found in the following study participants (versus respective counterparts): subjects supplementing vitamin D, those who reported more recent and more frequent sun and sunbed tanning, and more physical activity (Figs. 2A–F). Importantly, mean 25-hydroxyvitamin D concentration of participants who declared oral vitamin D supplementation was 16.1 ng/mL which indicates deficiency in the majority of these subjects (86 out of 119) (Fig. 2A). Overall, declared frequent or recent episodes of UVB exposure have had a major impact on the 25(OH)D status. Strongest statistical differences were found among subjects who claimed to have (sun and/or sunbed) tanned at least once weekly or after 1 October 2011 (Figs. 2B–E).

Interestingly, fewer infections were stated by participants with higher vitamin D concentrations (Fig. 2G).

The influence of examined factors on the probability of 25(OH)D exceeding 20 ng/mL was investigated in uni- and multivariate analysis (Table IV). Factors were arranged according to the strength of their prediction value. In univariate analysis, UVB exposure-related and vitamin D supplementation factors were positive predictors for the assumed 25-hydroxyvitamin D concentration. Multivariant analysis showed that only suntanning frequency, vitamin D supplementation and the date of last sunbed tanning were statistically significant factors that were associated with the probability of 25(OH)D being higher than 20 ng/mL.

Interestingly, 21% of subjects had elevated PTH concentration, i.e. > 62 pg/mL, while mean parathyroid hormone was 48.6 ± 25.2 pg/mL. A linear correlation was found between the logarithm of PTH and logarithm of 25(OH)D concentrations ($r = –0.21$, $p < 0.001$) (Fig. 3).

Discussion

The 25-hydroxyvitamin D concentrations found here demonstrate its deficiency in the vast majority of subjects. Similar data has been acquired in other studies involving white adults during months of low UVB exposure.

In Webb et al.'s work, 109 ambulatory participants (85 female, 24 male, mean age 44 years, interquartile range, IQR, for age: 34–51, median BMI 24.9 kg/m^2, IQR 22.7–28), living in the Greater Manchester region

Table II. *Demographic, calcium-phosphate metabolism parameters, and chosen behavioural data according to 25(OH)D concentration range means with* **SDs** *or percentages and no of subjects*

Tabela II. *Dane demograficzne, wykładniki gospodarki wapniowo-fosforanowej i wybrane dane behawioralne w zależności od zakresów stężeń 25(OH)D średnie z OS albo odsetki i liczba badanych*

Group (according to 25(OH) D [ng/mL])	All subjects	Group 1 (< 10)	Group 2 (10–20)	Group 3 (20–30)	Group 4 (> 30)	Significance level p
Number of subjects (%)	448 (100%)	121 (27%)	254 (56.7%)	62 (13.8%)	11 (2.5%)	
Age (years)	46.3 (14.5)	46.4 (15)	46 (15)	49.1 (14.3)	39.2 (12.3)	0.04 (gr. 4 v. 3)
BMI [kg/m^2]	25.3 (4.7)	25.7 (5.1)	25.5 (4.7)	25.4 (4.1)	23.4 (4.9)	0.04 (gr. 4 v. 1, 2 and 3)
Calcium-phosphate metabolism parameters						
25(OH)D [ng/mL]	14.3 (6.57)	7.88 (1.65)	13.96 (2.67)	24.44 (2.99)	35.64 (4.69)	< 0.0001
PTH [pg/mL]	48.6 (25.2)	55.24 (30.79)	47.29 (22.79)	40.82 (18.34)	43.60 (25.28)	0.004 (gr. 1 v. 3)
Calcium [mg/dL]	9.56 (0.44)	9.52 (0.54)	9.56 (0.46)	9.50 (0.53)	9.41 (0.35)	NS
Phosphorous [mg/dL]	3.49 (0.62)	3.51 (0.56)	3.48 (0.67)	3.43 (0.56)	3.58 (0.32)	NS
ALP [IU/L]	67.6 (23.8)	68.20 (22.45)	67.04 (25.32)	67.79 (20.32)	59.00 (16.13)	NS
Vitamin D supplementation						
Vitamin D supplementation	26.6% [119]	24.8% [30]	22% [56]	43.5% [27]	54.5% [6]	0.001
Daily vitamin D supplementation	19.2% [86]	12.4% [15]	16.5% [42]	40.3% [25]	36.3% [4]	0.001
UVB exposure						
Suntanning ≥ 1 weekly	11.4% [51]	5% [6]	9.4% [24]	27.4% [17]	36.4% [4]	< 0.0001
Suntanning after 1st October	8.3% [37]	3.3% [4]	6.3% [16]	21% [13]	36.4% [4]	< 0.0001
Sunbed tanning ≥ 1 monthly	9.8% [44]	3.3% [4]	6.7% [17]	29% [18]	45.5% [5]	< 0.0001
Sunbed tanning after 1st October	4.2% [19]	0% [0]	2% [5]	16.1% [10]	36.4% [4]	< 0.0001
Sunscreen usage	55.1% [247]	57% [69]	53.5% [136]	58.1% [36]	54.5% [6]	NS
Lifestyle						
Physical activity ≥ 1 weekly	31.3% [140]	23.1% [28]	30.7% [78]	41.9% [26]	72.7% [8]	0.008
Non-smokers	68.5% [307]	71.1% [86]	66.9% [170]	69.4% [43]	72.7% [8]	NS

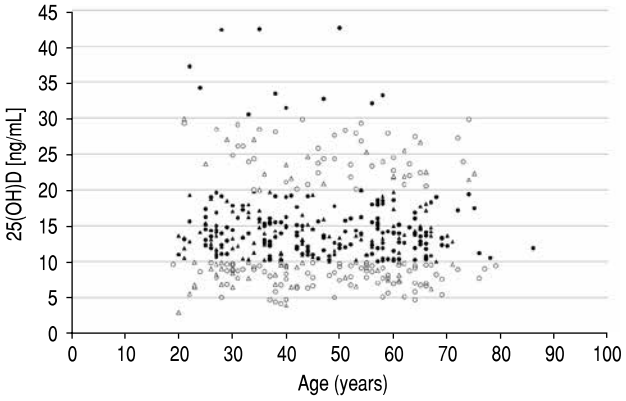
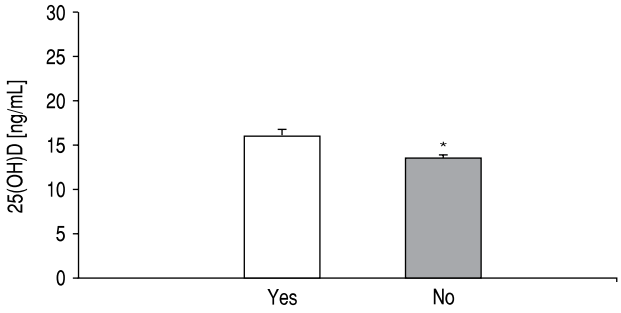
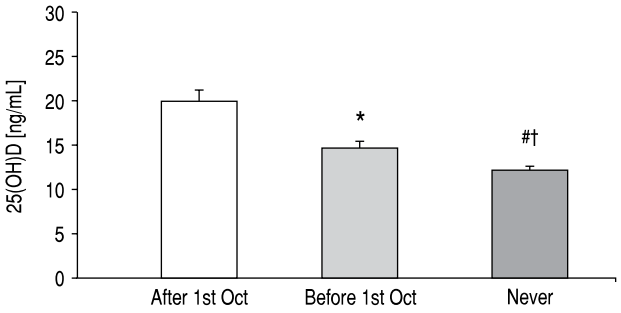


Figure 1. *25(OH)D concentration versus age and sex. "O" and "Δ" point contours refer to women and men res pectively. Point fillings differentiate four vitamin D concentration ranges (< 10, 10–20, 20–30, > 30 ng/mL)*

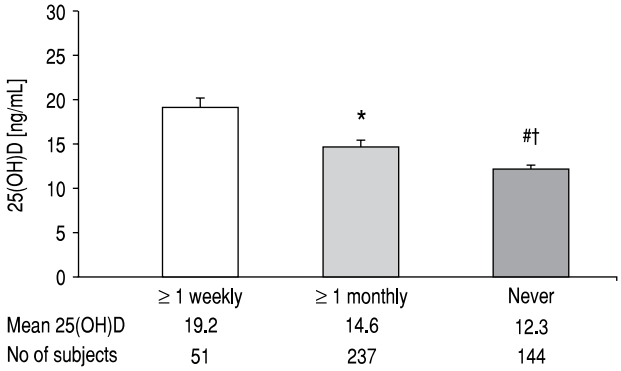
Rycina 1. *Stężenie 25(OH)D w zależności od wieku i płci. Punkty „O" i „Δ" oznaczają odpowiednio kobiety i mężczyzn. Wypełnienia punktów różnicują 4 zakresy stężeń 25(OH)D (< 10, 10–20, 20–30, >30 ng/ml)*



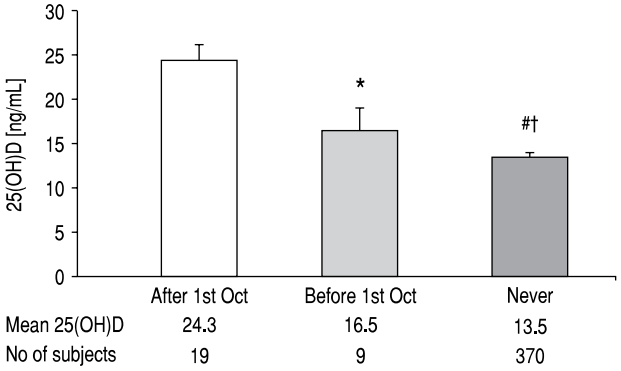
A. *25(OH)D concentration and vitamin D supplementation; *p < 0.005*



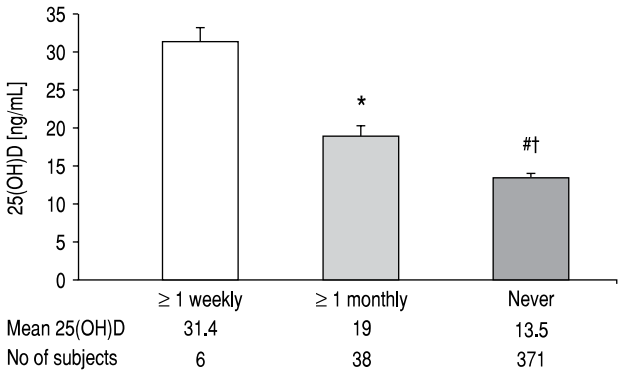
B. *25(OH)D concentration and date of suntanning. In the questionnaire, the date of last suntanning was asked. "1st October" refers to 1 October 2011. *p < 10^{-5}; #p < 10^{-6}; †p < 0.005 ("never" v. "after 1st Oct")*



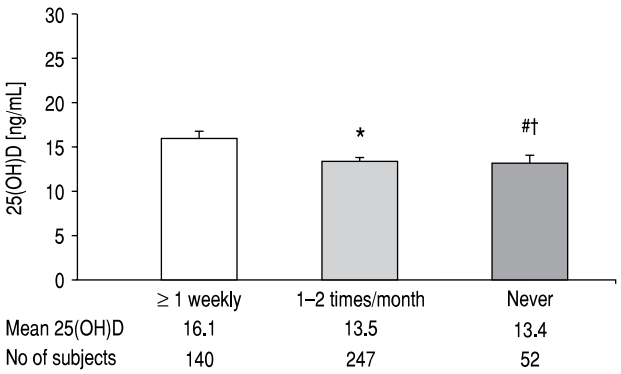
C. ***25**(OH)D concentration and suntanning frequency; *p < 0.0005, #p < 10^{-6}, †p < 0.0005 ("never" v. "≥ 1 monthly")*



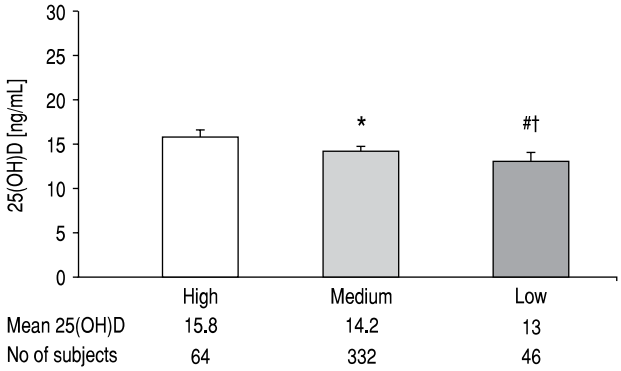
D. *25(OH)D concentration and date of sunbed tanning. In the questionnaire, the date of last sunbed tanning was asked. "1st October" refers to 1 October 2011. ; *p < 0.05; #p < 10^{-12}*



E. *25(OH)D concentration and sunbed tanning frequency; *p < 0.0005, #p < 10^{-11}, †p < 10^{-6} ("never" v. "≥ 1 monthly")*



F. *25(OH)D concentration and frequency of physical activity; *p < 0.0005, #p < 10^{-11}, †p < 10^{-6} ("never" v. "≥ 1 weekly")*



G. *25(OH)D concentration and infection susceptibility; Declared "low" infection susceptibility was no infections from November 2011, "high" — at least one infection per month; *p < 0.05 ("low" v. "high")*

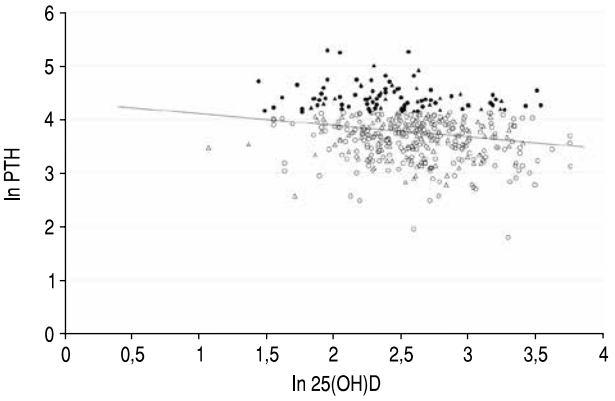
Figure 2A–G. *25(OH)D and chosen behavioural factors. t-Student test was used to compare 25(OH)D between groups after applying Box-Cox transformation of 25(OH)D concentration values*

Rycina 2A–G. *Stężenie 25(OH)D w zależności od wybranych czynników behawioralnych. Do porównań między grupami użyto testu t Studenta po zastosowaniu transformacji Box-Coxa w odniesieniu do stężeń 25(OH)D. Wykresy przedstawiają średnie, słupki błędów — standardowe błędy średniej*

Table III. *Chosen data for all study participants and according to age-group and gender*
Tabela III. *Wybrane dane dla ogółu badanych i w zależności od grupy wiekowej i płci*

Sex	Both	F	M	F	M	F	M	F	M
Age group (years)	**–**	**–**	**–**	**19–39**		**40–59**		**60–86**	
Number of subjects	448	305	143	100	70	127	43	78	30
Age (years)	46.3 (14.9)	48.1 (14.5)	42.8 (15.1)	31.2 (5.2)	29.8 (5.7)	50.2 (6.2)	48.6 (6.1)	66 (5.3)	64.8 (4.3)
25(OH)D [ng/mL]	14.3 (6.6)	14.5 (7.1)	13.9 (5.3)	15.3 (7.9)	13.3 (5.2)*	14.7 (7.2)	13.4 (5)	13 (5.6)†	15.9 (5.4)‡ #
PTH [pg/mL]	48.6 (25.2)	49.3 (26.5)	44.1 (22)	48.7 (20.6)	56.9 (18.1)	46.9 (26.6)	42.1 (27.5)	52.6 (31.4)	50 (19.4)
BMI [kg/m^2]	25.8 (4.7)	24.7 (4.5)	27.3 (4.8)	22.4 (3.7)	25.9 (3.6)**	25.4 (4.6)	28 (6)	26.5 (4.1)	29.6 (3.8)##
Vit. D supplementation (% subjects)	26.7	28.5	22.4	27	15.7	26	27.9	35.6	30
Daily vit. D supplementation (% subjects)	19.2	23	11.2	22	7.1	17.3	16.3	33.3	13.3
≥ 1 weekly vit. D supplementation (% subjects)	11.1	8.2	14.7	13	7.1	8.7	16.3	6.4	30
Suntanning (before or after 1st Oct) (% subjects)	34.8	40.7	22.4	45	14.3	42.5	30.2	47.2	30
Physical activity (% subjects)	86.4	85.9	87.4	90	91.4	81.9	83.7	87.2	83.3

"F" and "M" refer to women and men respectively. Age, 25(OH)D, PTH and BMI data are presented as "mean (standard deviation)". Percentages of vitamin D supplementation, suntanning and physical activity were obtained by dividing subjects' positive answers (i.e. "yes" with respect to vitamin D supplementation; suntanning date as opposed to "never"; physical activity frequency of at least once monthly *v.* "never") by the number of subjects in a given group. T student test was used to compare 25(OH)D and BMI values between groups after applying Box-Cox transformation. Significance levels are as follows: * 25(OH)D in women *v.* men aged < 40 years: $p < 0.05$; ** BMI in women *v.* men in the < 40 years age group: $p < 10^{-8}$; # 25(OH)D in women *v.* men in the over ≥ 60 years age group: $p < 0.05$; ## BMI in women *v.* men in the ≥ 60 years age group: $p < 0.001$; † 25(OH)D in women aged < 40 years *v.* women ≥ 60 years: $p < 0.05$; ‡ 25(OH)D in men aged < 40 years *v.* s men aged ≥ 60 years: $p < 0.05$



PTH — concentrations in pg/mL; 25(OH)D — concentrations in ng/mL; ln — natural logarithm. "O" and "Δ" point contours denote women and men respectively. Black point filling denotes subjects with PTH concentration higher than 62 ng/mL, i.e. upper reference limit (ln62 = 4.13)

Figure 3. *Correlation between logarithms of 25(OH)D and parathyroid hormone. Spearman rank correlation coefficient r = –0.21, p < 0.001*

Rycina 3. *Korelacja między logarytmami stężeń witaminy D i parathormonu. Współczynnik korelacji rang Spearmana r = –0,21, p < 0,001*

of the UK, (latitude 53.48° N; Gdańsk lies at 54.35° N) had lowest annual 25(OH)D concentrations in February: 18.3 ± 8.7 ng/mL, which is a comparable result to the one obtained here [18]. Apart from different study groups (elderly women were excluded by Webb et al.) vitamin D fortification may be one of the reasons for the difference in recorded concentrations.

In Poland, a recent study included 132 citizens of Krakow (population about 760,000, 50.06°N): 82 females and 50 males aged 41–81 years (median 62 years) examined during "winter" [17]. Median 25(OH)D concentration was 16.7 ng/mL and vitamin D deficiency was recorded in 90.2% of study participants.

In another study, mean 25-hydroxyvitamin D concentration was 13.5 ng/mL for 274 women from Warsaw, aged 60-90 (mean 69.1 ± 4.7 years) and examined during "winter" [19].

Data presented here shows the vital effect of UVB exposure on vitamin D status. Despite insufficient UV radiation for cutaneous calcidiol synthesis during winter in moderate geographic latitude regions [10, 20], the declared suntanning frequency may reflect the tissue

stores of 25(OH)D acquired during earlier months [9]. Based on the results obtained here, it seems sunbed tanning provides an effective vitamin D synthesis source (the date of last sunbed usage was shown to be significant in multivariate analysis).

Similarly to our results, previous studies have also reported correlations between 25(OH)D and PTH concentrations. In the above-mentioned works, weak correlations were found between plasma concentrations of the two hormones: correlation coefficients were –0.13 and –0.23 ($p < 0.007$) in papers by (respectively) Napiórkowska et al., and Trofimiuk-Muldner, Kieć-Klimczak and Hubalewska-Dydejczyk [17, 19]. An analogous trend was recorded by Pilz et al. (subjects were hypertensive adult patients examined not only in winter at 47° north latitude): in their work the discussed coefficient was –0.17 ($p = 0.07$) [21]. As Thacher and Clarke state in their review paper: "In adults, multiple cross-sectional examinations of the relationship between serum PTH and 25(OH) levels demonstrate a plateau in suppression of PTH when 25(OH)D level reaches approximately 30 ng/mL." [2].

Also, factors associated here with higher 25(OH) D concentrations such as UVB exposure (both natural and artificial) as well as physical exercise have been well-established [2, 22–24]. Concerning the incidence of infections, further studies are necessary to ascertain the consequences of given vitamin D status with susceptibility to them.

In respect of age group and gender comparisons, several significant differences in 25(OH)D levels were found.

Mean 25-hydroxyvitamin D concentration was lower in young (aged < 40 years) men compared to women, while their BMI was significantly higher. The latter result is most probably one of the explanations of the former one, since adiposity "is a risk factor for low 25(OH)D" [22]. However, the reported sun tanning date probably had a greater influence on this difference between the genders: 14.3% of men and 45% of women declared to have tanned. Further, a higher percentage of females reported vitamin D supplementation (27% *v.* 15.7%).

Young males recruited here also had lower 25(OH)D concentration than men aged 60+. This result contrasts with the generally acknowledged notion that older age is a risk factor for vitamin D deficiency, mainly due to decreased cutaneous vitamin D synthesis [24]. An example of this are women examined in this study (young females versus elderly). The explanation might be that older male participants use more vitamin D supplementation and actual sun exposure is significantly higher in this group, while young males spend little time outside.

Finally, the difference between 25(OH)D concentrations in elderly men and women found here has been previously reported [23]. In our study, men had higher 25(OH)D levels despite higher mean BMI values (Table III). As suggested by Janssen et al., possibly hormonal changes due to menopause and/or actual time spent outdoors by men (despite similar 'suntanning' declarations) explain these observations [23].

Results acquired here are a vital input to the current state of knowledge concerning vitamin D status in Poland among non-elderly (only 56 participants were 65 and older) and non-osteoporotic adults (33 subjects declared this diagnosis in the questionnaire, 22 of them were women aged 60 and over).

However, several limitations need to be considered when interpreting the results. Firstly, the participants in this study by no means represent a model of the Polish adult population: almost all live in the agglomeration area of Tri-city in Poland (73.9% in either Gdańsk, population ca. 456,000, Gdynia, 250,000 inhabitants, or Sopot, 40,000), 68.1% were female, 42.2% were aged 19-39, all used the services of a private outpatient clinic. Also, it is unknown whether participants were suffering from diseases apart from those mentioned in the questionnaire (past fractures, osteoporosis, diabetes mellitus, multiple sclerosis, rheumatoid arthritis, asthma, sarcoidosis, Crohn's disease, depression, psoriasis, cancers, "liver disease", irritable bowel syndrome and "digestive tract diseases").

Secondly, the methodology of acquiring information concerning dietary vitamin D and calcium intake was semi-quantitative only, i.e. the frequency of a particular food type was asked per week or month. It was, therefore, impossible to estimate the ingested vitamin D amount, although, since foods in Poland are not fortified with the vitamin, there is little chance that it could be significant. The same disadvantage of the questionnaire holds for vitamin D supplementation: no doses were obtained.

Thirdly, renal function was not evaluated concomitantly to laboratory examinations, which makes it impossible to exclude secondary hyperparathyroidism due to renal disease for subjects with increased PTH concentration. On the other hand, only 18 study participants reported to have and/or to have had "kidney disease" (only one of these had increased PTH concentration), while 428 responded negatively to this question. This makes it highly unlikely kidney disease caused elevated PTH levels in our participants.

There are also a number of vital, strong points of the study. Importantly, 326 of all 448 subjects assessed their general health as "very good" (98 persons) and "fair" (226) rather than "satisfactory" (100) or "bad" (8). Despite this positive (subjective) assessment, most

Table IV. *Chosen factors' influence on the probability of serum 25(OH)D concentration higher than 20 ng/mL*

Tabela IV. *Wpływ wybranych czynników na prawdopodobieństwo przekroczenia stężenia surowiczego 25(OH)D wartości 20 ng/ml*

	Univariate	Multivariate	Odds ratio (± 95% CI)	Population attributable risk**
1. Suntanning date (never; before 1st Oct; after 1st Oct)	< 0,0001	0,8741907*	1,08 (0,43–2,66)	52.5% (31.6–73.3%) [after 1st Oct]
2. Suntanning frequency (never; ≥ once monthly and ≥ once weekly)	< 0,0001	< 0,0001	3,09 (1,8–5,31)	57.9% (37.5–78.3%) [≥ once weekly]
3. Vitamin D supplementation frequency (never; ≥ once monthly; ≥ once weekly; daily)	< 0,0001	0,2232306*	1,19 (0,9–1,57)	39.7% (23–56.5%) [daily]
4. Sunbed tanning frequency (never; ≥ once weekly; ≥ once monthly)	< 0,0001	0,574018*	1,54 (0,34–7,06)	30.1% (17.9–42.4%) [yes]
5. Vitamin D supplementation (yes; no)	< 0,0001	< 0,0001	4,57 (2,34–8,94)	32.1% (15.5–48.6%)
6. Sunbed tanning date (never; before; after 1st Oct)	< 0,0001	< 0,0001	1,45 (1,27–1,67)	30.1% (17.9–42.4%) [yes]
7. Frequency of egg consumption (never/≥ once monthly/≥ once weekly)	0,05	0,2729527*	1,48 (0,73–3)	50.6% (–50.3–151.5%) [≥ once weekly]

*p value was provided on its removal from the logistic regression model; ***v.* absence of a given factor

The influence of several tested factors did not reach statistical significance, therefore, these factors were excluded: a) herring, salmon and eel consumption frequency; b) mackerel, cod and other fish consumption frequency; c) liver oil consumption; d) erythema after suntanning; e) BMI; f) sunscreen usage

of them were vitamin D deficient. Data such as this presented here is scarce for the Polish adult population.

Further, results indicate insufficient vitamin D supplementation, since the majority of those who stated it were 25(OH)D deficient or insufficient (their mean 25(OH)D was 16.1 ± 7.9 ng/mL).

Also, based on our findings, it is clear vitamin D deficiency must be considered a viable cause of elevated parathyroid hormone concentrations.

Finally, it might be possible to extrapolate the acquired results to other regions of Poland. While the participants enrolled here lived in the Pomeranian province (54.2° northern latitude), the blood sample collection was performed during months of insignificant skin vitamin D production not only in northern Poland but also in other areas of the country. Such an assumption can be drawn from the results of the study by Webb, Kline and Holick (1988) in which sunlight exposure was insufficient for vitamin D synthesis both in Boston (42.2°N) and Edmonton (52°N) from October to April [20]. On the other hand, in another study, a six degree latitude difference (Scotland, 51° and 57°) was associated with significant 25(OH)D concentration differences both in winter and summer [25].

Conclusions

The presented results demonstrate widespread vitamin D deficiency among predominantly urban adults during winter months in the Pomeranian province in Poland, inappropriate vitamin D supplementation, and the importance of 25(OH)D status assessment in the differential diagnosis of hyperparathyroidism.

A monitoring and prophylaxis programme of hypovitaminosis D in Poland should be implemented to ensure all potential health benefits of optimal vitamin D status.

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