ORIGINAL ARTICLE

Vitamin D status in Poland

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KEY WORDS

vitamin D, vitamin D deficiency, 25-hydroxyvitamin D

ABSTRACT

INTRODUCTION Epidemiological data on vitamin D status in the Polish population are limited.
OBJECTIVES The aim of the study was to evaluate the vitamin D status in a representative group of adult inhabitants of 22 Polish cities, based on the analysis of serum 25-hydroxyvitamin D [25(OH)D] levels.
PATIENTS AND METHODS This cross-sectional study included a total of 5775 adult volunteers (4464 women; 1311 men; mean age, 54.0 ±15.9 years; range, 15.6–89.8 years), who were enrolled and examined through late winter and spring 2014. Serum concentrations of 25(OH)D were determined using the Liaison XL system (DiaSorin; CLIA method). Demographic and anthropometric data were also analyzed.
RESULTS The mean 25(OH)D concentration in the studied population was 18.0 ±9.6 ng/ml; 65.8% of the patients had 25(OH)D levels of less than 20 ng/ml; 24.1% had suboptimal levels of 20 to 30 ng/ml; and only 9.1% demonstrated the optimal levels of 30 to 50 ng/ml. In 89.9% of the studied population, 25(OH)D levels of less than 30 ng/ml were found. Obesity, defined as body mass index (BMI) over 30 kg/m^2, was associated with lower 25(OH)D levels compared with normal weight (15.8 ±8.5 vs 18.5 ±9.7 ng/ml; P <0.0001). Lower 25(OH)D levels were observed in men, younger individuals, and individuals with excess body weight and higher BMI.
CONCLUSIONS The results of our study, which involved the most representative sample size of Polish adults, support the previously reported data on vitamin D status. The levels of 25(OH)D determined for adults in our study demonstrate that the majority of the Polish population is vitamin D deficient, at least during winter and spring, and that preventive or interventional strategies must be considered to improve the vitamin D status in Poland.

INTRODUCTION Vitamin D is an important prohormone that can be synthesized by the skin exposed to sunlight (UVB) or ingested with food. However, low outdoor activity, sun protection, and low vitamin D content of staple foods reduce the significance of sun and diet as natural sources for efficacy of vitamin D metabolism and related health effects. In consequence, evidence from various populations highlighted vitamin D deficiency as a public health problem with high prevalence.[1-17] The prevalence of vitamin D deficiency depends on diagnostic thresholds defining vitamin D status that is determined by total serum 25(OH)D levels,[18] and the recommended levels of 25(OH)D are still an issue of debate.[19-22] Currently, it is accepted that maintaining serum 25(OH)D at a level of 20 ng/ml (50 nmol/l) or above is beneficial at least for bone health and calcium homeostasis.[23,24] Levels required for noncalcemic functions of vitamin D seem to be higher (30–50 ng/ml; 75–125 nmol/l),[25] but still are considered uncertain. Some authors, however, argue that even for proper bone mineralization, levels higher than 30 ng/ml (75 nmol/l) are necessary.[26] Indisputably, low 25(OH)D levels (below 20 ng/ml) are common and were reported worldwide,[1-7] and this is a drawback because epidemiological data underlined an association between vitamin D deficit and a higher risk for chronic conditions and multimorbidity, including musculoskeletal disorders, cancer, autoimmune diseases, cardiovascular disease, diabetes, and infectious diseases.[1,3,27-30]

One of the countries with limited data on vitamin D status is Poland (49–54°N; Central Europe). Results of studies carried out in our country indicated that the problem of vitamin D deficiency considerably affects the Polish population. In a study of 448 adult residents of urban areas

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living in the northern part of Poland (mean age, 46.3 ±14.9 years; range, 19–86 years), the mean 25(OH)D level was 14.3 ±6.6 ng/ml.[31] As many as 84% of the subjects revealed the levels of less than 20 ng/ml; 13%, of 20 to 30 ng/ml; and only 2.5%, of more than 30 ng/ml.[31] Still, epidemiological data focused on 25(OH)D levels in the Polish population should be regarded as unsatisfactory. In addition, the potential health benefits of vitamin D sufficiency remain unknown in our population; however, the problem of vitamin D deficiency has been recently highlighted in Polish patients suffering from multiple sclerosis,[32] systemic lupus erythematosus,[33] metabolic syndrome,[34] primary hypertension,[35] or type 1 diabetes.[36] Moreover, the distribution of 25(OH)D levels related to age, sex, place of residence, and anthropometric characteristics has not yet been investigated. The aim of this cross-sectional study was to determine the current vitamin D status in a representative sample of men and women living in the urban areas of various regions of Poland, based on an assessment of the serum 25(OH)D level.

PATIENTS AND METHODS

Study group The group consisted of 5775 adult volunteers at a mean age of 54.0 ±15.9 years (range, 15.5–89.8 years), including 4464 women (mean age, 54.2 ±15.5 years; range, 15.6–89.8 years) and 1311 men (mean age, 53.1 ±17.1 years; range, 15.5–89.7 years). Information about possibilities to participate in this program was published in the press, radio, and television on the local and national levels, as well as in the Internet. From February 14 to March 1, and then from April 28 to May 15, 2014 blood samples were taken in 22 Polish cities from patients who volunteered for the study. According to the advertisements published in the media, the main purpose of this study was to allow adults living in Poland to perform the free-of-charge determination of vitamin D status, combined with education, that is, information on the physiological role of vitamin D, the essence of vitamin D action on human body, the reasons leading to vitamin D deficiency, possible health consequences of vitamin D deficiency, as well as recent guidelines for supplementation. In addition, each participant of this project received complete information about the test result and its interpretation. The study was open for all volunteers, there were no exclusion criteria. The study was conducted in order of receipt of volunteers, and the only limitation was the number of available test kits for the assessment of 25(OH)D levels. Our survey was based on a voluntary, informed consent for the procedure and the anonymity of the participants; therefore, it did not pose any ethical dilemmas.

Methods

Blood samples One-time donation of blood from volunteers registered in this study was carried out in the public and private health care centers, with the participation of nurses and the physician on duty. Blood samples collected from the participants were immediately sent to the local medical laboratory in a given city; however, all laboratories were equipped with the same diagnostic equipment. In addition to blood sampling, during the patient's visit trained nurses measured body height and weight with standard calibrated equipment with accuracy of up to 1 cm and 0.5 kg, respectively. Body mass index (BMI; kg/m^2) was calculated using a standard formula.

Laboratory measurements Serum 25(OH)D levels were determined using diagnostic system Liaison XL DiaSorin (CLIA method; DiaSorin, Saluggia, Italy). The "DiaSorin LIAISON® 25 OH Vitamin D TOTAL Assay" enabled determination of the total 25(OH)D (25-hydroxyvitamin D2 and 25-hydroxyvitamin D_3) in the range of 4.0 to 150.0 ng/ml. As declared by the manufacturer, a repeatability of the method expressed as % coefficient of variation (%CV) value was less than 7.0%, and the reproducibility expressed as %CV was less than 12.0%. Unfortunately, cross-calibration techniques between laboratories in different cities were not performed; however, the methodology used in this study was a uniform technique that meets the requirements of good laboratory practice. The data were analyzed according to the following 25(OH)D ranges: 1) potentially toxic concentrations of 25(OH)D levels: >100 ng/ml; 2) a high concentration of 25(OH)D: 50–100 ng/ml; 3) the optimal concentration of 25(OH)D: 30–50 ng/ml; 4) the suboptimal concentration of 25(OH)D: 20–30 ng/ml; 5) vitamin D deficiency: <20 ng/ml; and severe vitamin D deficiency: <10 ng/ml.

Statistical analysis The StatSoft STATISTICA software was used for all analyses (v.10.0; StatSoft Inc., Tulsa, Oklahoma, United States). Continuous variables were expressed as mean ± SD, median and minimum–maximum values. The significance of difference in the prevalence of 25(OH)D level ranges between sex groups was assessed using the 2-sample Kolmogorov–Smirnov test. The Kruskall–Wallis and Mann–Whitney tests were used to compare 25(OH)D levels between the subgroups. The Bonferroni correction was applied in cases of multiple comparisons. The Spearman's rank correlation coefficient was calculated to evaluate correlations between 25(OH)D levels and anthropometric variables. For all tests, a P value of less than 0.05 were considered statistically significant.

RESULTS

Characteristics of the study group General characteristics of the study group are shown in TABLE 1. Significant differences between 25(OH)D levels were noted when blood samples taken during late winter and spring were compared. In late winter, mean and median 25(OH)D values of 17.7 ±10.1 ng/ml and 15.9 ng/ml, respectively (n = 2687), were significantly lower than the values of 18.3 ±9.1 ng/ml and 16.1 ng/ml, respectively (n = 3088), assayed from blood samples taken in the spring season (P <0.0001). The mean 25(OH)D level in the group as a whole (n =

TABLE 1 Basic characteristics of the study population from 22 cities in Poland

Parameter	Women (n = 4464)		Men (n = 1311)		Total (n = 5775)	
	mean (SD)	median (min–max)	mean (SD)	median (min–max)	mean (SD)	median (min–max)
age, y	54.2 (15.5)	56.9 (15.6–89.8)	53.1 (17.1)	55.9 (15.5–89.7)	54.0 (15.9)	56.8 (15.5–89.8)
height, cm	163.1 (6.2)	164.0 (136.0–190.0)	176.2 (7.1)	176.0 (143.0–198.0)	166.0 (8.5)	164.0 (136.0–198.0)
weight, kg	68.5 (12.8)	67.0 (37.0–152.0)	83.9 (13.6)	83.0 (45.0–150.0)	72.0 (14.5)	70.0 (37.0–152.0)
BMI, kg/m^2	25.8 (4.7)	25.3 (15.4–52.6)	27.0 (4.0)	26.7 (15.5–47.9)	26.0 (4.6)	25.7 (15.4–52.6)
25(OH)D, ng/ml	18.2 (9.7)	16.0 (<4.0 to >150.0)	17.5 (9.1)	16.0 (<4.0–82.0)	18.0 (9.6)	16.0 (<4.0 to >150.0)

Abbreviations: BMI, body mass index; 25(OH)D, 25-hydroxyvitamin D

TABLE 2 General and sex-specific proportions of 25-hydroxyvitamin D [25(OH)D] levels in the Polish national registry

25(OH)D level, ng/ml	No. of women	% women	No. of men	% men	Total	% of total
<10	722	16.2	205	15.6	927	16.0
10–20	2172	48.7	702	53.5	2874	49.8
20–30	1101	24.7	291	22.2	1392	24.1
30–50	427	9.6	99	7.5	526	9.1
50–100	39	0.9	14	1.1	53	0.9
>100	3	0.1	0	0.0	3	0.0

5775) was 18.0 ±9.6 ng/ml (median, 16.0 ng/ml). In 3801 volunteers (65.8%), serum 25(OH)D levels were lower than 20 ng/ml. In 1392 participants (24.1%), the levels of 20 to 30 ng/ml were noted, and 526 cases (9.1%) had the levels of 30 to 50 ng/ml. In the group of 53 people (0.9%), 25(OH)D levels were increased (50–100 ng/ml) and 3 persons (2 women from a city of Bydgoszcz and 1 woman from a city of Białystok) revealed potentially toxic levels: 2 cases with 25(OH)D levels exceeding 150 ng/ml and 1 case with a level of 101 ng/ml. Surprisingly, among studied participants, a total number of 927 adults (16.0%) showed 25(OH)D levels lower than 10 ng/ml. In general, 89.9% of 5775 volunteers demonstrated 25(OH)D levels that were lower than 30 ng/ml. TABLE 2 shows a distribution of 25(OH)D by sex, expressed in percentages. There was a significant relationship between a particular category of 25(OH)D levels and sex (2-sample Kolmogorov–Smirnov test; P <0.05).

25(OH)D levels according to a city of residence Serum 25(OH)D levels of volunteers living in 22 cities from different parts of Poland are shown in TABLES 3 and 4. Among 5775 adults participating in this survey, the lowest means and medians were noted in subpopulations from Bydgoszcz and Wrocław, 15.2 ±12.0 ng/ml (median, 12.6 ng/ml) and 15.1 ±6.5 ng/ml (median, 14.0 ng/ml). The highest mean and median values were observed in Białystok (25.8 ±14.0 ng/ml; median, 22.7 ng/ml) and Szczecin (23.5 ±10.1 ng/ml; median, 21.9 ng/ml). Mean 25(OH)D levels adjusted for age and body weight were slightly lower compared with unadjusted values. In 18 of 22 participating cities, unadjusted means and medians for 25(OH)D levels were lower than 20 ng/ml (TABLES 3 and 4). Mean 25(OH)D levels adjusted for age and body weight were lower than 20 ng/ml in 20 cities.

25(OH)D in relation to age, body weight, and body mass index TABLE 5 shows the means of 25(OH)D calculated in respective 10-year age groups. The lowest mean and median 25(OH)D values were noted in the youngest group (15–20 years old) and the highest—in a group aged from 70 to 80 years. The correlation analysis showed a weak, although statistically significant, positive correlation between 25(OH)D levels and age (r = 0.07; P <0.0001; n = 5775), which was observed irrespective of sex (r = 0.06 and r = 0.11, P <0.0001, for women and men, respectively). Weak but significant negative correlations were shown between 25(OH)D levels and body weight as well as BMI. The correlation between 25(OH)D levels and body weight revealed the following coefficient values: r = –0.14 for the whole group (P <0.0001), r = –0.15 for the female subgroup (P <0.0001; n = 4464), and r = –0.10 for the male subgroup (P = 0.00015; n = 1311) . The respective r values of –0.13 (P <0.0001), –0.14 (P <0.0001), and –0.08 (P <0.01) for a correlation between 25(OH)D levels and BMI were calculated for the whole group and for the female and male subgroups, respectively. Furthermore, in the whole study group, 1022 volunteers (17.7%) met a diagnostic criterion of obesity (BMI ≥30 kg/m^2). In the obese subgroup, mean 25(OH)D levels of 15.8 ±8.5 ng/ml (median, 14.0 ng/ml) was significantly lower than the value observed in individuals with BMI of less than 30 kg/m^2 (18.5 ±9.7 ng/ml; median, 16.5 ng/ml; P <0.0001; n = 4753).

DISCUSSION To the best of our knowledge, this study is the first to provide a comprehensive overview of vitamin D status among 5775 adult individuals living in 22 cities in Poland. The study was aimed to evaluate 25(OH)D levels in relation to the geographical region and latitude (city of residence), sex, age, and anthropometric features. The dates of blood sampling were chosen to estimate the scope of vitamin D deficiency during late winter and spring seasons (low season), when the

TABLE 3 Region-specific characteristics of 25-hydroxyvitamin D [25(OH)D] levels in the populations from the national sample representing 11 Polish cities (in an alphabetical order) (continued on the next page)

City	Group / sex	n	Age (SD), y	Height (SD), cm	Weight (SD), kg	BMI (SD), kg/m^2	25(OH)D, ng/ml		
							mean (SD)	median (min–max)	adjusted[a] mean (95% CI)
Białystok	female	270	54.0 (14.6)	163.2 (5.7)	69.4 (12.8)	26.0 (4.6)	25.9 (13.9)	23.2 (<4.0–100.6)	21.9 (21.0–22.8)
	male	80	51.0 (16.1)	177.3 (6.5)	84.5 (12.2)	26.9 (3.9)	25.3 (14.3)	21.9 (7.9–79.0)	21.4 (19.8–22.9)
	all	350	53.3 (15.0)	166.4 (8.3)	72.8 (14.1)	26.2 (4.5)	25.8 (14.0)	22.7 (<4.0–100.6)	21.8 (21.0–22.6)
Bydgoszcz	female	289	49.8 (17.3)	164.1 (6.2)	66.8 (12.8)	24.8 (4.6)	15.3 (13.0)	12.2 (<4.0 to >150.0)	12.1 (11.2–13.0)
	male	108	52.8 (17.8)	175.6 (8.2)	82.8 (13.7)	26.8 (3.9)	15.1 (8.9)	13.6 (4.0–54.3)	12.5 (11.2–13.8)
	all	397	50.6 (17.5)	167.2 (8.5)	71.2 (14.9)	25.4 (4.5)	15.2 (12.0)	12.6 (<4.0 to >150.0)	12.4 (11.6–13.1)
Gdańsk	female	165	55.5 (15.0)	164.2 (6.5)	69.7 (13.0)	25.9 (4.7)	17.8 (10.0)	15.3 (4.1–56.3)	15.5 (14.3–16.6)
	male	35	52.2 (18.0)	175.3 (7.9)	83.2 (12.7)	27.1 (3.8)	16.0 (9.6)	13.8 (6.2–54.5)	13.3 (10.9–15.6)
	all	200	55.0 (15.5)	166.1 (8.0)	72.0 (13.9)	26.1 (4.6)	17.5 (9.9)	15.1 (4.1–56.3)	15.1 (14.1–16.2)
Gdańsk-Przymorze	female	170	51.7 (12.9)	164.6 (6.2)	70.1 (14.6)	25.9 (5.1)	21.2 (9.5)	19.7 (<4.0–53.8)	19.2 (18.0–20.3)
	male	39	46.3 (18.7)	178.1 (6.5)	84.1 (13.7)	26.6 (4.8)	21.5 (10.1)	20.4 (8.8–49.3)	19.6 (17.4–21.8)
	all	209	50.7 (14.3)	167.1 (8.2)	72.7 (15.4)	26.0 (5.1)	21.2 (9.6)	19.7 (<4.0–53.8)	19.2 (18.2–20.2)
Gdynia	female	87	51.2 (16.5)	164.8 (6.0)	68.3 (10.3)	25.2 (4.3)	16.8 (12.0)	13.7 (5.6–98.0)	14.3 (12.7–15.9)
	male	41	47.9 (16.9)	180.8 (6.9)	90.5 (16.2)	27.7 (4.6)	13.8 (5.2)	13.4 (5.0–24.8)	13.0 (10.9–15.2)
	all	128	50.2 (16.6)	170.0 (9.8)	75.4 (16.2)	26.0 (4.5)	15.8 (10.4)	13.7 (5.0–98.0)	14.0 (12.7–15.3)
Jastrzębie Zdrój	female	166	56.9 (14.1)	162.4 (6.1)	71.1 (13.7)	26.9 (4.9)	16.2 (7.1)	14.5 (5.0–56.0)	15.1 (13.9–16.2)
	male	34	58.4 (15.8)	174.5 (6.7)	85.5 (14.8)	28.0 (4.1)	15.2 (3.8)	15.5 (9.0–22.0)	14.4 (12.1–16.8)
	all	200	57.2 (14.3)	164.5 (7.7)	73.6 (14.9)	27.1 (4.7)	16.0 (6.6)	15.0 (5.0–56.0)	14.9 (13.8–15.9)
Kalisz	female	103	53.1 (14.2)	162.5 (6.8)	70.6 (14.0)	26.7 (4.8)	16.0 (6.5)	14.0 (5.0–38.0)	15.0 (13.5–16.5)
	male	31	52.1 (13.0)	178.5 (6.1)	89.5 (10.6)	28.1 (3.2)	20.7 (12.1)	17.0 (7.0–56.0)	18.3 (15.9–20.8)
	all	134	52.9 (13.9)	166.2 (9.4)	75.0 (15.4)	27.0 (4.5)	17.1 (8.3)	15.0 (5.0–56.0)	15.8 (14.5–17.1)
Katowice	female	155	57.6 (13.0)	162.9 (5.8)	68.0 (12.5)	25.7 (4.7)	16.9 (7.8)	15.0 (4.0–43.0)	15.0 (13.8–16.2)
	male	39	56.1 (15.6)	174.4 (8.1)	80.2 (12.2)	26.4 (4.1)	17.0 (7.6)	16.0 (5.0–38.0)	15.0 (12.8–17.2)
	all	194	57.3 (13.5)	165.2 (7.8)	70.5 (13.3)	25.8 (4.6)	16.9 (7.8)	16.0 (4.0–43.0)	15.0 (13.9–16.0)
Kielce	female	298	55.3 (16.2)	162.6 (6.1)	66.4 (11.6)	25.2 (4.3)	18.7 (10.6)	16.7 (<4.0–66.4)	15.9 (15.1–16.8)
	male	112	54.5 (16.9)	175.7 (6.0)	85.4 (13.7)	27.6 (4.1)	18.7 (9.8)	16.7 (<4.0–53.3)	17.0 (15.7–18.4)
	all	410	55.1 (16.4)	166.2 (8.5)	71.6 (14.8)	25.8 (4.4)	18.7 (10.3)	16.7 (<4.0–66.4)	16.2 (15.4–16.9)

TABLE 3 Region-specific characteristics of 25-hydroxyvitamin D [25(OH)D] levels in the populations from the national sample representing 11 Polish cities (in an alphabetical order) (continued from the previous page)

City	Group / sex	n	Age (SD), y	Height (SD), cm	Weight (SD), kg	BMI (SD), kg/m²	25(OH)D, ng/ml		
							mean (SD)	median (min–max)	adjusted[a] mean (95% CI)
Koszalin	female	83	56.9 (13.0)	163.1 (5.8)	69.4 (12.4)	26.1 (4.5)	14.4 (5.1)	14.0 (6.0–29.0)	13.4 (11.8–15.1)
	male	25	55.4 (18.5)	178.4 (8.8)	87.2 (16.3)	27.2 (3.7)	15.4 (3.7)	16.0 (9.0–25.0)	14.9 (12.1–17.6)
	all	108	56.6 (14.4)	166.6 (9.2)	73.5 (15.3)	26.4 (4.3)	14.6 (4.8)	14.0 (6.0–29.0)	13.8 (12.3–15.2)
Kraków	female	500	55.3 (15.5)	162.4 (6.2)	68.5 (12.0)	26.0 (4.5)	16.0 (7.6)	15.0 (4.0–50.0)	14.3 (13.6–15.0)
	male	92	56.0 (17.4)	174.7 (6.2)	82.4 (14.4)	27.0 (4.2)	14.6 (6.9)	13.0 (5.0–39.0)	12.9 (11.5–14.3)
	all	592	55.4 (15.8)	164.3 (7.6)	70.7 (13.3)	26.2 (4.4)	15.7 (7.5)	14.0 (4.0–50.0)	14.0 (13.4–14.6)

a adjusted for age and body weight

Abbreviations: CI, confidence interval; others, see TABLE 1

lowest 25(OH)D values are expected due to lack or limited vitamin D synthesis in the skin. Based on the largest 25(OH)D sample size analyzed so far in Poland, we were able to find that 65.8% of studied adults had 25(OH)D levels lower than 20 ng/ml (50 nmol/l) and nearly 90% showed the levels below 30 ng/ml (75 nmol/l). The most important finding of our study is that as many as 16% of adults investigated in this survey revealed severe hypovitaminosis D, defined as 25(OH) D levels lower than 10 ng/ml (25 nmol/l). This large proportion of severe deficiency is a significant problem because such low 25(OH)D levels are linked with serious health problems, widely reported elsewhere,[20-30] or at least are related to an increased risk of osteomalacia, according to more skeptical views.[18,19,23,24]

The prevalence of vitamin D deficiency, insufficiency, and sufficiency is still the subject of debate that will last as long as the debate on 25(OH)D level thresholds for respective definitions characterizing vitamin D status will continue.[19-23] From the perspective of Central Europe and recent Central European guidelines for vitamin D supplementation,[25] our study revealed that 9 per every 10 adults had 25(OH)D levels below the recommended optimal range that was set at a range of 30 to 50 ng/ml (75–125 nmol/l).

Estimates of vitamin D status within different European populations show large variation. Comparison of studies across Europe has been difficult so far because of different methodologies used for the studies. Fortunately, Vitamin D Standardization Program (VDSP) developed protocols for standardizing 25(OH)D measurement in national health/nutrition surveys around the world that were introduced and implemented, as have been described in detail elsewhere.[37,38] The prevalence of vitamin D deficiency has been reported to be more common in countries with a higher proportion of risk groups or with a low consumption of vitamin D supplements.[39]

In a review focused on 25(OH)D levels among Central Europeans, mean 25(OH)D levels were, in general, less than 30 ng/ml (75 nmol/l), with the lowest values attributable to the winter season.[4] The national health survey among adults in Germany (n = 6995) revealed that 61.6% of participants had serum 25(OH)D levels of less than 20 ng/ml (<50 nmol/l), which was in accordance with our findings.[40] The most recent study on vitamin D status in Europe, which appears to be the first report on the prevalence estimates of vitamin D deficiency based on standardized serum 25(OH)D data, suggested that vitamin D deficiency, defined as 25(OH)D levels of less than 20 ng/ml (50 nmol/l), is widespread across Europe with the yearly prevalence of 40.4% among residents living in Europe and above prevalence rate meets the criteria of a pandemic.[41]

In a study conducted in northern Poland from February to mid-April, the mean 25(OH)D level was 14.3 ±6.6 ng/ml.[31] Among a total of 448 adults aged from 19 to 86 years, 84.4% showed 25(OH)D of less than 20 ng/ml (<50 nmol/l), 13.2% had levels of 20 to 30 ng/ml (50–75 nmol/l), and 11 cases (2.5%) revealed 25(OH)D levels of more than 30 ng/ml (>75 nmol/l).[31] In another study carried out in 274 postmenopausal women (mean age, 69.3 ±5.7 years; living in the city of Warsaw), with blood samples taken during winter (December–March), the mean 25(OHD) level was 13.5 ng/ml, whereas 83% of the study group had 25(OH) D values of less than 20 ng/ml (<50 nmol/l), 12.8% showed the levels of 20 to 30 ng/ml (50–75 nmol/l), and 4% had 25(OH)D levels of more than 30 ng/ml (75 nmol/l).[42] Furthermore, up to 35% of studied women reveled 25(OH)D levels lower than 10 ng/ml (25 nmol/l).[42]

Our present study confirms the significance of the problem in the Polish population, though to a lesser extent. The prevalence of cases with 25(OH)D below 10 ng/ml (25 nmol/l), still relatively high (16%), was 2-fold lower, compared with

TABLE 4 Region-specific characteristics of 25-hydroxyvitamin D [25(OH)D] levels in the populations from the national sample representing another 11 Polish cities (in an alphabetical order) (continued on the next page)

City	Group / sex	n	Age (SD), y	Height (SD), cm	Weight (SD), kg	BMI (SD), kg/m^2	25(OH)D, ng/ml		
							mean (SD)	median (min-max)	adjusted[a] mean (95% CI)
Lublin	female	246	50.8 (15.3)	163.4 (6.0)	68.2 (12.7)	25.6 (4.8)	17.4 (8.5)	15.7 (<4.0–48.9)	15.7 (14.7–16.6)
	male	94	48.1 (16.1)	177.6 (6.5)	83.9 (13.7)	26.6 (3.9)	17.2 (7.9)	15.9 (4.1–41.6)	16.0 (14.6–17.4)
	all	340	50.1 (15.5)	167.3 (8.8)	72.6 (14.7)	25.9 (4.6)	17.4 (8.3)	15.8 (<4.0–48.9)	15.8 (15.0–16.6)
Łódź	female	370	58.2 (14.3)	162.5 (6.2)	68.3 (13.7)	25.9 (5.1)	17.0 (7.9)	16.0 (<4.0–55.0)	15.2 (14.4–16.0)
	male	117	54.3 (15.9)	177.1 (7.4)	83.1 (13.7)	26.5 (3.9)	14.3 (6.9)	13.0 (5.0–41.0)	12.5 (11.2–13.8)
	all	487	57.2 (14.7)	166.0 (9.0)	71.9 (15.1)	26.0 (4.8)	16.4 (7.7)	15.0 (<4.0–55.0)	14.6 (13.9–15.3)
Nowy Sącz	female	121	57.4 (13.8)	162.5 (5.2)	65.9 (11.6)	24.9 (4.1)	17.7 (8.4)	16.0 (5.0–47.0)	15.7 (14.3–17.0)
	male	37	58.1 (17.8)	174.0 (6.8)	82.6 (19.8)	27.1 (5.3)	17.8 (5.1)	17.0 (8.0–31.0)	16.6 (14.4–18.9)
	all	158	57.6 (14.8)	165.2 (7.4)	69.8 (15.6)	25.4 (4.5)	17.7 (7.8)	17.0 (5.0–47.0)	15.9 (14.7–17.1)
Ostrołęka	female	174	48.2 (15.2)	163.4 (5.8)	68.6 (12.1)	25.8 (4.7)	19.0 (9.4)	17.1 (6.2–59.6)	17.4 (16.2–18.5)
	male	59	49.6 (16.7)	176.7 (5.7)	82.2 (12.9)	26.3 (3.5)	19.7 (8.0)	17.7 (6.7–46.9)	18.1 (16.3–19.9)
	all	233	48.5 (15.5)	166.8 (8.2)	72.1 (13.6)	25.9 (4.5)	19.2 (9.1)	17.4 (6.2–59.6)	17.6 (16.6–18.5)
Siedlce	female	154	51.2 (15.4)	163.9 (6.2)	70.3 (13.8)	26.2 (4.9)	18.1 (7.6)	17.0 (5.0–43.0)	17.0 (15.8–18.2)
	male	40	56.0 (14.3)	175.8 (7.2)	87.6 (14.0)	28.3 (3.9)	16.4 (6.6)	15.0 (7.0–37.0)	15.4 (13.2–17.6)
	all	194	52.2 (15.3)	166.3 (8.1)	73.9 (15.5)	26.6 (4.8)	17.8 (7.3)	16.0 (5.0–43.0)	16.6 (15.6–17.7)
Szczecin	female	134	58.5 (17.1)	162.8 (6.6)	68.5 (12.9)	25.9 (4.8)	23.5 (9.9)	21.8 (6.9–53.2)	20.6 (19.3–21.9)
	male	41	64.2 (14.9)	171.1 (8.3)	82.6 (12.5)	28.2 (4.0)	23.3 (10.9)	22.0 (8.1–63.1)	19.9 (17.8–22.1)
	all	175	59.8 (16.7)	164.8 (7.8)	71.8 (14.1)	26.4 (4.7)	23.5 (10.1)	21.9 (6.9–63.1)	20.5 (19.4–21.6)
Świdnica	female	167	51.6 (15.4)	162.4 (6.8)	69.9 (15.3)	26.5 (5.4)	16.9 (7.0)	16.0 (5.0–39.0)	15.8 (14.7–17.0)
	male	35	52.6 (16.5)	174.8 (7.7)	85.7 (12.4)	28.1 (4.2)	17.5 (7.1)	18.0 (8.0–43.0)	16.5 (14.3–18.8)
	all	202	51.8 (15.5)	164.5 (8.4)	72.6 (16.0)	26.8 (5.3)	17.0 (7.0)	16.0 (5.0–43.0)	15.9 (14.8–16.9)
Warszawa	female	459	53.8 (17.1)	163.6 (6.3)	67.1 (12.5)	25.1 (4.6)	20.3 (9.5)	19.0 (4.0–55.0)	17.9 (17.2–18.6
	male	175	50.0 (18.5)	176.6 (7.0)	81.8 (11.5)	26.2 (3.4)	17.6 (7.6)	16.0 (5.0–54.0)	16.3 (15.3–17.4)
	all	634	52.7 (17.6)	167.2 (8.7)	71.1 (13.9)	25.4 (4.3)	19.5 (9.1)	18.0 (4.0–55.0)	17.5 (17.0–18.1)
Wrocław	female	146	56.0 (15.8)	161.5 (7.0)	68.5 (12.5)	26.3 (4.8)	15.2 (6.9)	13.5 (6.0–40.0)	13.7 (12.5–15.0)
	male	38	56.0 (15.3)	175.6 (5.8)	85.0 (15.2)	27.5 (4.1)	14.6 (5.2)	14.5 (5.0–31.0)	13.5 (11.3–15.7)
	all	184	56.0 (15.6)	164.4 (8.9)	71.9 (14.7)	26.5 (4.6)	15.1 (6.5)	14.0 (5.0–40.0)	13.6 (12.6–14.7)

TABLE 4 Region-specific characteristics of 25-hydroxyvitamin D [25(OH)D] levels in the populations from the national sample representing another 11 Polish cities (in an alphabetical order) (continued from the previous page)

City	Group / sex	n	Age (SD), y	Height (SD), cm	Weight (SD), kg	BMI (SD), kg/m²	25(OH)D, ng/ml		
							mean (SD)	median (min-max)	adjusted[a] mean (95% CI)
Zakopane	female	51	49.9 (10.4)	164.2 (6.1)	66.6 (10.1)	24.7 (3.6)	21.0 (10.1)	20.0 (4.0–51.0)	18.4 (16.4–20.5)
	male	9	51.1 (14.4)	176.8 (6.2)	89.0 (11.8)	28.5 (3.8)	14.8 (5.2)	15.0 (7.0–22.0)	14.1 (9.5–18.7)
	all	60	50.1 (10.9)	166.1 (7.5)	70.0 (13.1)	25.3 (3.8)	20.1 (9.8)	19.0 (4.0–51.0)	17.7 (15.8–19.6)
Żyrardów	female	156	57.5 (13.1)	161.5 (5.8)	70.4 (12.6)	27.0 (4.7)	16.1 (6.9)	15.0 (5.0–43.0)	14.8 (13.6–16.0)
	male	30	58.2 (16.5)	174.3 (7.7)	82.8 (13.5)	27.2 (3.3)	17.3 (13.3)	15.0 (6.0–82.0)	13.6 (11.1–16.2)
	all	186	57.7 (13.7)	163.6 (7.7)	72.4 (13.5)	27.0 (4.5)	16.3 (8.2)	15.0 (5.0–82.0)	14.5 (13.4–15.6)

a adjusted for age and body weight

Abbreviations: see TABLES 1 and 3

TABLE 5 Significant differences between 25-hydroxyvitamin D [25(OH)D] levels in relation to age (based on 10-year ranges)

10-year age groups	Alphabetical order	n	25(OH)D, ng/ml			Significant differences; Kruskal–Wallis test
			mean	SD	median (min–max)	
15–20 years	a	71	15.9	7.8	14.0 (4.6–38.0)	g; $P < 0.05$
20–30 years	b	518	17.9	10.3	15.9 (<4.0–82.0)	g; $P < 0.05$
30–40 years	c	667	17.9	9.8	15.0 (<4.0–79.0)	g; $P < 0.05$
40–50 years	d	782	16.8	8.9	14.9 (<4.0–68.9)	e; f; g; h; $P < 0.05$
50–60 years	e	1430	18.0	9.7	16.0 (<4.0 to >150.0)	d; $P < 0.05$
60–70 years	f	1468	18.1	8.7	16.9 (<4.0–79.8)	d; $P < 0.05$
70–80 y years	g	641	19.5	10.6	18.0 (4.7–101.0)	a; b; c; d; $P < 0.05$
80–90 years	h	198	19.2	10.1	17.5 (<4.0–49.6)	d; $P < 0.05$
total		5775	18.0	9.6	16.0 (<4.0 to >150.0)	$P = 0.0000$

that reported by Napiorkowska et al,[42] who found severe insufficiency in 35% of Polish women living in the Warsaw city area. Notably, the prevalence of subjects showing 25(OH)D levels below 20 ng/ml was 84%[31] and 83%[42] in their studies, compared with 66% found in our study. Both studies also revealed markedly lower mean 25(OH)D levels analyzed for the subpopulations, whereas the prevalence of cases with 25(OH)D levels above 30 ng/ml (75 nmol/l) was up to 4 times lower in comparison with that observed in our study.[31,42] These differences highlighted a potential 25(OH)D drift to higher levels, at least in Poland. The trend toward increasing 25(OH)D levels during the last years in Poland is unclear but may presumably reflect an increase in supplementation rate among our society. Additionally, the volunteers participating in our study may have been more aware of the importance of vitamin D for overall health, and consumed more vitamin D supplements or diet rich in this important vitamin.

Our data obtained from almost 5800 individuals living in 22 urban areas of Poland seem to be sufficiently reliable to confirm the relevance of the problem on a large scale. The recruitment and blood collections were done within a relatively short time, during late winter and spring (low season), thus, at the unfavorable seasons regarding UVB availability. Interestingly, the 25(OH)D levels significantly though weakly correlated with age, that is, higher levels were observed in elderly individuals than in young adults. This finding seems contradictory to a commonly held notion that older age is a risk factor for the deficiency resulting from ineffective skin synthesis and age-related negative metabolic influence of fat tissue.[43] Possible explanation of our results may include higher awareness of the older population regarding the needs of vitamin D supplementation, prevention of osteoporosis, and perhaps more leisure time spent outdoor, compared with younger generations. In fact, we did not have data on lifestyle and habits of our participants, which should be regarded a limitation of this study. However, considerations on sun exposure were negligible in this study as it was evidenced by the lack of a clinically meaningful difference between mean 25(OH)D levels measured strictly in late winter compared with those measured in the spring season. Nonetheless, a possible increase of 25(OH)D levels during summer and early autumn should be kept in mind in our population. A study focused on seasonal variation of 25(OH)D levels in 1307 Hungarians with repeated 25(OH)D measurements revealed that the 25(OH)D level during summer months increased by 20 ng/ml for those aged from 0 to 9 years, by 14 to 15 ng/ml for those aged from 10 to 49 years, by 10 ng/ml for those aged from 50 to 69 years, and by 5 to 6 ng/ml for those aged from 70 to 89 years.[44] Furthermore, overall 25(OH)D levels in the study group started to decline in September, reached wintertime values (20–23 ng/ml) by October and then plateaued until June.[44]

The significant associations between vitamin D deficits and studied variables included male sex, younger age, excess body weight, and higher BMI, and also some geographical areas. The combination of these factors conferred an increased risk of the deficiency. There were certain differences in 25(OH)D levels between cities; however, the effect of biogeography and latitude should rather be minimal, and conclusions should be drawn cautiously, as Poland is neither a large nor diversified country. By contrast, some associations between vitamin D supply and body weight or overweight may be of importance in this study. Negative correlations of 25(OH)D and BMI support the evidence reported elsewhere and showing deficits of vitamin D in obesity.[43] Our results obtained from the adult population with a BMI of 30 kg/m^2 or higher compared with those from the normal-weight population distinctly confirm an increased risk of deficiency, and therefore are compelling in the context of public health. Special recommendations for an increased vitamin D supplementation should be addressed to the groups of overweight or obese men and women.[25]

This is not the first epidemiological report on vitamin D status conducted in Poland; nevertheless, our study appears to be the most representative so far, by having included the largest sample size in this region of Europe. The data add new reliable information about vitamin D supply in Poland, even if the underlying mechanisms and factors (except for those well recognized such as limited UVB irradiation and diet poor in vitamin D) producing deficits remain not fully explained.

The study has obviously several limitations affecting possible interpretations. Despite a large and representative population recruited in the survey, this has not been a population-based study as the investigation was conducted only in major cities, presumably without residents of the rural areas of Poland. On the other hand, there are no explicit differences regarding sun/UBV exposition between rural and urban areas across the country. Another limitation may have been the lack of strict exclusion criteria, thus the proportion of individuals with chronic conditions, prolonged medication use, or use of vitamin D supplements was unknown. A population registry based on the voluntary participation and a short questionnaire used for data collection were yet unable to detect such associations. Assuming that the volunteering participants were more aware of the significance of vitamin D than the rest of the society, this may be considered an asset. Even if they were taking supplements on a regular basis during the winter season, a large proportion of these subjects included in the study still had suboptimal vitamin D status. We believe that some methodological aspects regarding cross-calibrations and comparisons of 25(OH)D levels between cities and laboratories had a minor influence on the results. Noticeably, all procedures were using the same standard quality technologies and were based on good laboratory practice. However, data on standardized 25(OH)D levels, with the use of the VDSP protocol,[37,38,41] could add some other insights into our study.

In summary, this large-scale study showed an evident deficit of vitamin D in the Polish urban population, documented by severely or, at least, moderately decreased 25(OH)D levels in up to 90% of the society. In contrast, only a very limited part of the studied population (9.1%) revealed adequate 25(OH)D levels. Our findings are consistent with the majority of the European and American reports on vitamin D status. At least 2 factors may explain the above findings: low UVB irradiation (or "vitamin D winter") lasting in Poland from October through March,[45] and low intake of vitamin D-rich food products.[46,47] Well-designed preventive strategies and educational policies should be implemented to improve the vitamin D status and enhance potential health benefits for the majority of the Polish population.

Contribution statement PP and CD contributed to study design, statistical analysis, data interpretation, and final revision of the manuscript. JK was responsible for data interpretation and final revision of the manuscript. MJ was responsible for statistical analyzes, data interpretation, and final revision of the manuscript.

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Status zaopatrzenia w witaminę D w Polsce

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SŁOWA KLUCZOWE

deficyt witaminy D, witamina D, 25-hydroksywitamina D

STRESZCZENIE

WPROWADZENIE Dane epidemiologiczne dotyczące zaopatrzenia w witaminę D populacji polskiej są ograniczone.

CELE Celem badania było określenie stanu zaopatrzenia w witaminę D w reprezentatywnej grupie dorosłych mieszkańców 22 miast Polski na podstawie analizy stężenia 25-hydroksywitaminy D [25(OH)D] w surowicy.

PACJENCI I METODY W badaniu przekrojowym wzięło udział 5775 zdrowych ochotników (4464 kobiet, 1311 mężczyzn; średni wiek 54,0 ±15,9 roku; zakres 15,5–89,8 roku), których rekrutowano i badano w okresie późnej zimy oraz wiosny 2014 r. Stężenie 25(OH)D w surowicy krwi oceniono za pomocą systemu Liaison XL (DiaSorin; metoda CLIA). Analizie poddano również parametry demograficzne i antropometryczne.

WYNIKI Średnie stężenie 25(OH)D w badanej grupie wyniosło 18,0 ±9,6 ng/ml; 65,8% badanych ujawniło stężenia 25(OH)D <20 ng/ml, 24,1% – stężenia suboptymalne wynoszące 20–30 ng/ml, zaś u jedynie 9,1% zbadanych stwierdzono wartości optymalne (30–50 ng/ml). U 89,9% badanych odnotowano stężenia 25(OH)D poniżej wartości 30 ng/ml. Otyłość, zdefiniowana jako wskaźnik masy ciała (*body mass index* – BMI) >30 kg/m^2, wiązała się z niższymi stężeniami 25(OH)D w porównaniu z normalną masą ciała (odpowiednio 15,8 ±8,5 *vs* 18,5 ±9,7 ng/ml; p <0,0001). Niższe wartości stężenia 25(OH)D notowano u mężczyzn, u osób młodszych oraz u osób z podwyższoną masą ciała i wartościami BMI.

WNIOSKI Wyniki tego badania, obejmującego największą dotychczas pod względem liczebności próbę populacyjną dorosłych Polaków, pozostają zgodne z publikowanymi wcześniej raportami zasobów ustrojowych witaminy D. Ujawnione wartości stężeń 25(OH)D u dorosłej części społeczeństwa, przynajmniej w miesiącach zimowych i wiosną, wskazują na niezadowalający stan zaopatrzenia w witaminę D u większości Polaków oraz na konieczność rozważenia działań prewencyjnych lub interwencyjnych w celu wyrównania ujawnionych niedoborów witaminy D.

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