Little published information is available regarding epidemiological data on vitamin D status in the large geographical region of Central Europe (CE). We searched the journal literature with regard to 25(OH)D concentrations among community-dwelling or healthy people living in CE. 25(OH)D concentrations varied by age, season, study sample size, and methodological approach [i.e., 25(OH)D assay used]. Concentrations of 25(OH)D in CE appeared lower than 30 ng/mL, and the magnitude of hypovitaminosis D was similar to that reported in Western Europe. While most of the studies reviewed were cross-sectional studies, a longitudinal study was also included to obtain information on seasonal variability. The longitudinal study reported wintertime 25(OH)D values close to 21–23 ng/mL for all studied age groups, with a significant increase of 25(OH)D in August reaching 42 ng/mL for those aged 0–9 years, but only 21 ng/mL for the elderly aged 80–89 years. The decrease in 25(OH)D with respect to age was attributed to decreased time spent in the sun and decreased vitamin D production efficiency. Based on the literature review on vitamin D status in the CE populations, it can be concluded that 25(OH) vitamin D levels are on average below the 30 ng/mL level.

1. Introduction

The literature published over the two last decades indicates increasing awareness of vitamin D’s pleiotropic, multi-directional action in the human body. Evidence from large-scale studies contributed to the understanding that vitamin D deficiency may be a significant risk factor for many civilization diseases. There is recognized benefit of vitamin D for bone health based on both observational studies and randomized controlled trials [1]. There is also evidence largely from cross-sectional, ecological, laboratory, and observational studies that vitamin D reduces risk of many types of cancer, cardiovascular disease, diabetes, autoimmune and metabolic disorders, infectious diseases linked to decreased immunity, and even some neuropsychiatric disorders [2–8]. Based on the journal literature for the
nonskeletal effects of vitamin D, it appears that serum 25-hydroxyvitamin D [25(OH)D] concentrations between 30 and 50 ng/mL are associated with significantly reduced risk of such diseases [9–12]. Therefore, a variety of practical and research activities are being undertaken worldwide to evaluate vitamin D deficiency and improve vitamin D status. In Central Europe (CE), researchers representing the region developed recommendations to treat vitamin D deficiency for Poland in 2009 [13] and for Hungary in 2012 [14]. Because of convincing findings showing potential health benefits of vitamin D, investigators in CE focus on determining serum vitamin D, and long-term effects, with appropriate safety considerations. The primary conclusion reached by the participants at the Warsaw conference was consensus on optimal (target) serum 25(OH)D concentration throughout the year [15].

2. Materials and Methods

This paper reviews the available spectrum of data on serum 25(OH)D concentrations in CE, compared with selected findings from other European countries. We found several articles through advanced searches of the National Library of Medicine’s PubMed database and Scopus, using keywords “vitamin D” or “serum 25-hydroxyvitamin D” along with country names or “Europe.” Some of the CE “epidemiologic” studies reported at the vitamin D conference in Warsaw were also included for further analyses. Papers dealing with healthy or community-dwelling people were included in the tables, but people with diseases were not. However, one set of data for patients was given in a separate table because it provided longitudinal data on serum 25(OH)D concentrations throughout the year [15].

3. Results

Tables 1–4 provide explicit comparative information on serum 25(OH)D concentrations in Central European countries as a function of age [16–46], whereas Table 5 gives information as a function of season (monthly intervals) stratified by age for a Hungarian population [15].

3.1. Neonates and Infants. Eight studies in this review reported serum 25(OH)D concentrations for neonates and infants in CE: one from the Czech Republic and seven from Poland (Table 1). Mean serum 25(OH)D concentration among neonates ranged between 7 and 24 ng/mL depending on season. Winter and spring values were low, 7–14 ng/mL, whereas summertime values were better (19–24 ng/mL). Recent Polish studies confirmed the above observations, showing higher summertime than winter/spring mean 25(OH)D concentrations in the umbilical cord: 24.0 ± 8.5 ng/mL versus 13.5 ± 8.2 ng/mL (P < 0.001), respectively [20–22]. Serum 25(OH)D values found in these studies appeared lower than those recommended on the basis of a recent randomized controlled trial of vitamin D supplementation during pregnancy. This study, performed by Hollis and colleagues, demonstrated association between the 25(OH)D level of 40 ng/mL and optimal serum 1,25-dihydroxyvitamin D concentrations [47]. Fortunately, implementing recommendations for neonates to start vitamin D supplementation from the first days after delivery resolved, at least partly, vitamin D deficiency during the first few months of life. As Czech-Kowalska and colleagues showed, supplementing neonates with daily doses of ~550 IU of vitamin D increased serum 25(OH)D to 55 ng/mL at the third month of life [22]. Further, in the group of infants (n = 43) regularly supplemented with a vitamin D dose of ~1160 IU/day at both the 6th and 12th month, 25(OH)D serum concentrations unexpectedly decreased from 40.2 ± 18.8 ng/mL at the 6th month to 32.0 ± 12.7 ng/mL at the 12th month (P < 0.01) [17]. However, reduced daily vitamin D intake expressed in international units/kilogram of body weight may account for the observed decrease in 25(OH)D concentration [23].

3.2. Children and Adolescents. Table 2 shows serum 25(OH)D concentrations in children and adolescents. In Central European countries, wintertime values ranged from 9 ng/mL in Belarus [24] to 23 ng/mL in Hungary [25]; summertime values ranged from 36 to 56 ng/mL. The large winter range may be due to different 25(OH)D assays used, which will be discussed later. In addition, studies with smaller sample size may have been associated with variations in 25(OH)D concentrations due to recruiting people who may not have been representative of the larger population.

3.3. Adults. Table 3 presents serum 25(OH)D concentrations for adults aged 20–60 years. In CE, wintertime 25(OH)D concentrations ranged from 11 ng/mL in Poland to 18 ng/mL in Estonia. Summertime 25(OH)D concentrations ranged from 18 ng/mL in Ukraine to 35 ng/mL in Hungary, and annual values found in larger studies (>100 cases) ranged from 14 ng/mL in Ukraine to 29 ng/mL in Belarus. In Western European countries of similar latitude, wintertime values ranged from 13 ng/mL in Denmark to 20 ng/mL in Austria, whereas those in summertime ranged from 23 to 35 ng/mL.
| Country          | City      | Latitude, longitude | Year            | Number, sex | Age           | Population         | Season   | Assay, machine (manufacturer) | Serum 25(OH)D (ng/mL) | Reference |
|------------------|-----------|---------------------|-----------------|-------------|---------------|---------------------|----------|------------------------------|----------------------|-----------|
| Czech Republic   | Pilzen    | 49.8°N 13.3°E      | April–June 2006 | 28          | Newborn       | Term, cross section| Spring   | CLIA, Liaison (DiaSorin)     | 7 (6–13)             | [16]      |
| Poland           | Warsaw    | 52.2°N 21.0°E      | 2001-2002       | 20 M 17 F   | Newborn 1 week| Healthy            | Winter   | Radiocompetitive, Exтрelut column and radioassay | 7 ± 5                 | [17]      |
| Poland           | Warsaw    | 52.2°N 21.0°E      | 2001-2002       | 56          | Newborn 3 weeks| Healthy            | Annual   | CLIA, Liaison (DiaSorin)     | 15 ± 9                | [18]      |
| Poland           | Warsaw    | 52.2°N 21.0°E      | 2001-2002       | 76          | Newborn cord blood| Healthy            | Winter   | CLIA, Liaison (DiaSorin)     | 14 ± 8                | [19]      |
| Poland           | Warsaw    | 52.2°N 21.0°E      |                 | 40          | Newborn cord blood| Healthy            | Summer   | CLIA, Liaison (DiaSorin)     | 24 ± 9                | [20]      |
| Poland           | Warsaw    | 52.2°N 21.0°E      | 2 weeks         | 15 M 15 F   | 10 weeks       | Healthy, after supplementation | Winter, summer | CLIA, Liaison (DiaSorin)     | 8.5 (7–12)             | [21]      |
| Poland           | Warsaw    | 52.2°N 21.0°E      | 6 months        | 134         | Healthy, after supplementation | RIA                  |          |                              | 43 ± 20               | [22]      |
| Poland           |           | 98                  | 12 months       | 98          | Healthy, after supplementation | RIA                  |          |                              | 29 ± 12               | [23]      |
| Country     | City     | Latitude, longitude | Year       | Number, sex | Age (yrs) | BMI | Population       | Season            | Assay, machine (manufacturer) | Serum 25(OH)D (ng/mL) | Reference |
|-------------|----------|---------------------|------------|-------------|-----------|-----|------------------|--------------------|-------------------------------|----------------------|-----------|
| Belarus     | Minsk    | 53.9° N, 27.6° E    | 2011-2012  | 47 M        | 11 (8–13) | Healthy | Autumn-winter | ECLIA, Cobas e411 (Roche Diagnostics) | 9 (5–15)            | [24]      |
| Hungary     | Budapest | 47.5° N, 17.1° E    |            | 100 M       | 11-14     | 20   | Healthy, Cross section | Winter            | CLIA, IDS (IDS)                                | 23 ± 6               | [25]      |
| Hungary     |         |                     |            | 66 M        | 11-14     | 20   | Healthy          | Summer            |                               | 41 ± 13              | [25]      |
| Hungary     |         |                     |            | 91 F        | 11-14     | 20   | Healthy          | Winter            |                               | 21 ± 8               | [25]      |
| Hungary     |         |                     |            | 53 F        | 11-14     | 20   | Healthy          | Summer            |                               | 38 ± 14              | [25]      |
| Poland      |         | 49–54° N, 15–24° E  |            | 199 F       | 13 ± 1    | Community, cross section | Winter            | HPLC                              | 12                   | [26]      |
Table 3: Serum 25-hydroxyvitamin D concentrations reported for adults in Central Europe.

| Country          | City       | Latitude, longitude | Year       | Number, sex | Age (yrs) | BMI     | Population                     | Season | Assay, machine (manufacturer)          | Serum 25(OH)D (ng/mL) | Reference |
|------------------|------------|---------------------|------------|-------------|-----------|---------|--------------------------------|--------|--------------------------------------|------------------------|-----------|
| Belarus          | Western    | 53° N 24–26° E      | 2010-2011  | 6 M 22 F    | 46 ± 7    | 27 ± 4  | Healthy                        | Annual | ECLI, Elecsys (Roche Diagnostics)     | 18 ± 7                 | [28]      |
| Belarus          | Minsk      |                     | 2011-2012  | 168 F 176 F | 45–55     | 55–65   | Healthy                        | Annual | ECLI, Cobas e411 (Roche Diagnostics) | 29 ± 15                | [29]      |
| Czech Republic   | Prague     | 50.1° N 14.4° E     | 2004–2006  | 217/5       |           |         | Clinic patients                 | Annual | RIA, IDS, UK                        | 31 ± 18                | [30]      |
| Czech Republic   | Pilsen     | 49.8° N 13.3° E     | 2008       | 239 M 321 F | 53 ± 14   | 27 ± 5  | Community, cross section       | Oct. 6–Nov. 28 | ECLI, Cobas e411 (Roche Diagnostics) | 25 ± 4                 | [31]      |
| Estonia          | Väike-Maarja| 59.1° N 26.3° E    | 2006       | 167 M       | 49 ± 12   | 28 ± 5  | Community, cross section from patients | Winter | RIA, DiaSorin                      | 17 ± 6                 | [32]      |
| Estonia          |            |                     |            | 200 F       | 49 ± 12   | 29 ± 7  | Community                      | Winter | RIA, DiaSorin                      | 18 ± 6                 | [32]      |
| Estonia          |            |                     |            | 167 M       | 49 ± 12   | 28 ± 5  | Community                      | Summer | RIA, DiaSorin                      | 24 ± 7                 | [32]      |
| Estonia          |            |                     |            | 200 F       | 49 ± 12   | 29 ± 7  | Community                      | Summer | RIA, DiaSorin                      | 23 ± 7                 | [32]      |
| Hungary          | County Vas | 47.2° N 16.8° E    | 2011       | 32 M        | <43       |         | Healthy blood donors and others, cross section | March–May | ECLI, Cobas e411 (Roche Diagnostics) | 29 (25–40)             | [33]      |
| Hungary          | County Vas |                     |            | 48 M        | <43       |         | Healthy                        | Healthy | Radiocompetitive, Extrelut column and radioassay | 11 ± 7                 | [17]      |
| Hungary          | County Vas |                     |            | 36 M        | >43       |         | Healthy                        | Healthy | Radiocompetitive, Extrelut column and radioassay | 24 ± 9 (17–34)         | [17]      |
| Poland           | Warsaw     | 52.2° N 21.0° E     | 2003–2004  | 17 F        | 52 ± 4    | 24 ± 2  | Mothers at delivery            | Annual | RIA, Bio-Source Europe             | 39 ± 18                | [34]      |
| Poland           | Opole      | 50.6° N 179° E      | 2004–2005  | 31 F        | 47 (25–79)|         | Healthy, employees of the Center of Oncology, Opole | November–March | ECLI, (Roche Diagnostics)          | 17                     | [35]      |
| Poland           | Warsaw     |                       |            | 76          | Mothers after delivery | Healthy | Winter | CLIA, Liaison (DiaSorin)        | 15 ± 8                | [20, 21] |
| Poland           | Warsaw     |                       |            | 40          | Mothers after delivery | Healthy | Summer | CLIA, Liaison (DiaSorin)        | 20 ± 7                | [20, 21] |
| Poland           | Warsaw     |                       |            | 119         | Lactating women | Healthy | Annual | CLIA, Liaison (DiaSorin)        | 26 ± 7                | [20, 21] |
| Poland           | Warsaw     |                       |            | 138 F       | Pregnant women 1st trimester | Healthy | Annual | 17.6 (4–57) | [36]      |
| Poland           | Warsaw     |                       |            | 138 F       | Pregnant women 3rd trimester | Healthy | Annual | 18.5 (4–40) | [36]      |
Table 3: Continued.

| Country  | City      | Latitude, longitude | Year | Number, sex | Age (yrs) | BMI | Population | Season | Assay, machine (manufacturer) | Serum 25(OH)D (ng/mL) | Reference |
|----------|-----------|---------------------|------|-------------|-----------|-----|------------|--------|-------------------------------|----------------------|-----------|
| Poland   | Warsaw    | 55°                   | 2007 | 162 F       | 34        |     | Healthy    | Annual | ECLIA, Elecsys 2010 (Roche Diagnostics) | 33 ± 13              | [38]      |
| Poland   | Warsaw    | 55°                   | 2007 | 649 F       | 47 (20–59)| 28 ± 6| Healthy    | Annual | ECLIA, Elecsys 2010 (Roche Diagnostics) | 14 ± 9               | [39, 40] |
| Ukraine  |           | 44°27′ N – 52°22′ N   | 2010–2011 | 129 M 102 F 28 M | 44 (20–59) | 26 ± 6 | Healthy    | Annual | ECLIA, Elecsys 2010 (Roche Diagnostics) | 15 ± 10              | [39, 40] |
| Ukraine  |           | 44°27′ N – 52°22′ N   | 2010–2011 | 160 F 37 M | 45 ± 11 | 27 ± 5 | Healthy    | Winter | ECLIA, Elecsys 2010 (Roche Diagnostics) | 13 ± 8               | [39, 40] |
| Ukraine  |           | 44°27′ N – 52°22′ N   | 2010–2011 | 160 F 37 M | 45 ± 11 | 27 ± 5 | Healthy    | Summer | ECLIA, Elecsys 2010 (Roche Diagnostics) | 18 ± 10              | [39, 40] |
Table 4: Serum 25-hydroxyvitamin D concentrations reported for seniors.

| Country | City     | Latitude, longitude | Year               | Number, sex | Age (yrs) | BMI | Population | Season | Assay, machine (manufacturer)          | Serum 25(OH)D (ng/mL) | Reference |
|---------|----------|---------------------|--------------------|--------------|-----------|-----|------------|--------|--------------------------------------|----------------------|-----------|
| Belarus |          |                     |                    | 178 F        | 65–75     |     |            | Annual | ECLIA, Cobas e411 (Roche Diagnostics) | 26 ± 14              | [29]      |
| Belarus |          |                     |                    | 101 F        | >75       |     |            | Annual |                                       | 19 ± 9               | [29]      |
| Hungary | Debrecen | 47.5°N 21.6°E       | September 2009     | 319 F        | 65 (41-91) | 26 ± 4 | Community  | Year   | ECLIA, Cobas e411 (Roche Diagnostics) | 19 (5–54)            | [43]      |
| Hungary | Debrecen |                     | September 2010     | 206 M        | 60 (51-81) | 29 (17-42) | Healthy  | Year   | HPLC                                | 29 (4–74)            | [44]      |
| Hungary | Debrecen |                     | September 2010     | 59 M         | 60        | 28   | Community  | Spring  | RIA, DiaSorin                        | 17 (5–40)            | [43]      |
| Hungary | Debrecen |                     | September 2010     | 96 M         | 61        | 30   | Community  | Summer  | RIA, DiaSorin                        | 20 (5–41)            | [43]      |
| Hungary | Debrecen |                     | September 2010     | 24 M         | 59        | 29   | Community  | Autumn  | RIA, DiaSorin                        | 21 (5–54)            | [43]      |
| Hungary | Debrecen |                     | September 2010     | 30 M         | 59        | 29   | Community  | Winter  | RIA, DiaSorin                        | 20 (5–41)            | [43]      |
| Poland  |          |                     |                    | 65 F         | 72 ± 1    |     |            | Healthy | HPLC                                | 13 ± 7               | [26]      |
| Ukraine |          |                     |                    | 149 F        | 65        | 29 ± 5 | Healthy, not treated with vitamin D, cross section Healthy, | Winter | CLIA, Liaison (DiaSorin) and ECLIA, Elecsys 2010 (Roche Diagnostics) | 13 ± 7               | [39, 40] |
| Ukraine |          |                     |                    | 124 F        | 75        | 30 ± 4 | Healthy, | Winter  | CLIA, Liaison (DiaSorin) and ECLIA, Elecsys 2010 (Roche Diagnostics) | 14 ± 8               | [39, 40] |
| Ukraine |          |                     |                    | 2010-2011    | 711 F      | 69 (60–95) | 29 ± 5 | Healthy, | Annual  | CLIA, Liaison (DiaSorin) and ECLIA, Elecsys 2010 (Roche Diagnostics) | 13 ± 8               | [39, 40] |
| Ukraine |          |                     |                    | 2010-2011    | 86 M       | 71 (60–91) | 28 ± 4 | Healthy, | Annual  | CLIA, Liaison (DiaSorin) and ECLIA, Elecsys 2010 (Roche Diagnostics) | 16 ± 9               | [39, 40] |
| Ukraine |          |                     |                    | 2010-2011    | 120 F      | 69 ± 6  | 30 ± 6  | Healthy, | Winter  | CLIA, Liaison (DiaSorin) and ECLIA, Elecsys 2010 (Roche Diagnostics) | 11 ± 6               | [39, 40] |
| Ukraine |          |                     |                    | 2010-2011    | 305 F      | 68 ± 6  | 28 ± 5  | Healthy, | Summer  | CLIA, Liaison (DiaSorin) and ECLIA, Elecsys 2010 (Roche Diagnostics) | 15 ± 8               | [39, 40] |
and annual values were reported as 25 ng/mL in France [41].
Thus, 25(OH)D serum concentrations of Central European and
Western European countries showed consistent agreement.
Some information is available in the studies regarding
serum 25(OH)D concentrations in men and women. A study
from Great Britain involving 45-year-olds in a cohort study
found that women had statistically higher concentrations
than men in winter, while men had statistically higher
concentrations in summer [42]. The differences might be due
to men spending more time outdoors and women taking
more oral vitamin D. A study from Estonia found similar
but statistically nonsignificant results: in summer, men had
a mean serum 25(OH)D concentration of 24.2 ng/mL while
women had 23.4 ng/mL, while in winter the values for males
and females were 17.1 ng/mL and 17.8 ng/mL, respectively [32].

### 3.4. The Elderly

Table 4 gives serum 25(OH)D concentrations for seniors aged 60 years or older. In Central European
countries, wintertime 25(OH)D concentrations ranged from
11 ng/mL in Ukraine to 20 ng/mL in Hungary. Summertime
25(OH)D concentrations ranged from 15 ng/mL in Ukraine
to 33 ng/mL in Hungary. Annual 25(OH)D concentrations
ranged from 13 ng/mL in Ukraine to 29 ng/mL in Hungary. In
Western European countries, wintertime values ranged from
17 to 20 ng/mL. Analyzing serum 25(OH)D concentrations
with respect to latitude in either Central or Western European
countries revealed no consistent variability. At least in part,
the reasons for this could include that the solar ultraviolet-B
(UVB) dose gradient during European summer is not large
above 40°N latitude and that skin pigmentation becomes
lighter as latitude increases, making it easier to generate
vitamin D from solar UVB [48]. As noted in Table 5, serum
25(OH)D concentrations decrease with age above about 50
years. Since most studies summarized in this table reported
25(OH)D concentrations for a limited range of ages, stated
in the table, the values in the table should be considered
representative of those for the age ranges studied and not for
those over the age of 60 years.

### 3.5. Effect of Age and Season

A useful study on the variation of serum 25(OH)D3 concentration with respect to age in
10-year groupings and month of measurement (Table 5) was reported for a population from Budapest, Hungary
(47°5′N latitude, 16°8′E longitude) [15]. Although the subjects studied were patients, nothing indicated that their mor-
bidity affected serum 25(OH)D3 concentration. However,
the report noted that, for the 1307 subjects with repeated
measurements, serum 25(OH)D concentrations were lower
for the second measurement (26 ± 9 ng/mL) than for the first
(27 ± 13 ng/mL), suggesting that the medical staff did not
recommended taking vitamin D supplements. Table 5 gives
a summary of data from that study. Several months were
omitted for which serum 25(OH)D3 concentrations either
did not change or were inconsistent with concentrations for
other months; values in January were similar to those in May.
Several associations become clear from the content of Table 5:
serum 25(OH)D3 concentration increased minimally before
June except for the population aged 0–9 years. For all
ages, serum 25(OH)D3 concentration started to decline in
September and reached wintertime values by October. Peak
serum 25(OH)D3 concentrations were the highest for the
youngest people and the lowest for the oldest people. The
wintertime mean serum 25(OH)D concentration was about
20–23 ng/mL for all ages. The increase in summer amounted
to 20 ng/mL for those aged 0–9 years, 14–15 ng/mL for those
aged 10–49 years, 10 ng/mL for those aged 50–69 years,
and 5–6 ng/mL for those aged 70–89 years. Two primary
factors accounted for age-related seasonal fluctuations (i.e.,
differences in summertime peak values): limited time spent
outdoors in sunlight and reduced efficiency of vitamin D
production from UVB irradiance. In a mid-1980s study,
vitamin D production efficiency reported for people older
than 60 years was about 25% of that for those younger than
20 years [49], owing to less 7-dehydrocholesterol in the skin,
which is converted to vitamin D3 through the action of
UVB irradiance followed by a thermal process. The change
in vitamin D production in summer as a function of age
agrees with the efficiency study. Those with darker skin make
vitamin D more slowly than those with light skin since the
melanin in the skin reduces the transmission of solar UVB to
the 7-dehydrocholesterol. In addition, Table 5 gives calculated
standard vitamin D doses (SDD) for whole-day irradiation
for solar UVB measured in Belsk, Poland (52°N latitude, 21°E
longitude) [50]. However, because vitamin D3 production is
limited to 10 000–20 000 IU/day (since UV both produces

### Table 5: Serum 25(OH)D3 concentration (ng/mL) versus age range and month measured for patients at Semmelweis University, Budapest, between April 2009 and March 2010 [9].

| Month  | 0–9 years | 10–19 | 20–29 | 30–39 | 40–49 | 50–59 | 60–69 | 70–79 | 80–89 | SDD |
|--------|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-----|
| March  | 25        | 23    | 23    | 23    | 22    | 22    | 23    | 23    | 20    | 4   |
| May    | 31        | 23    | 25    | 24    | 23    | 24    | 24    | 21    | 21    | 21  |
| June   | 30        | 26    | 30    | 30    | 28    | 26    | 29    | 28    | 21    | 56  |
| July   | 35        | 30    | 33    | 31    | 28    | 27    | 27    | 25    | 19    | 55  |
| August | 42        | 37    | 35    | 35    | 36    | 29    | 33    | 25    | 21    | 42  |
| September | 36      | 30    | 30    | 29    | 30    | 29    | 26    | 26    | 16    | 18  |
| October | 31       | 23    | 23    | 27    | 24    | 24    | 23    | 20    | 15    | 9   |
| November | 23      | 23    | 25    | 26    | 27    | 23    | 27    | 26    | 23    | 2   |
| December | 22      | 22    | 21    | 21    | 21    | 19    | 23    | 20    | 15    | 1   |
vitamin D and destroys its metabolites), one cannot use the SDD values to estimate vitamin D production for a given time in the sun. For such information, the graphs in the papers by Webb and Engelsen [51] and Bakos and Mikó [52] are useful. Vitamin D production potential peaks near the end of June, whereas serum 25(OH)D3 concentration peaks in August. The lag of about 6 weeks is related primarily to the time required to build up serum 25(OH)D concentration. Serum 25(OH)D is the most important clinically available measurement of vitamin D status, reflecting lifestyle and dietary habits [53]. Determining the amount provided by the sun or food is difficult. The duration and intensity of exposure to sunlight are not easily measurable, and age, skin pigmentation, sunscreens, clothing, and even window glass reduce its effects [54]. In equatorial regions exposure to the sun alone is adequate, but at latitudes above 40 degrees north or south and higher, people make little vitamin D in the winter. Measurement of serum 25(OH)D provides direct information. Although its concentration depends on vitamin D production and intake, its serum half-life is much longer than that of vitamin D (weeks versus hours), and it therefore provides an integrated assessment of vitamin D status. Serum 25(OH)D concentrations depend on age, sunlight exposure, vitamin D dietary intake, or supplementation.

3.6. 25(OH)D Assays Used. The spectrum of methods commonly used in research and laboratory practice includes three types: manual immunoassays, automated immunoassays, and direct detection methods. Most instruments or approaches yield reasonably accurate measurements; however, some instruments appear problematic [44]. Several reports have also discussed analogous pitfalls of the assays [55–59]. In a comparison of 25(OH)D assays in Sweden, a high-pressure liquid chromatography (HPLC) assay measured 34 ± 2 ng/mL, a radioimmunoassay (RIA) measured 28 ± 2 ng/mL, and a competitive immunochemiluminescence assay (CILA) measured 24 ± 2 ng/mL [56]. In a comparison of assays with liquid chromatography-tandem mass spectrometry methods in Australia, DiaSorin LIASON, IDS, and Siemens assays met minimum performance goals [59]. In a comparison study in Warsaw, the Elecsys (total vitamin D) from Roche measured about 2 ng/mL higher than the LIASON from DiaSorin [60]. Immunoassays are sensitive to 24,25-dihydroxyvitamin D, which can occur at concentrations up to 5 ng/mL [61]. Vitamin D-binding protein concentrations also affect the accuracy of serum 25(OH)D concentration measurement [62]. Some laboratories validated their assay performance by comparing measurements with samples submitted to the international Vitamin D External Quality Assessment Scheme (DEQAS) [58]. Comparability of 25(OH)D results could be facilitated if all laboratories were to participate with DEQAS.

4. Discussion

To our knowledge, this study is the first to summarize available data regarding vitamin D status and epidemiology in Central European populations of different ages. Most populations and most age groups have at least a moderate deficit of 25(OH)D according to currently binding standard references. The potential limitation we acknowledge is that all studies in this review are either retrospective or cross-sectional. To draw firm conclusions on intraindividual variations in 25(OH)D levels in different seasons, a prospective study design would be desirable. With the exception of two studies [43, 44], no particular inclusion or exclusion criteria for study participation were assumed; therefore, we recognize that studied populations may have been heterogeneous. Furthermore, 25(OH)D3 and total 25(OH)D concentrations were usually similar but not identical, so we analyzed results from studies irrespective of type of vitamin D determination. A review of 394 studies of unadjusted serum 25(OH)D concentrations from around the world found a mean value of 22 ± 1 ng/mL, with no effect of latitude for nonwhites [63]. However, the regression fit to the data for white people went from approximately 40 ng/mL near the equator to approximately 16 ng/mL at the poles. What happens in Europe is still not clear from that paper. Evidently, skin pigmentation (as well as diet at high latitudes) have adapted well to solar UVB doses where people have lived for millennia [48]. A review of serum 25(OH)D concentrations among dark-skinned people living in Europe—primarily those of African, Asian, or Middle Eastern origin—supports this hypothesis. These ethnically different groups had lower serum 25(OH)D concentrations than the indigenous white inhabitants [64]. The three important factors contributing to the difference were darker skin, clothing that covered more skin area, and limited oral vitamin D intake from food. Serum 25(OH)D concentrations in winter do not drop as low as might be expected on the basis of solar UVB doses in winter for two reasons: (1) the decay time of 25(OH)D is 4–6 weeks—that is, the time it takes to drop to half its value—and (2) when serum 25(OH)D concentrations are low, the body converts vitamin D to 25(OH)D much more efficiently [65].

The following question emerges: if the natural sources of vitamin D that arrived at over millennia lead to mean annual serum 25(OH)D concentrations slightly above 20 ng/mL, why is this value not adequate? One point to be addressed is that life expectancy has considerably increased in Europe and elsewhere during the past century because of health care advances that reduced the risk of dying from accidents, digestive diseases, and respiratory and other infections [66]. Europeans are therefore much more likely to die now from cancer or cardiovascular disease. Ecological and observational studies offer moderate evidence that vitamin D reduces the risk of cancer [67–69] and cardiovascular disease [70]. Thus, raising serum 25(OH)D concentrations above 30–40 ng/mL should reduce mortality rates by about 15% and increase life expectancy by 2 years in Europe [71]. Although the above associations may be regarded cautiously and require further long-term prospective investigation, it is rather justified to recommend an individualized vitamin D supplementation to all age groups in CE. The practical approach of such a strategy is aimed to alleviate the vitamin D status in this region—that is, to consequently diminish the risk of 25(OH)D deficits.
5. Summary and Conclusion

The essential finding in this review is that most people living in both Central and Western Europe have serum 25(OH)D concentrations below the optimal values of 30–50 ng/mL. The main reason is that solar UVB, being the primary source of vitamin D, is limited for most CE populations; thus, producing vitamin D from solar UVB from October through March is nearly impossible above 40°N latitude. By consequence, the concentrations are particularly low from October through May, implicating the deficiency to a large extent [15]. Also, most people spend most time indoors and so they produce vitamin D only through casual sunlight exposure, which raises mean serum 25(OH)D concentration from 15 ng/mL in February to 30 ng/mL in September for individuals aged 45 years living in the UK [42]. The groups at particularly high risk of vitamin D deficiency include those largely staying indoors, pregnant and nursing women, newborns, breast-fed infants without vitamin D supplementation, overweight or obese people [72], patients with chronic or infectious disease, and those older than 50 years. A variety of preventive means and interventions can be implemented in CE to increase serum 25(OH)D concentrations, including increased but reasonable solar UVB irradiance, fortification of food, and augmented consumption of vitamin D supplements.

Conflict of Interests

William B. Grant receives funding from Bio-Tech Pharmacal (Fayetteville, AR) and the Sunlight Research Forum (Veldhoven) and has received funding from the UV Foundation (McLean, VA), the Vitamin D Council (San Luis Obispo, CA), and the Vitamin D Society (Canada). Other authors declare that there is no conflict of interests regarding the publication of this paper.

Funding

This work was supported in part by the Polish Grant of MNiSW 5412/B/P01/2010/39 and EU Structural Grant no. POIG.02.01.00-14-059/09.

References

[1] A. C. Ross, J. E. Manson, S. A. Abrams et al., “The 2011 report on dietary reference intakes for calcium and vitamin D from the Institute of Medicine: what clinicians need to know,” Journal of Clinical Endocrinology and Metabolism, vol. 96, no. 1, pp. 53–58, 2011.
[2] W. B. Grant, “Ecological studies of the UVB-vitamin D-cancer hypothesis,” Anticancer Research, vol. 32, no. 1, pp. 223–236, 2012.
[3] P. Pludowski, M. F. Holick, S. Pilz et al., “Vitamin D effects on musculoskeletal health, immunity, autoimmunity, cardiovascular disease, cancer, fertility, pregnancy, dementia and mortality—a review of recent evidence,” Autoimmunity Reviews, vol. 12, no. 10, pp. 976–989, 2013.
[4] P. Pludowski, E. Karczmarewicz, M. Bayer et al., “Practical guidelines for the supplementation of vitamin D and the treatment of deficits in Central Europe—recommended vitamin D intakes in the general population and groups at risk of vitamin D deficiency,” Endokrynologia Polska, vol. 64, no. 4, pp. 319–327, 2013.
[5] C. Palacios and L. Gonzalez, “Is vitamin D deficiency a major global public health problem?” The Journal of Steroid Biochemistry and Molecular Biology, 2013.
[6] J. L. Anderson, H. T. May, B. D. Horne et al., “Relation of vitamin D deficiency to cardiovascular risk factors, disease status, and incident events in a general healthcare population,” The American Journal of Cardiology, vol. 106, no. 7, pp. 963–968, 2010.
[7] J. R. Sabetta, P. DePetrillo, R. J. Cipriani, J. Smardin, L. A. Burns, and M. L. Landry, “Serum 25-hydroxyvitamin d and the incidence of acute viral respiratory tract infections in healthy adults,” PLoS ONE, vol. 5, no. 6, p. e10088, 2010.
[8] L. R. Harms, T. H. J. Burne, D. W. Eyles, and J. J. McGrath, “Vitamin D and the brain,” Best Practice and Research: Clinical Endocrinology and Metabolism, vol. 25, no. 4, pp. 657–669, 2011.
[9] A. Hossein-Nezhad and M. F. Holick, “Vitamin D for health: a global perspective,” Mayo Clinic Proceedings, vol. 88, no. 7, pp. 720–755, 2013.
[10] M. F. Holick, N. C. Binkley, H. A. Bischoff-Ferrari et al., “Evaluation, treatment, and prevention of vitamin D deficiency: an endocrine society clinical practice guideline,” Journal of Clinical Endocrinology and Metabolism, vol. 96, no. 7, pp. 1911–1930, 2011.
[11] M. F. Holick, N. C. Binkley, H. A. Bischoff-Ferrari et al., “Guidelines for preventing and treating vitamin D deficiency and insufficiency revisited,” Journal of Clinical Endocrinology and Metabolism, vol. 97, no. 4, pp. 1153–1158, 2012.
[12] A. Valcour, F. Blocki, D. M. Hawkins, and S. D. Rao, “Effects of age and serum 25-OH-vitamin D on serum parathyroid hormone levels,” The Journal of Clinical Endocrinology and Metabolism, vol. 97, no. 11, pp. 3989–3995, 2012.
[13] J. Charzewska, D. Chlebna-Sokół, A. Chybicka et al., “Recommendations of prophylaxis of vitamin D deficiency in Poland (2009),” Medycyna Wieku Rozwojowego, vol. 14, no. 2, pp. 218–223, 2010.
[14] I. Takács, I. Benkó, E. Toldy et al., “Hungarian consensus regarding the role of vitamin D in the prevention and treatment of diseases,” Orvosi Hetilap, vol. 153, pp. S5–S26, 2012.
[15] B. Vásárhelyi, A. Sátóri, F. Olajos, A. Szabó, and G. Beko, “Low vitamin D levels among patients at Semmelweis University: retrospective analysis during a one-year period,” Orvosi Hetilap, vol. 152, no. 32, pp. 1272–1277, 2011.
[16] J. Dort, M. Bayer, E. Dortová, and V. Hadravová, “Vitamin D and other parameters of calcium and phosphate metabolism in healthy term newborns after birth,” Osteologicky Bulletin, vol. 12, no. 2, pp. 70–73, 2007.
[17] A. Pluta, A. Karwacki, and K. Prószyńska, “Vitamin D status of mothers and newborns in relation to the season of a year,” Polski Tygodnik Lekarski, vol. 42, pp. 254–256, 1987.
[18] J. Czech-Kowalska and A. Dobrzanska, “Vitamin D status in term newborn infants,” Kliniczna Perinatologia i Ginekologia, vol. 36, pp. 41–46, 2002.
[19] J. Czech-Kowalska, A. Dobrzanska, J. Janowska et al., “Neonatal vitamin D status and calcium-phosphorus homeostasis in the third week of life,” Medycyna Wieku Rozwojowego, vol. 8, no. 1, pp. 115–124, 2004.
[20] J. Czech-Kowalska, E. Kryskiewicz, M. Jaworski et al., “Mothers and newborns vitamin D status and bone mass according to season—preliminary results,” Acta Médica Portuguesa, vol. 25, supplement 2, article 151, 2012.

[21] J. Czech-Kowalska, J. Latka-Grot, D. Bulsiewicz et al., “Maternal vitamin D supplementation during lactation—influence on maternal and offspring vitamin D status—randomised control trial—preliminary results,” Standardy Medyczne Pediatria, vol. 9, no. 5, article 730, 2012.

[22] J. Czech-Kowalska, P. Pludowski, A. Dobrzanska et al., “Impact of vitamin D supplementation on markers of bone mineral metabolism in term infants,” Bone, vol. 51, no. 4, pp. 781–786, 2012.

[23] P. Pludowski, P. Socha, E. Karczmarewicz et al., “Vitamin D supplementation and status in infants: a prospective cohort observational study,” Journal of Pediatric Gastroenterology and Nutrition, vol. 53, no. 1, pp. 93–99, 2011.

[24] A. S. Pachkalia, E. V. Rudenka, and H. Zhernosek, “Vitamin D status in healthy Belarusian children in accordance with the blood levels of 25-hydroxyvitamin D3 and total 25-hydroxyvitamin D,” Standardy Medyczne, vol. 9, no. 5, article 743, 2012.

[25] M. Antal, A. Regőly-Mérei, L. Bíró et al., “Nutrition, life-style practice, serum vitamin D concentration and bone density in Hungarian adolescents,” Acta Alimentaria, vol. 35, no. 1, pp. 53–61, 2006.

[26] R. Andersen, C. Mølgaard, L. T. Skovgaard et al., “Teenage girls and elderly women living in northern Europe have low winter vitamin D status,” European Journal of Clinical Nutrition, vol. 59, pp. 533–541, 2005.

[27] T. R. Hill, A. A. Cotter, S. Mitchell et al., “Vitamin D status and its determinants in adolescents from the Northern Ireland Young Hearts 2000 cohort,” British Journal of Nutrition, vol. 99, no. 5, pp. 1061–1067, 2008.

[28] V. A. Snezhitskiy, L. V. Yankovskaya, V. V. Povoroznyuk et al., “Vitamin D deficiency/insufficiency among residents of the western region of Belarus suffering from cardiovascular pathology,” Standardy Medyczne Pediatria, vol. 9, pp. 577–582, 2012.

[29] E. Rudenka, “Vitamin D status among adults living in a Republic of Belarus,” in Proceedings of the “Vitamin D-Minimum, Maximum, Optimum” Conference, Warsaw, Poland, October 2012.

[30] M. Vosatkova, P. Hoskovcova, and R. Bílek, “Vitamin D and its metabolites—supply of patients with various endocrine disorders and comparison of analytical methods,” Endocrine Regulations, vol. 41, no. 1, pp. 19–28, 2007.

[31] O. Mayer Jr., J. Filipovsky, J. Seidlerová et al., “The association between low 25-hydroxyvitamin D and increased aortic stiffness,” Journal of Human Hypertension, vol. 26, no. 11, pp. 650–655, 2012.

[32] M. Kull Jr., R. Kallikorm, A. Tamm, and M. Lember, “Seasonal variance of 25-(OH) vitamin D in the general population of Estonia, a Northern European country,” BMC Public Health, vol. 9, article 22, 2009.

[33] E. Virag, D. Horváth, Z. Löcsei et al., “Vitamin D supply among healthy blood donors in County Vas, Hungary,” Orvosi Hetilap, vol. 153, no. 41, pp. 1629–1637, 2012.

[34] M. Holecki, B. Zalorska-Markiewicz, J. Chudek, and A. Więcek, “Changes in bone mineral density and bone turnover markers in obese women after short-term weight loss therapy during a 5-year follow-up,” Polskie Archiwum Medycyny Wewnętrznej, vol. 120, no. 7-8, pp. 248–254, 2010.

[35] A. Pardej, K. Czerw, M. Gryboś, and W. Guzikowski, “Blood serum hydroxyvitamin D concentration in ovarian cancer,” Ginekologia i Polonoztwo, vol. 22, no. 4, pp. 63–68, 2011.

[36] T. Laskowska-Klita, M. Chelchowska, J. Ambroszkiewicz, P. Kubik, and J. Leibschang, “The effect of vitamin-mineral supplementation on vitamins D, A (beta-carotene) and E concentration in blood of matched maternal-cord pairs,” Przegląd lekarski, vol. 61, no. 7, pp. 755–759, 2004.

[37] Z. Bartoszewicz, A. Kondracka, M. Krasnodebska, B. Niedzwiedzka, and T. Bednarczuk, “Vitamin D deficiency in pregnant women from Warsaw,” Standardy Medyczne, vol. 9, no. 5, article 738, 2012.

[38] P. Masaryk, A. Letkowska, A. Stecová et al., “Prevalence of vitamin D in population of healthy premenopausal women of Slovakia with normal bone mineral density,” Rheumatologia, vol. 24, no. 2, pp. 39–43, 2010.

[39] V. V. Povoroznyuk, N. I. Balatska, F. Klymovytsky, O. Synenky, and V. Vaya, “Frequency of vitamin D deficiency amount Ukrainian population,” Journal of Musculoskeletal and Neuronal Interactions, vol. 12, no. 2, article 109, 2012.

[40] V. V. Povoroznyuk and N. I. Balatska, “Vitamin D deficiency and insufficiency among Ukrainian population: age and gender peculiarities,” Problem of Osteology, vol. 3, pp. 3–6, 2012.

[41] P. Engel, G. Fagherazzi, A. Boutten et al., “Serum 25(OH) vitamin D and risk of breast cancer: a nested case-control study from the French E3N cohort,” Cancer Epidemiology Biomarkers and Prevention, vol. 19, no. 9, pp. 2341–2350, 2010.

[42] E. Hyppönen and C. Power, “Hypovitaminosis D in British adults at age 45 y: nationwide cohort study of dietary and lifestyle predictors,” The American Journal of Clinical Nutrition, vol. 85, no. 3, pp. 860–868, 2007.

[43] H. P. Bhattoa, P. Bettembuk, S. Ganacharya, and A. Balogh, “Prevalence and seasonal variation of hypovitaminosis D and its relationship to bone metabolism in community dwelling postmenopausal Hungarian women,” Osteoporosis International, vol. 15, no. 6, pp. 447–451, 2004.

[44] H. P. Bhattoa, E. Nagy, C. More et al., “Prevalence and seasonal variation of hypovitaminosis D and its relationship to bone metabolism in healthy Hungarian men over 50 years of age: the HunMen Study,” Osteoporosis International, vol. 24, no. 1, pp. 179–186, 2013.

[45] L. Napiórkowska, T. Budlewski, W. Jakubas-Kwitkowska, V. Hamzy, D. Gozdowski, and E. Franek, “Prevalence of low serum vitamin D concentration in an urban population of elderly women in Poland,” Polskie Archiwum Medycyny Wewnętrznej, vol. 119, no. 11, pp. 699–703, 2009.

[46] D. Durup, H. L. Jorgensen, J. Christensen, P. Schwarz, A. M. Heegaard, and B. Lind, “A reverse J-shaped association of all-cause mortality with serum 25-hydroxyvitamin D in general practice, the CopD Study,” The Journal of Clinical Endocrinology and Metabolism, vol. 97, no. 8, pp. 2644–2652, 2012.

[47] B. W. Hollis, D. Johnson, T. C. Hulse, M. Ebeling, and C. L. Wagner, “Vitamin D supplementation during pregnancy: double-blind, randomized clinical trial of safety and effectiveness,” Journal of Bone and Mineral Research, vol. 26, no. 10, pp. 2341–2357, 2011.

[48] N. G. Jablonski and G. Chaplin, “Human skin pigmentation as an adaptation to UV radiation,” Proceedings of the National Academy of Sciences of the United States of America, vol. 107, no. 2, pp. 8962–8968, 2010.
Submit your manuscripts at http://www.hindawi.com