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# Vitamin D deficiency in northern Vietnam: Prevalence, risk factors and associations with bone mineral density

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ABSTRACT

*Purpose:* Vitamin D deficiency has been linked to osteoporosis and also to the risk of cancer, autoimmune disorders and cardiovascular diseases. This study sought to determine the prevalence of, and risk factors for, vitamin D deficiency and its relationship with bone mineral density (BMD) in a Vietnamese population.
*Methods:* This cross-sectional study involved 269 women and 222 men aged 13–83 years, who were randomly selected from urban and rural areas in northern Vietnam. Serum concentrations of 25-hydroxy-vitamin D [25(OH)D] and parathyroid hormone (PTH) were measured by electrochemiluminescence immunoassay. Vitamin D deficiency was defined as serum 25(OH)D levels below 20 ng/mL. BMD was measured by dual X-ray absorptiometry.
*Results:* The prevalence of vitamin D deficiency in women was 30%, almost two-fold higher than in men (16%). Significant predictors of vitamin D deficiency in women were urban residency ($p<0.01$) and age less than 30 years ($p<0.01$), whereas use of contraceptive pills was protective ($p<0.01$). In men, winter season was the only significant predictor of vitamin D deficiency ($p<0.01$). In multiple linear regression analysis, serum levels of 25(OH)D were positively associated with BMD in both women ($p<0.001$) and men ($p<0.001$).
*Conclusions:* These data suggest that the prevalence of vitamin D deficiency is high in the Vietnamese population, and that part of this prevalence could be explained by low exposure to sunlight (urban residency and winter season). The high prevalence of vitamin D deficiency should raise the awareness of potentially important health issues such as osteoporosis within the Vietnamese society.



## Introduction

Osteoporosis and its consequence of fracture represent a global public health problem, because fracture is associated with increased mortality, concomitant morbidity, and reduced quality of life [1]. We have recently reported a high prevalence of osteoporosis in Vietnam [2]. In spite of a high consumption of soy and other phytoestrogens and a sub-tropical climate with high sun exposure, the prevalence of osteoporosis in Vietnam was found similar to that of many Western populations [2–4]. We hypothesize that part of this high prevalence could be explained by vitamin D deficiency in the Vietnamese population.

Vitamin D plays a classically important role in the regulation of calcium and bone metabolism [5–7]. Lack of 25-hydroxy-vitamin D [25(OH)D] is a cause of rickets due to abnormality in bone remodelling, and supplementation of 25(OH)D reverses the abnormal bone formation [8]. Recent studies have also demonstrated the presence of specific receptors in a wide variety of tissues [7,9,10], and indicated many important effects of vitamin D besides bone health [6,7,9]. Indeed, vitamin D deficiency has been associated with certain forms of cancer [9,11–13], type II diabetes [14,15], hypertension and other types of cardiovascular disease [16–19], autoimmune and infectious disease [20–23]. A recent meta-analysis found a marked increase in the risk of mortality among vitamin D deficient individuals as compared to those with normal 25(OH)D levels [24].

Although there is no consensus of a definition of vitamin D deficiency, it has been generally agreed that measurement of 25(OH)D should be used as an indicator of an individual's vitamin D status [8,25]. Serum 25(OH)D levels below 20 ng/mL are considered as “deficiency”. Using

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this criterion, studies on vitamin D status in different populations have shown considerable variation in the prevalence of vitamin D deficiency [26]. The common trend in all studies is that populations in temperate regions have higher prevalence than populations in tropical regions [25,26], which indicates the effect of sunlight exposure on vitamin D variation.

Approximately 90% of vitamin D is synthesized in the skin after sunlight exposure [8,27]. Melanin is extremely efficient in absorbing UVB radiation and thus, increased skin pigmentation markedly reduces vitamin D synthesis [8,28,29]. A small amount of vitamin D can be absorbed through food intake [30]. It is therefore assumed that people living in countries with high amounts of sunlight may have a lower risk of vitamin D deficiency. However, recent studies in tropical countries have indicated that the prevalence of vitamin D deficiency still could be as high as that observed in Western populations [26]. Reports from Hong Kong [31], Malaysia and Singapore [32] have indicated that between 60% and 100% of the population have vitamin D levels below 30 ng/mL, the level that is considered "insufficient". However, these studies were conducted on urban residents who may have a lower level of sunlight exposure than rural residents. Moreover, 25(OH)D production is known to be affected by seasonal variation [33,34] which was not taken into account in these studies.

North Vietnam is perhaps one of the ideal settings for evaluating the effect of urbanization and seasonality on the risk of 25(OH)D deficiency. North Vietnam is located in the Southeast Asia where there is a tropical monsoon climate with different seasons. Due to recent economic development, Vietnam has undergone rapid urbanization, in which there is a clear separation between urban and rural areas. The present study was designed to assess the prevalence of, and risk factors for, vitamin D deficiency in a representative sample of urban and rural women and men in North Vietnam.

## Material and methods

### *Study design*

The study was designed as a cross-sectional investigation with a multistage sampling scheme. Within the setting of northern Vietnam (latitude 21°N), two districts (Dong Da in Hanoi and Kim Bang in Hanam) were selected to represent urban and rural areas, respectively. From each of these districts, 4 communes were randomly selected, and a full list of all inhabitants was obtained from the local government authority which served as the sampling frame. The lists of inhabitants were then sorted by age in 10-year groups. For each age group, a total of 140 individuals (70 women, 70 men) were randomly selected by a computer-generated numbers and invited for screening interview.

Based on published literature [26,30], the prevalence of vitamin D deficiency in the world populations ranged between 30-50%, we estimated that a sample size of 170 individuals would be adequate to calculate the prevalence within 8 percentage points of the true proportion with 95% confidence. In order to estimate the prevalence in both men and women, we aimed to recruit at least 400 individuals.

The research protocol and procedures were approved by the ethics council of Hanoi Medical University. All participants were provided with adequate information about the objectives of the study and had given their oral informed consent to participate, according to the principles of medical ethics of the World Health Organization.

### *Data collection*

A letter of invitation was sent to a total of 980 individuals. Out of these 823 came for screening. Screening interviews were performed at the local health care centre by health professionals from Hanoi Medical University and participants were offered a free health check-up. Exclusion criteria were chronic diseases and disorders which affect vitamin D and bone metabolism such as cancer, malabsorption syndrome, hepatic and renal diseases, diabetes, ongoing pregnancy or lactation, use of medications influencing bone and vitamin D metabolism within the last four weeks, and a history of immobility for more than one month. Women were excluded if they had undergone hysterectomy/oophorectomy.

After screening, a total of 604 individuals fulfilled the inclusion criteria. Out of these 559 attended for the study. They were all subjects to individual interviews carried out at Bach Mai hospital by health professionals from Hanoi Medical University. Data were collected on age, clinical history, lifestyle, dietary habits, smoking, alcohol and coffee intake. Height without shoes (in centimetres) was measured by a wallmounted stadiometer. Weight, without shoes or clothing, was measured on an electronic scale. Body mass index (BMI) was then derived as the ratio of weight (kg) over height squared (in $m^2$).

Bone mineral density (BMD) was measured at lumbar spine (LS), left and right femoral neck (FN) and total hip (TH) in all qualified subjects. The measurement was done with dual energy X-ray absortiometry (DXA) densitometer (Hologic Explorer 4500). The precision error (%CV) in our laboratory was 1.75% for lumbar spine and 1.50% for hips. The machine was standardized by standard phantom every time before measurement. In this analysis, BMD at the lumbar spine was estimated from L1-L4. Femoral neck and total hip BMD used in the analysis were estimated from the right side.

### *Serum analyses*

Blood samples were drawn in the fasting condition and centrifuged within 30 minutes after collection. Serum samples were frozen at −80 °C until analysis. Serum concentrations of 25(OH)D and parathyroid hormone (PTH) were measured by electrochemiluminescence immunoassay (ECLIA, Roche diagnosis). The measuring range was from 4 to 100 ng/mL (10–250 nmol/L) and from 1.2 to 5000 pg/mL (0.127-530 pmol/L) for 25(OH)D and PTH, respectively. The intra-assay coefficient variation (CV) was 5.6% for 25(OH)D and 11.62% for PTH. The inter-assay CVs were 9.9% and 11.9%, respectively.

### *Statistical analysis*

Characteristics of the participants are presented as mean and standard deviation or median and range. For categorical data, frequency counts and percentages are presented. In comparison between men and women, with respect to the characteristics of the participants, *t* test for independent samples was used for continuous data and the Chi-square test for data measured on a nominal scale. To find the most important factors predicting the outcome of vitamin D deficiency (<20 ng/mL) both univariate and stepwise logistic regression analyses were performed. All analyses regarding the regression analyses were done separately for men and women. The predictors were age classes, <30, 30–49, 50–59 and >60 years, height, weight, BMI, residency, season, smoking, alcohol- and coffee drinking and also for women contraceptive pill use. The results from the logistic regression are presented as odds ratio (OR) and 95% confidence interval (CI). Furthermore, univariate and forward stepwise multiple linear regression analysis was used to evaluate to what extent the variation in different BMD measures could be explained by Vitamin D, PTH, age, height, weight, BMI, residency, smoking, alcohol- and coffee drinking and also for women contraceptive pill use. The results from the stepwise regression models are presented as unstandardized regression coefficient, 95% CI and $R^2$. A p-value <0.05 was considered statistically significant.

## Results

The study involved 222 men and 269 women, aged between 13 and 83 years (Table 1). There were no differences between men and women in terms of age and BMI. As expected, men had greater height and weight than women. The prevalence of smoking, alcohol and coffee consumption was several times higher in men than in women.

**Table 1**
Characteristics of participants.

| Variable | Women | Men | P – value |
|---|---|---|---|
| N | 269 | 222 | |
| Age (yr) | 50 (13–80) | 49 (14–83) | 0.426 |
| Weight (kg) | 48 (31.5-68.0) | 53 (35–85) | <0.001 |
| Height (cm) | 154 (134–168) | 164.2 (148–181) | <0.001 |
| Body mass index (kg/m$^2$) | 20.4 (13.5-30.2) | 19.7 (14.5-30.8) | 0.085 |
| Current smoking* | 1 (0.4%) | 96 (43.2%) | <0.001 |
| Alcohol drinking* | 11 (4.1%) | 124 (55.9%) | <0.001 |
| Coffee drinking* | 21 (7.8%) | 46 (20.8%) | <0.001 |
| 25(0 H)D (ng/mL) | 23.2 (7.4) | 28.6 (8.9) | <0.001 |
| 25 (OH) D<20 ng/mL | 82 (30.5%) | 35 (15.8%) | <0.001 |
| PTH (ng/L) | 29.1 (11.2) | 31.8 (13.5) | <0.05 |
| BMD, femoral neck (g/cm$^2$) | 0.69 (0.11) | 0.76 (0.12) | <0.001 |
| BMD, total hip(g/cm$^2$) | 0.78 (0.11) | 0.85 (0.12) | <0.001 |
| BMD, lumbar spine (g/cm$^2$) | 0.83 (0.15) | 0.90 (0.14) | <0.001 |

Age, weight, height, and BMI are given as median and range (in brackets); 25(OH)D, PTH and BMD are given as mean and standard deviation (in brackets); and *categorical variables are given as number and percentage (in brackets).

Serum levels of 25(OH)D and PTH were significantly higher in men than in women (Table 1). The prevalence of vitamin D deficiency, as defined as 25(OH)D<20 ng/mL, was twice as large in women and reached 30% in comparison with 16% in men. Values of BMD in femoral neck, total hip and lumbar spine were significantly higher in men than in women.

The prevalence of vitamin D deficiency differed significantly between age groups in both women and men (Fig. 1). Indeed in women the prevalence was found to be highest in the age groups younger than 30 years as well as older than 60 years compared with those between 30–59 years ($p<0.01$). A similar trend was also observed in men, i.e. the prevalence of vitamin D deficiency was highest in the youngest age group (less than 30 years) compared with the older age groups ($p<0.05$).

There was also a markedly higher prevalence of vitamin D deficiency among women and men living in urban areas than in rural areas ($p<0.001$) (Fig. 2). While the prevalence was similar for subjects of both sexes living in urban areas, vitamin D deficiency in rural areas was significantly higher in women than in men ($p<0.001$).

The prevalence of vitamin D deficiency varied significantly by season (Fig. 3). Indeed vitamin D deficiency was more prevalent in the winter season (December and January) than in autumn (October and November) and summer (May and June) for both women and men ($p<0.001$). In the summer and autumn seasons, but not in the winter, the prevalence of vitamin D deficiency was significantly higher in women than in men ($p<0.01$, respectively).

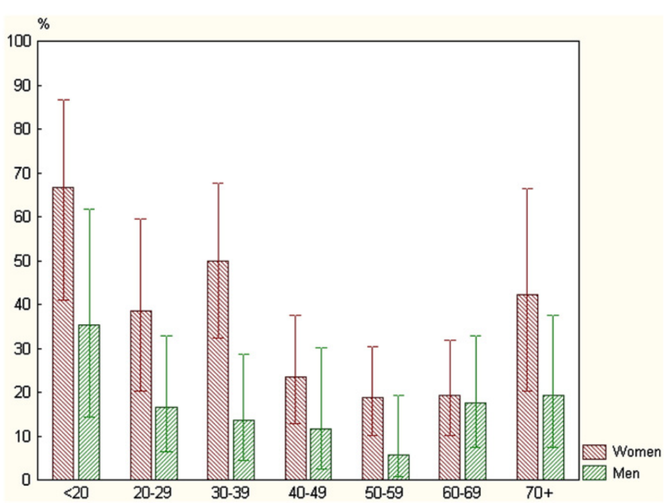


**Fig. 1.** Prevalence of vitamin D deficiency (<20 ng/mL) by age and sex.

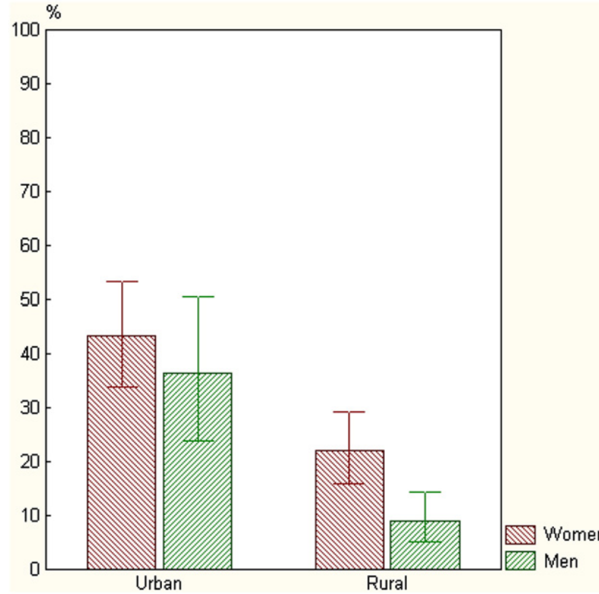


**Fig. 2.** Prevalence of vitamin D deficiency (<20 ng/mL) by area and sex. The prevalence of vitamin D deficiency in both women and men was significantly higher in urban areas than in rural areas ($p<0.001$, respectively). In rural areas, vitamin D deficiency was significantly higher in women than in men ($p<0.001$).

Multiple linear regression analysis revealed that the strongest predictors of vitamin D deficiency in women were age less than 30 years ($p<0.01$) and living in urban area ($p<0.01$), whereas the use of contraceptive pill was protective ($p<0.01$) (Table 2). In univariate analyses, winter season ($p<0.001$) and coffee drinking ($p<0.05$) were also associated with vitamin D deficiency in women. In men, multiple regression analysis showed that winter season was the only significant predictor of vitamin D deficiency ($p<0.01$) (Table 2). In the univariate analyses, urban area ($p<0.001$) and younger age than 30 years compared

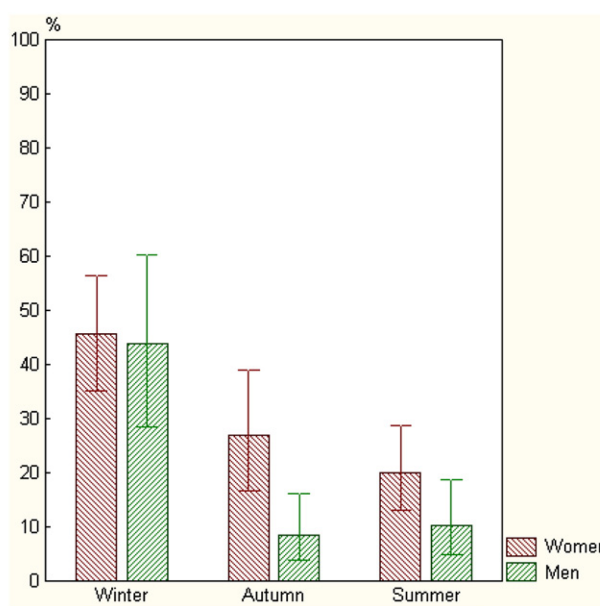


**Fig. 3.** Prevalence of vitamin D deficiency (<20 ng/mL) by season and sex. The prevalence of vitamin D deficiency was significantly higher in winter than in autumn and summer for both women and men ($p<0.001$, respectively). In summer and autumn seasons, the prevalence of vitamin D deficiency was significantly higher in women than in men ($p<0.01$, respectively).

**Table 2**
Significant predictors for vitamin D deficiency (<20 ng/mL) in women and men.

| Variables | Women | | Men | |
|---|---|---|---|---|
| | Univarate | Multivariate | Univariate | Multivariate |
| Age<30 **vs** 30–49 years | ns | ns | ns | ns |
| 50-59 year | **0.23 (0.10-0.55)** | **0.26 (0.11-0.64)** | **0.21 (0.04-0.99)** | ns |
| >60 years | **0.33 (0.15-0.73)** | **0.29 (0.13-0.66)** | ns | ns |
| Weight (kg) | ns | ns | ns | ns |
| Height (cm) | ns | ns | ns | ns |
| Body mass index (kg/m$^2$) | ns | ns | ns | ns |
| Current smoking | na | na | ns | ns |
| Alcohol drinking | na | na | ns | ns |
| Coffee drinking | **2.74 (1.12-6.74)** | ns | ns | ns |
| Contraceptive pill use | **0.246 (0.07-0.84)** | **0.19 (0.05-0.67)** | na | na |
| Urban vs Rural | **2.71 (1.59-4.61)** | **2.65 (1.50-4.70)** | **5.79 (2.7-12.43)** | ns |
| Winter vs summer | **3.36 (1.80-6.26)** | ns | **6.78 (2.69-17.11)** | **7.63 (2.94-19.81)** |
| Autumn vs summer | ns | ns | ns | ns |

Data shown as odds ratio (OR) and 95% CI; na: not analyzed, ns: not significant.

to middle age (50–59 years) ($p<0.05$) were also associated with vitamin D deficiency in men.

The relationship between serum levels of 25(OH)D, PTH and BMD was examined in multiple regression analysis. Among women, serum levels of 25(OH)D were significantly associated with BMD in total hip ($p<0.001$). Also, serum levels of PTH were associated with BMD in the femoral neck and the lumbar spine ($p<0.001$) (Table 3). In men, there were positive associations between vitamin D concentration and BMD in both total hip and lumbar spine ($p<0.001$, respectively). Among predictors for BMD in women, age, body weight, residence, coffee drinking, serum level of PTH and 25(OH)D were estimated to explain around 40% of the variation in BMD at different sites. In men, significant predictors for BMD were age, BMI and vitamin D concentration.

## Discussion

Due to lack of data, it is commonly believed that vitamin D deficiency is more prevalent in Caucasian populations than in tropical populations [26]. However, in the present study, we found that more than 30% of the women and 16% of the men in a Vietnamese population had serum levels of 25(OH)D below 20 ng/mL (50 nmol/L). Moreover, in this population, we found that being woman, of younger age, living in city and winter season were independent predictors of vitamin D deficiency.

There is no general consensus on which circulating levels should be representative for sufficient amounts of vitamin D, but certainly all authorities agree that a cut off level below 20 ng/mL is a strong indicator of deficiency [8,26,35,36]. Such low levels have been clearly linked not only to osteoporosis but also to a variety of severe conditions like hypertension, other cardiovascular diseases and cancer [6,16]. According to some authors, even levels below 30 ng/mL should be regarded as vitamin D insufficiency and still represent significant risk factor. However, this notion is more controversial and uncertain [26,37]. In the present material, more than 80% of the women and 60% of the men had 25(OH) D values below 30 ng/mL.

The prevalence of vitamin D deficiency (30% for women and 16% for men) in our study is much higher than the findings in the urban Ho Chi Minh City in the southern Vietnam (13% for women and 2% for men) [38] and in Thailand [39,40]. On the other hand, the prevalence is lower than what has been reported for Vietnamese immigrants in Oslo [41] or Vietnamese people living in Sydney [42]. Similarly, it is lower than in North China (Beijing), Hong Kong (where 90% of young women had vitamin D levels lower than 20 ng/mL) [43,44], Indonesia, Malaysia [45], and India [46]. However, the prevalence in our study is comparable to Caucasian Americans in the USA [47] and also to recent findings from Australia [48]. The variation in prevalence of vitamin D deficiency might be due to differences in ethnicity, pigmentation, nutrition and sun light exposure.

Aging is associated with decreased concentrations of the precursor 7-dehydrocholesterol in the skin and thus a reduced capacity to produce vitamin D. Therefore, a higher proportion of 25(OH)D deficiency among older people could have been expected. However, except for those over 70 years, we found a higher prevalence among both men and women below the age of 30 as compared to those aged 30–59. The difference

**Table 3**
Significant predictors for BMD in women and men.

| Variables | Femoral neck | | Total hip | | Lumbar spine | |
|---|---|---|---|---|---|---|
| | Women | Men | Women | Men | Women | Men |
| Age (yr) | **−0.004** (−0.005)-(−0.004) | **−0.004** (−0.005)- (−0.003) | **−0.004** (−0.004)- (−0.003) | **−0.003** (−0.003)- (−0.002) | **−0.06** (−0.007)- (−0.005) | **−0.002** (−0.003)- (−0.001) |
| Weight (kg) | **0.005** (0.004)-(0.007) | ns | **0.006** (0.004)-(0.008) | ns | **0.006** (0.004)-(0.008) | ns |
| Height (cm) | ns | ns | ns | ns | ns | ns |
| Body mass index (kg/m2) | ns | **0.014** (0.010)-(0.002) | ns | **0.17** (0.012)-(0.022) | ns | **0.017** (0.010)-(0.024) |
| Current smoking | na | ns | na | ns | na | ns |
| Alcohol drinking | ns | ns | ns | ns | ns | ns |
| Coffee drinking | ns | ns | ns | ns | **−0.68** (−0.119)- (−0.016) | ns |
| Contraceptive pill | **0.041** (0.008)-(0.074) | na | ns | na | **0.69** (0.26)-(0.11) | na |
| Urban vs rural | **0.05** (0.029)-(0.072) | ns | **0.54** (0.30)-(0.78) | ns | ns | ns |
| PTH (ng/L) | **- 0.001** (−0.002)- (0.000) | ns | ns | ns | **−0.001** (−0.003)-(0.000) | ns |
| 25(OH) D (ng/mL) | ns | ns | **0.002** (0.000)-(0.003) | **0.002** (0.000)-(0.003) | ns | **0.02** (0.000)-(0.004) |
| **R²** | 0.45 | 0.40 | 0.38 | 0.27 | 0.47 | 0.16 |

Data shown as unstandardized regression coefficients (b), 95% CI and total adjusted $R^2$.
na: not analyzed, ns: not significant.

was more apparent among the women than for the men. This finding could possibly reflect an effect of different clothing practices on vitamin D synthesis [26,38]. Following the rapid economic growth and an increasing cultural influence from e.g. western countries, white skin may have become part of a modern "beauty concept", especially attractive to the younger generation of women. The trend among younger people to try to avoid exposure to sunlight was also observed in a previous study from urban residents in Ho Chi Minh City [38].

Besides gender and age, multiple regression analysis demonstrated that residence and season were the strongest predictors of vitamin D deficiency in the investigated population. As expected, the prevalence of 25(OH)D deficiency was significantly higher among the participants from the urban Hanoi than for those from the rural district of Hanam. Limiting outdoor activity will clearly reduce the amount of sun exposure and the cutaneous vitamin D formation [26]. Urbanization is known as a predictor of low levels of vitamin D and has been identified as a risk factor for deficiency in previous reports from Asia and the Middle East [46]. Both men and women more often work indoors compared to those in rural areas. In the present material, about 35 percent of the young women (<30 years) were employed. However, for this group there was no apparent association between the length of working hours and vitamin D levels ($r=-0.06$). Also, air pollution in cities could contribute by acting as a barrier against UV light. However, in women the prevalence of vitamin D deficiency was also high in rural areas, and significantly higher than in men. This may indicate that women in general are more prone to cover their skin with clothing than men.

Synthesis of vitamin D is dependent on solar radiation of the skin. Latitude and seasonal variations influence the amount of possible solar radiation that a population may receive. Here the prevalence of vitamin D deficiency was much more pronounced in blood samples collected during the winter season (December and January) than in samples from autumn (October and November) and summer (May and June). This difference was apparent in both women and men and there was a significant trend for seasonal variations. Summer values for vitamin D deficiency were similar to those previously reported for urban residents in Ho Chi Minh City, which has a more tropical climate than the northern part of the country. This finding is in agreement with several previous reports, and seasonal variations in 25(OH)D concentration have been found even in subtropical locations [26]. Adjustment for seasonal variation would be important for the definition of threshold values for vitamin D deficiency in different populations.

In women, the use of oral contraceptives was associated with lower risk of vitamin D deficiency. Activated vitamin D is bound to a binding protein in the circulation and estrogen is known to stimulate the production of this protein in the liver [49]. Furthermore, estrogen stimulates hydroxylation of vitamin D in the skin. By these two mechanisms oral contraceptives may enhance the levels of vitamin D.

Vitamin D is an important hormone for calcium and bone metabolism. Vitamin D deficiency has been linked to malabsorption of calcium and may cause secondary hyperparathyroidism. Vitamin D deficiency will increase bone resorption, cortical bone loss and the risk of fracture [5–7,50]. Age, gender, body weight, smoking, alcohol and coffee have been implied as other risk factors for osteoporosis [51]. Smoking, alcohol, and coffee consumption were more frequent in men. The average levels of vitamin D, PTH and BMD were all higher in men than in women. The individual variation of PTH values was large and the mean level was lower in women although they also had lower vitamin D levels than men. However, individual serum levels of 25(OH)D were positively associated, and PTH levels negatively associated with BMD at different sites in women. In men, vitamin D concentrations were also positively associated with BMD at total hip and lumbar spine.

We previously reported a high prevalence of osteoporosis in a sample of Vietnamese women [2]. Vitamin D deficiency has been linked to osteoporosis, and also to risk of cancer, autoimmune disorders and cardiovascular disease [6,11,20]. The high prevalence of vitamin D deficiency in the present material should raise the awareness of potentially important health issues within the Vietnamese society. Young women in urban areas may be an especially important target group for information about possible risks associated with vitamin D deficiency. Screening for 25(OH)D levels during pregnancy might be important for this risk group. Efforts to change attitudes towards sun exposure and the perception that white skin is a mark of attractiveness and a measure of high social status should be carried out. In fact, tanning has been associated with optimal vitamin D levels and higher BMD [52]. Defining resident groups at risk for vitamin D deficiency should be important to stimulate prevention strategies employed in a clinical setting. Vitamin D supplementation, increased exposure to UV light, fortification of food products with vitamin D and recommendations for better dietary intake could all be important tools and help to reduce potential health problems on a national level. At present, foods are not fortified with vitamin D in Vietnam.

This is one of the largest studies of vitamin D status in the Asian population. Therefore, it increased the reliability of estimation of vitamin D deficiency in age- and sex-subgroups. Furthermore, the results can be generalized for both urban and rural settings. The study population was highly homogeneous, which reduces the effects of potential ethnic confounders that could compromise the estimates. Moreover, the technique employed to measure 25(OH)D was a novel Elecsys vitamin D3 automated assay, which has been shown to be a precise method and highly concordant with the HPLC and liquid chromatography tandem mass spectrometry methods [53]. Nevertheless, the study has some potential weaknesses. Levels of 25-hydroxyvitamin D2 (ergocalciferol) and 1,25(OH)D were not measured in this study. Some specific foods e.g. sun dried mushroom, may contain significant amounts of 25-hydroxyvitamin D2. However, the occurrence of these vitamin D metabolites in blood is very low and levels of 25(OH)D are considered to adequately reflect Vitamin D status. This was a cross-sectional study, so no causal inferences could be made for the observed relationships between factors.

In conclusion, our study showed a high prevalence of vitamin D deficiency in a Vietnamese population, corresponding to 30% in women and 16% in men. The strongest risk factors in women were younger age and living in urban residency, whereas winter season was the strongest predictor of vitamin D deficiency in men. These results indicate the importance of sun exposure for vitamin D status. Serum levels of 25(OH)D and vitamin D deficiency were significantly associated with bone mass in both women and men. The high prevalence of vitamin D deficiency should raise the concern about bone health, including risk of osteoporosis and fracture within the Vietnamese society.

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