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Original article

Prevalence of vitamin D deficiency and the effect of anthropometric and lifestyle factors on thevitamin D statuses of healthy women residing in Riyadh

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Summary. *Objective:* Hypovitaminosis D is a global health issue, and its increasing prevalence affects people of all ages. This study aimed to determine the vitamin D statuses of healthy women residing in Riyadh, based on measured serum calcidiol ($25(OH)_2D_3$) levels and to assess the effects of demographic, anthropometric, and lifestyle factors on vitamin D status. *Method:* A structured questionnaire was designed and completed after patient consent acquisition to obtain demographic, anthropometric, and lifestyle information. A food frequency questionnaire was used to assess dietary intake, and an immunoassay was used to determine serum vitamin D levels. *Result:* The mean age of the participants was 33.46 years, and approximately 56% of the participants reported no exposure to sunlight. Only 26.98% of the participants had a normal body mass index (BMI), and 42.86% of the participants had a waist circumference <80 cm. Approximately 86% of the participants were identified as vitamin D deficient (mean, 22.73 nmol/L), and only 7.94% had a normal vitamin D concentration (mean, 96.34 nmol/L) with a cutoff value of 50 nmol/L (for deficiency). A highly significant difference ($p \leq 0.05$) was found between the means of various vitamin D status groups. Regarding BMI, the difference in vitamin D levels was highly significant ($p \leq 0.05$). There was a strong, positive, and highly significant ($p \leq 0.05$) correlation between BMI and waist circumference and a negative (or inverse) correlation between BMI and vitamin D and between waist circumference and vitamin D. The participants' diets were found to be deficient in vitamin D-rich foods. *Conclusion*: Education to enhance awareness of the importance of vitamin D is needed, and vitamin D supplementation apart from adequate sun exposure and suitable dietary intake is suggested for individuals with serum calcidiol $25(OH)_2D_3$ levels below 50 nmol/L.

Key words: vitamin D, BMI, sunlight, Riyadh, obesity

Introduction

Vitamin D is a fat-soluble vitamin and preprohormone (1) that is known to be found in two forms, vitamin D_2 (also known as ergocalciferol) and vitamin D_3 (also known as cholecalciferol) (2). Vitamin D_2 is mostly obtained from foods, such as fish, egg yolk, and mushrooms, and vitamin D_3 is formed in the skin after exposure to sunlight or ultraviolet light (3-4). Hypovitaminosis D is a worldwide issue, and approximately one billion people are at risk regardless of their ethnicity and age group (5-6). There are several causes of vitamin D deficiency, including decreased bioavailability, decreased synthesis, increased catabolism or metabolic demands, and increased urinary loss (7). Other factors that contribute to a low vitamin D level are cultural norms that lead to a lack of sunlight exposure, such as clothing style, housing designs, and outdoor sun protection (8, 9). Although sun exposure is considered a major source of vitamin D, the prevalence of its deficiency is paradoxically much higher in countries with a sunny climate, such as Saudi Arabia (10), Egypt (11), and the United Arab Emirates (12) than in those with a less sunny climate. The status of vitamin D is of great interest given that vitamin D insufficiency is widespread worldwide (13). Vitamin D is recognized for its physiological role in regulating calcium homeostasis (14) by increasing the efficacy of intestinal calcium and phosphorus absorption to maintain signal transduction, neuromuscular function, and metabolic activities and to promote skeletal mineralization (15). Its receptors are expressed in multiple tissues within the body, including vascular smooth muscle, the endothelium, and cardiomyocytes (14). Inadequate vitamin D levels in the body have been linked to osteomalacia due to a skeletal mineralization defect, and its insufficiency is a risk factor for osteoporosis in adults (16). In children, its deficiency leads to rickets (8).

Increasing evidence from biochemical, cellular, animal, and epidemiological investigations also highlights vitamin D as a pleiotropic regulator of several physiological processes, including the modulation of immune responsiveness, cellular differentiation and proliferation and central nervous system function (17). Epidemiological studies have reported that lower vitamin D levels are associated with diabetes-related microvascular complications (18), retinopathy (19), multiple sclerosis (20) hypertension and cardiovascular disease (21) and that a higher vitamin D level is related to a reduced cancer incidence and decreased cancer-related mortality (22).

Although Saudi Arabia receives a substantial amount of sunlight throughout the year, many Saudi Arabian people have severe vitamin deficiency, particularly Saudi Arabian women (23). The objective of this study was to determine vitamin D status by measuring serum calcidiol ($25(OH)_2D_3$) levels and to assess the effects of demographic, anthropometric, and lifestyle factors on the vitamin D statuses of healthy women (young and old) residing in Riyadh.

Methods

Research design

A descriptive cross-sectional approach was used in the present study. Sixty-three women (age range between 20 and 80 years) were recruited using a random sampling method. A pro forma of inclusion and exclusion criteria for selection of participants was prepared, and a house-to-house survey was then conducted to find participants.

Inclusion criteria

All nonpregnant and nonlactating Saudi women who consented to provide blood samples were included in this study.

Exclusion criteria

Women without Saudi Arabian nationality; women who were pregnant and lactating; women previously diagnosed with metabolic bone diseases, diabetes mellitus, cardiovascular disease, or renal, hepatic endocrine or autoimmune diseases; and women unwilling to provide blood samples were excluded from the study.

Ethical considerations

This study was conducted in accordance with research policies of the King Saud University Research Centre. The purpose of the study was explained to all participants, and written consent was obtained. Participants' blood samples were withdrawn by a qualified nurse, and the participants were assured that the information they provided would be used exclusively for scientific purposes and be kept confidential.

Demographic characteristics

A structured questionnaire was completed after the acquisition of informed consent while interviewing the participants to obtain demographic information. Demographic characteristics included age and occupation. The second section of the questionnaire included risk factors for vitamin D deficiency, such as housing conditions, nonexposure to sunlight, and clothing habits. Participants were questioned about their duration of time spent in sunlight and principal exposure times during the day, their use of sunscreen, and their dietary habits. Anthropometric measurements were undertaken by the study researcher. The comprehensiveness and relevance of the study tools were reviewed by a panel of experts, and a pilot study was undertaken to test the validity and applicability of the measurement tools.

Anthropometric measurements

Anthropometric measurements in this study included body weight, height and waist circumference. All anthropometric measures were assessed by the researcher, and the participants were measured barefoot and wearing light-weight clothing. Height and weight were used to calculate BMI (weight (kg)/height^2 (m)^2). The participants were classified as follows: underweight (BMI <18.5), normal (BMI between 18.5 and 24.9), overweight (BMI between 25 and 29.9), or obese (BMI >30) (24).

Dietary assessment

A food frequency questionnaire was used for dietary assessment. Participants were interviewed by a nutritionist to gather information regarding their consumption frequency of vitamin D-related food items, such as milk, fish, eggs, and mushrooms. The questionnaire included details regarding the exact portion sizes of the food consumed (serving size), the parts consumed (whole, half, quarter), and the fat content of the food (skim, low-fat, full-fat, fortified).

Biochemical tests

All participants were asked to keep a dietary record and were instructed not to take part in any high-intensity physical activity 12 hours prior to providing blood samples. Blood samples were acquired by a specialized nurse at King Khalid University Hospital after the participants had fasted for 8 hours. Samples were collected in sample tubes and centrifuged at 3,000 rpm for 10 minutes to prepare the serum. Vitamin D serum ($25(OH)_2D_3$) levels were assessed with an immunoassay using a radioactive device (Roche Analyzer Cobas e170 Immunoassay, Roche Diagnostic, USA) according to the method proposed by Vieth et al. (25).

A general definition of vitamin D deficiency could not be determined because there is no universally agreed cutoff value or normal range for serum $25(OH)_2D_3$ levels. The cutoff values for vitamin D have long been debated. The US Endocrine Society and the American Geriatric Society consider vitamin D levels inadequate if serum $25(OH)_2D_3$ levels are <50 nmol/L (<20 ng/ml). The US Institute of Medicine and the UK National Osteoporosis Society consider serum $25(OH)_2D_3$ levels <30 nmol/L (<12 ng/ml) to be inadequate, and both the WHO and the German Nutrition Society consider serum $25(OH)_2D_3$ levels <25 nmol/L (<10 ng/ml) to be inadequate (26). For the present study, the participants were grouped according to their vitamin D levels as follows: deficient (<50 nmol/L), relative insufficient (between 50 nmol/L and 72 nmol/L) and normal (>72 nmol/L) (27).

Statistical analysis

Data were analyzed using the SPSS statistical software package (version 22). Frequencies are presented as percentages (%), and continuous variables are presented as the mean ± standard deviation. The participants were stratified into 3 groups according to their serum $25(OH)_2D_3$ concentrations as follows: <50 nmol/L, between 50 nmol/L and 72 nmol/L, and >72 nmol/L. Pearson's chi-square test was performed to compare frequencies and to test differences between group proportions for categorical variables, and one-way ANOVA was used to determine associations between quantitative variables.

Results

Table 1 depicts the demographic characteristics, anthropometric measurements, and lifestyle habits of the participants. In this study, 49.21% of the participants were between 20 and 30 years of age, and 22.22% and 17.46% were between 31 to 40 and 41 to 50 years of age, respectively. Only 11.11% of the participants were greater than 50 years old. Approximately 30% of the participants were students, 27% were currently employed, and 42.86% were housewives. Sixty percent of the participants lived in villas, and the remainder lived in apartments. A total of 79% of the participants reported no vitamin D supplementation consumption of any type, and approximately 56% of the participants reported no exposure to sunlight. Approximately 42% of the participants were obese, and 28.57% were overweight. The percentage of participants with a normal BMI was 26.98%. A total of 42.86% of the participants had a waist circumference <80 cm, while 23.81% of the participants had a waist circumference between 80 cm and 90 cm, and 33.33% of the participants exhibited a waist circumference of more than 90 cm. Ta-

Table 1. Participant demographic characteristics, anthropometric measurement, and lifestyle habits

		Frequency	Percentage (%)
Demographic characteristics and lifestyle habits			
Age (Years)* (33.46±15.26)	20-30	31	49.21
	31-40	14	22.22
	41-50	11	17.46
	51 and over	7	11.11
Occupation	Student	19	30.16
	Job/Working	17	26.98
	Housewife	27	42.86
Housing	Villa	38	60.32
	Apartment	25	39.68
Do you take a vitamin D supplement?	Yes	13	20.63
	No	50	79.37
Do you expose yourself to sunlight?	Yes	28	44.44
	No	35	55.56
How often (days) do you expose yourself to sunlight?	Daily	17	26.98
	Alternate days	4	6.35
	No routine	7	11.11
	No exposure at all	35	55.56
Time of sunlight exposure (n=28)	6 to 9 am	5	17.86
	9 to 12 pm	16	57.14
	12 to 3 pm	7	25
Anthropometric measurements			
BMI* (30.42±9.67)	Underweight	2	3.18
	Normal	17	26.98
	Overweight	18	28.57
	Obese	26	41.27
Waist circumference* (84.43±16.65)	>80	27	42.86
	80-90	15	23.81
	<90	21	33.33

**Data are expressed as the mean ± std dev.*

Table 2. Distribution of serum $25(OH)_2D_3$ status of participants

Serum $25(OH)_2D_3$ status	Mean $25(OH)_2D_3$	Frequency	Percentage (%)	p value
Deficiency	22.73±9.42[a]	54	85.72	0.00
Relative insufficiency	60.35±6.25[b]	4	6.34	
Normal	96.34±8.33[c]	5	7.94	

Data are expressed as the mean ± standard deviation; Model ANOVA, p values < 0.05 are significant. Superscript abc indicate significant differences among serum $25(OH)_2D_3$ statuses as indicated by ANOVA followed by Duncan's multiple range test.

Table 3. Distribution of serum $25(OH)_2D_3$ levels, based on BMI and age

	N	Deficiency		Relative insufficiency		Normal		Chi squared value	P value
		No:	%	No:	%	No:	%		
Based on BMI								13.124	0.041
Underweight* (48.95±38.25)	2	1	50	0	0	1	50		
Normal* (30.23±22.15)	17	15	88.24	1	5.88	1	5.88		
Overweight* (32.29±25.52)	18	16	88.89	2	11.11	0	0		
Obese* (25.88±14.64)	26	22	84.62	1	3.85	3	11.53		
Based on Age								6.995	0.321
20-30* (26.79±19.48)	31	29	93.55	0	0	2	6.45		
31-40* (34.90±28.72)	14	11	78.57	1	7.14	2	14.29		
41-50* (37.17±28.61)	11	8	72.73	2	18.18	1	9.09		
51 and above* (28.04±17.33)	7	6	85.71	1	14.29	0	0		

** Data are expressed as the mean± standard deviation; p values < 0.05 are significant.*

ble 2 depicts the distribution of the serum $25(OH)_2D_3$ level statuses of the participants, and Table 3 depicts their BMI and age distributions. In the present study, the mean serum $25(OH)_2D_3$ level was 30.96±23.28 nmol/L (range, 5-105 nmol/L). Approximately 86% of the participants were found to be vitamin D deficient, with a mean value of 22.73 nmol/L, while the vitamin D concentrations in 6.34% of the participants were relatively insufficient, with a mean value of 60.35 nmol/L. Only 7.94% of the participants had a normal vitamin D concentration, with a mean value of 96.34 nmol/L, at a cutoff value of 50 nmol/L (for deficiency). A highly significant difference ($p \le 0.05$) was found between the means of various vitamin D status groups, and the difference in vitamin D levels was also highly significant ($p \le 0.05$) with regard to BMI. Only 17 women had a normal BMI, whereas 44 women were either overweight or obese. The results show that the highest number of participants (93.55%) deficient in serum $25(OH)_2D_3$ belonged to the age group between 20 and 30 years of age, followed by the older participants classified in the age group 51 years and older (85.71%), with mean serum $25(OH)_2D_3$ levels of 26.79 nmol/L and 28.04 nmol/L, respectively. A strong, positive, and highly significant ($p \le 0.05$) correlation was found between BMI and waist circumference (i.e., larger waist circumference measurements were correlated with a higher BMI), and a negative (or inverse) correlation was found between BMI and vitamin D (i.e., a higher BMI was correlated with a decreased vitamin D concentration) and between waist circumference and vitamin D (i.e., larger waist circumference

Table 4. Correlation between BMI, waist circumference and serum 25(OH)$_2$D$_3$ concentration in the studied sample

	BMI	Waist	Vitamin D
BMI	1	-0.658**	-0.006*
Waist	0.658**	1	-0.136
Vitamin D	-0.006*	-0.136	1

*** Correlation is significant at the 0.01 level (2-tailed)*

measurements were correlated with a decreased vitamin D concentration (Table 4). Figure 1 gives a brief description of the serum 25(OH)$_2$D$_3$ level distribution based on dietary intake. The percentage of participants consuming fish and mushrooms was very low, although fish is one of the best sources of vitamin D.

Discussion

Addressing health disparities is a major focus of current public health efforts (28), and during the last decade, no other micronutrient has gained as much attention in the health and biomedical research community as vitamin D (29). This study identified a number of demographic, environmental, and lifestyle factors associated with vitamin D levels. Various factors, such as environmental and lifestyle factors as well as demographic factors, are determinants of serum 25(OH)$_2$D$_3$ concentrations. Some studies suggest that vitamin D intake, sex, outdoor activity, latitude, season, age, and body fat levels are major determinants of the serum 25(OH)$_2$D$_3$ concentration (13, 30). Serum 25(OH)$_2$D$_3$ is most reflective of overall vitamin D stores and is used in research and clinical practice to determine vitamin D status.

In this study, only one fourth of the participants were exposed to sunlight on a daily basis, while more than 50% reported never being exposed to sunlight at all, which is consistent with the results of a cross-sectional study performed on females from Riyadh (31). Limited sun exposure is one of the main causes of vitamin D deficiency (14, 32) in addition to having an indoor lifestyle, prolonged breastfeeding, and lack of a

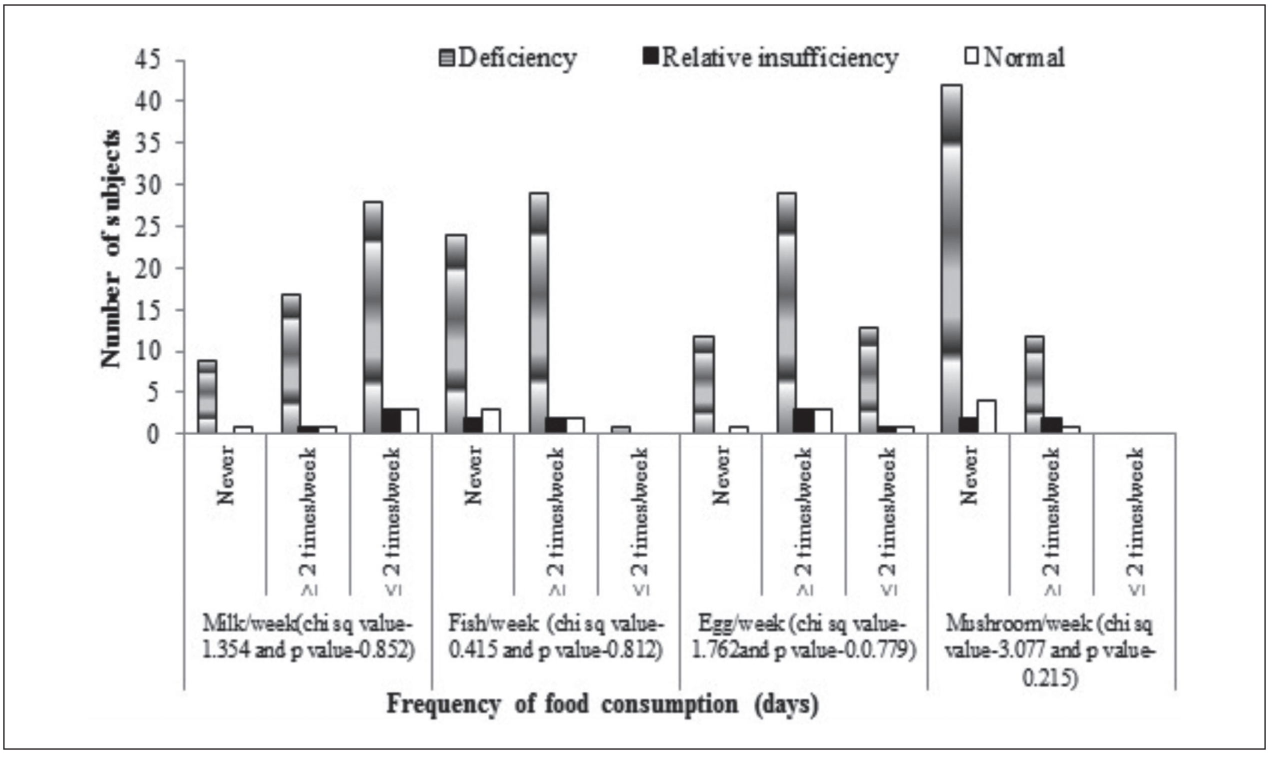

Figure 1. Distribution of serum 25(OH)$_2$D$_3$ levels based on dietary intake.
p values < 0.05 are significant.

balanced diet (33, 34). Moreover, because the body is covered for cultural reasons and because of intense heat and high temperatures, people tend to remain mainly indoors (6). In Muslim countries such as Saudi Arabia, Muslim women wear clothes (the abaya, hijab, and niqab) that completely cover their head and body; they seldom have any chance to expose their bodies to sunlight and are often vitamin D deficient (35). In a previous study, it was reported that covering the skin with clothing prevents the skin from contacting UV-B rays, which are essential for the production of vitamin D (6). The color of the skin of Saudi individuals varies from light brown to dark. Dark pigmentation has been found to decrease skin synthesis of vitamin D because ultraviolet light cannot reach the appropriate layer of the skin (36). In a study on Turkish women who wore veils (only the hijab), the mean serum $25(OH)_2D_3$ level was 32 nmol/L, while it was only 9 nmol/L when they were completely covered (niqab) and 56 nmol/L in those who wore Western-style clothing (37,38). In contrast, another study found no difference in vitamin D levels between veiled and nonveiled Bangladeshi women (39).

In this study, a large percentage (86%) of the participants was identified as vitamin D deficient, which is very similar to the results (83.0%) reported by Yousef et al. (40). Mogbel (41) and Ardawi et al. (42) reported prevalence rates of vitamin D deficiency of 79.1% and 80%, respectively, in their respective studies on Saudi Arabian women. Other reports from various countries show that more than 50% of the global population is at risk of hypovitaminosis (7, 43). One study in the United States revealed that almost 75% of individuals of European ethnic origin and 90% of those of nonEuropean ethnic origin suffered from vitamin D insufficiency (44). The mean $25(OH)_2D_3$ serum levels reported in elderly people were 28 nmol/L in Siberia (45), 30 nmol/L in Japan (46), and 36 nmol/L in India (47).

Similar to this study, Masoompour et al. (48) found that serum 25-hydroxyvitamin D levels did not decline with age, while in contrast to these findings, Smotkin-Tangorra et al. (49) concluded that vitamin D insufficiency was associated with an increase in age. Obese women were more deficient than women with a normal BMI in terms of vitamin D levels. Yousef et al. (40) and Al-Sultan et al. (50) found that vitamin D levels were significantly higher in the lean control participants than in obese subjects in their study and showed a significant decline in relation to categories of obesity. In a bidirectional Mendelian randomization analysis of multiple international adult cohorts, a high BMI was shown to directly lead to lower serum $25(OH)_2D_3$ levels (51). Vitamin D3 supplementation led to a reduction in body fat mass (52), and results from clinical trials in adults have suggested that decreasing vitamin D storage sites by reducing fat mass is the only way to restore normal serum $25(OH)_2D_3$ levels in overweight and obese individuals (53). Reinehr et al. (54) and Arunabh et al. (55) also reported a significant and inverse relationship between BMI and $25(OH)_2D_3$ serum levels. Moreover, several studies have shown no association between serum $25(OH)_2D_3$ levels and BMI, body weight, or fat-free mass (56,57,58). Additionally, an inverse relationship among total serum $25(OH)_2D_3$ concentrations, waist circumference and BMI has been observed (40), which is similar to the result reported in this study. The populations in the abovementioned studies differed to some extent with regard to their age, sex, and pregnancy, and most of these populations were more likely to trend towards being overweight than obese. These factors may explain the differences in the results between the studies. Although the interaction between the mechanism underlying the association between the serum $25(OH)_2D_3$ status and adiposity remains unclear, the most strongly supported elucidation is that increased body fat leads to increased sequestration of vitamin D in the adipose tissue, decreasing the circulating $25(OH)_2D_3$ serum levels (59, 60), or the effect of volume dilution due to the larger body size of obese individuals (61). The effect of BMI on serum $25(OH)_2D_3$ levels may be explained by people with a high BMI usually having a high body fat content and adipose tissue acting as a reservoir for lipid-soluble vitamin D and not releasing vitamin D to compensate for low serum calcium levels (62). It has been reported that reduced vitamin D bioavailability triggers a hypothalamic response that leads to increased hunger and decreased energy expenditure. Additionally, the resulting secondary hyperparathyroidism leads to an upregulation of lipogenesis (60). As the amount of adipose tissue increases, the uptake and clearance of vitamin D are further enhanced (62).

In this study, no significant association was observed between total serum $25(OH)_2D_3$ concentrations and vitamin D intake. Sadat Ali et al. (63) reported that food items consumed in the Kingdom of Saudi Arabia were either not fortified or contained very little vitamin D. In addition, they found no significant association between total serum $25(OH)_2D_3$ concentrations and vitamin D intake, which may have been due to the small sample size, and these results were similar to those in this study. In contrast, Al Mogbel (41) demonstrated a significant relationship between serum $25(OH)_2D_3$ levels and dietary intake. The recommended dietary allowance of vitamin D was found to be 600 IU/d for individuals between 1 and 70 years of age, corresponding on average to a 25-hydroxyvitamin D (25OHD) serum level of at least 50 nmol/L (20 ng/ml), and 800 IU/d for those older than 70 years of age (64).

In this study, most of the participants almost never ate any form of fish. Al Mobgel (41) reported that the Riyadh region is remotely located away from the seacoast; therefore, the people of Riyadh depend mainly on cattle and poultry meat rather than seafood, which is known to be a good source of vitamin D.

Conclusion

In conclusion, our study suggests that low vitamin D levels are prevalent in healthy females in all age groups residing in Riyadh, which may be related to a lack of adequate sunlight, a lack of consumption of vitamin D-rich foods, and a lack of awareness concerning the importance of vitamin D. This study identified a strong association between BMI and serum $25(OH)_2D_3$ levels. As such, obesity is another factor underlying hypovitaminosis D. There is no unified cut-off level for vitamin D deficiency; therefore, the development of local guidelines is needed in addition to providing vitamin D supplementation apart from adequate sun exposure and diet to all individuals whose serum $25(OH)_2D_3$ levels fall below 50 nmol/L. Public health education should be made available, focusing on the importance of consuming fish and dairy products and the health benefits of regular exposure to sunlight and regular physical exercise.

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