Mal J Nutr 24(3): 395-406, 2018

Vitamin D status of Filipino adults: Evidence from the 8th National Nutrition Survey 2013

Imelda Angeles-Agdeppa*, Leah Ancheta Perlas & Mario Villasaya Capanzana

Department of Science and Technology-Food and Nutrition Research Institute, DOST Compound, Gen. Santos Ave. Bicutan, Taguig City, Philippines 1631

ABSTRACT

Introduction: This study reports the vitamin D status of Filipino adults in selected areas in the Philippines and determinants of deficiency, based on the 2013 National Nutrition Survey (NNS). **Methods:** The NNS collected blood samples from all members aged ≥20 years from selected households of the National Capital Region (NCR), Cebu and Davao del Sur. Serum vitamin D was determined by electrochemiluminescence assay. Data on age, sunscreen use, intake of supplement were collected. Body mass index was calculated. **Results:** The overall prevalence of combined vitamin D deficiency (<50 umol/L) and insufficiency (51-75 umol/L) was 48.7%, and was highest in the NCR (54.1%) and lowest in Davao del Sur (28.9%). Adults in NCR were more likely to have vitamin D insufficiency compared with those in Cebu (OR=0.59) and Davao (OR=0.30). Females had higher prevalence (62.5%) of vitamin D insufficiency than males (32.1%). Higher prevalence of vitamin D insufficiency was observed among 20-39 y (55.5%) and lowest among ≥60 y (38.1%). The younger adults (20-39 y) were more likely to have vitamin D insufficiency compared to 40-59 y (OR=0.63) and the ≥60 y (OR=0.43). Among sunscreen users aged 20-39 y and 40-59 y in Cebu and Davao del Sur, mean vitamin D levels were significantly lower than non-sunscreen users. **Conclusion:** The 2013 NNS revealed a high prevalence of vitamin D insufficiency among Filipino adults. Gender, age, and area of residence were significant determinants of vitamin D insufficiency. Determining the vitamin D status is crucial in crafting interventions for its prevention and control.

Keywords: Vitamin D deficiency, Filipino, adults, survey

INTRODUCTION

Vitamin D, also known as the sunshine vitamin, is a fat-soluble vitamin whose primary physiological function is the maintenance of calcium levels in the body. Vitamin D, either from the diet or synthesised by sunlight is biologically inactive. It is converted to 25-hydroxyvitamin D or 25(OH)D by D-25-hydroxylase in the liver and then to 1,25-dihydroxyvitamin D or $1,25(OH)_2D$ by 25-hydroxyvitamin D-1α-hydroxylase in the kidney (DeLuca, 2004; Holick & Chen, 2008). The $1,25(OH)_2D$ is the biologically active form of vitamin D.

Although found naturally in food, only a small proportion of vitamin D is obtained from the diet (10-20%) with "good" sources, from salmon, fortified milk and other fortified products (IOM,

*Corresponding author: Imelda Angeles-Agdeppa
Department of Science and Technology-Food and Nutrition Research Institute, DOST Compound, Gen. Santos Ave. Bicutan, Taguig City, Philippines 1631
Tel: +837-8113 loc 327/+837-2071 to 82; Fax: 837-2934, 8376149
E-mail: iangelesagdeppa@yahoo.com.ph

1997). The rest is obtained through the conversion of sunlight (Holick, 1999). While sun exposure is an excellent source of vitamin D, sunscreen, clothing, skin pigmentation, and rainy season reduce vitamin D production (Mithal *et al.*, 2009).

Over the past decade, low concentrations of 25-hydroxyvitamin D (25-OH vitamin D) have been associated with bone and mineral metabolism. Clinical hypovitaminosis D has been associated with rickets in infancy and also causes muscle weakness and contributed to falls and bone fractures in adults (Mithal *et al.*, 2009). In the general population, serum 25-OH vitamin D concentrations <20 ng/ml are associated with poorer physical performance (Wicherts *et al.*, 2007) while concentrations <15 ng/ml are associated with musculoskeletal pain (McBeth *et al.*, 2010). Also, it has been associated with significant short- and long-term health effects including the risk of common chronic diseases such as diabetes, cardiovascular disease and cancer (Lee *et al.*, 2018; Tangpricha *et al.*, 2002).

The groups most at risk of vitamin D deficiency are breastfed infants, older adults, and dark-skinned people. Many factors reduce the skin's production of vitamin D3, including aging, sun protection behaviours such as application of sunscreen or covering most of their bodies with clothing, and the time of year with limited or no sunlight (Hyppönen & Power, 2007). Increased skin pigmentation is another factor. Melanin efficiently absorbs UVB radiations, so people with increased skin melanin pigmentation require longer exposures to sunlight to make the same amount of vitamin D3, compared with light skinned people (Holick, 2004).

Worldwide, an estimated 1 billion people have inadequate blood levels of vitamin D and deficiencies can be found in all ethnicities and age groups. Studies suggest that roughly 30–50% of the adult population is at risk of vitamin D deficiency (Holick, 2014).

The significant role of sunlight in vitamin D synthesis suggests a low prevalence of vitamin D deficiency in tropical countries. However, studies in some tropical countries carried out in Malaysia, India, Iran and Hawaii had shown a high prevalence of vitamin D deficiency (Moy & Bulgiba, 2011; Harinarayan, 2005; Rahnavard *et al.*, 2010; Binkley *et al.*, 2007). The Philippines is not spared from this problem even though the country is located at the Equator and is sunny all year round. The prevalence of vitamin D deficiency among post-menopausal Filipino women was 20% (Kruger *et al.*, 2010).

To date, there is a limited data about the vitamin D status of different age groups in the Philippines. This study reported the vitamin D status of Filipino adults aged ≥20 y in selected areas in the Philippines and its determinant factors of vitamin D deficiency, based on the 2013 National Nutrition Survey.

MATERIALS AND METHODS

Multi-staged stratified sampling design was employed in the 2013 National Nutrition Survey (NNS). The first stage of the sampling involved the selection of the Primary Sampling Unit (PSU), which consisted of one (1) barangay or contiguous barangays with at least 500 households. The second stage was the selection of Enumeration Area (EA) which consisted of contiguous areas in a barangay with 150-200 households. The last stage was the selection of the households in the sampled EA that served as the ultimate sampling unit. Samples were taken separately from the regions by urban and rural strata.

Study sites

The 2013 (8^{th}) NNS covered 80 provinces including the National Capital Region (NCR formerly called Metro Manila) in 17 regions. The survey used the Philippine Statistics Authority (PSA) 2003 Master Sample (MS) which was the same listing of households utilised for the 2009 Labour Force Survey (LFS). This MS consisted of 4 replicates wherein each replicate could give national and regional estimates. The biochemical component of the Survey utilised one of the four replicates of the MS covering 100% of sample households. About 8,592 sample households were selected for the survey; however this study focused on only three sites because of financial constraint: (1) National Capital Region (NCR) in Metro Manila, which is a highly urbanised city in Luzon, (2) Cebu province in the Visayas, and (3) Davao del Sur province in Mindanao. NCR lies along the flat alluvial lands entirely within the tropics. Its proximity to the equator means that temperatures are hot year-round. The province of Davao del Sur, otherwise known as the Padada Valley, is an agricultural area. Cebu province consists of a main island and 167 surrounding islands and islets.

Sample population

There were approximately 3,409 individuals aged ≥20 y over (Mean = 40.1; SD = 14.8) whose blood samples were analysed for total serum 25-hydroxyvitamin D [(25-OH (D)]. In NCR, there were about 1867 individuals, while Cebu and Davao del Sur had 864 and 678 respectively.

Measurements

Weight was measured using a standard calibrated electronic SECA weighing scale. At least two measurements were obtained, with the average recorded to the nearest 0.1 kg. Standing height was obtained using the Microtoise tape – an L-shaped device (head-bar) to which a spring-loaded coiled tape measure was attached. At least two measurements were obtained, and averages were computed, and recorded to the nearest 0.1cm. Body mass index (BMI) was computed as weight (kg)/height in m^2. BMI was based on WHO (1995) reference adopting the cut- off: Chronic Energy Deficiency <18.5 kg/m^2; Normal 18.5-24.9 kg/m^2; Overweight 25.0-29.9 kg/m^2; Obesity ≥30.0 kg/m^2.

Sample collection, preparation and analysis

Blood samples were obtained in the morning (0600H to 0900H) via venipuncture. Precautions were considered throughout the procedures to minimise exposure of samples to air and light. Approximately 10 ml venous blood samples to accommodate all the biomarkers needed for the survey was extracted using sterile syringe and transferred to a blue top tube. After a marked separation of serum and red cell was seen, the tube was centrifuged for 10 minutes. Serum was pipetted into microcentrifuge tubes and kept in freezers or in ice chests with dry ice. Frozen blood samples were transported from the field to the Biochemical Laboratory (BL) of FNRI where these were stored in freezers at -80°C until analysis.

The best indicator of vitamin D status is the serum 25-hydroxyvitamin D [25(OH)D] concentration (IOM, 2011). Total serum 25-hydroxyvitamin D [(25-OH(D)] was analysed using Electro-chemiluminescence binding assay (ECLIA) method in a selected ISO 15189 accredited laboratory in Metro Manila. The cut offs for Vitamin D levels were: Deficient (<50 nmol/l), Insufficient (51-74 nmol/l) and Sufficient was ≥75 nmol/l (Holick, 2009; Holick & Chen, 2008).

Collection of other data

Data on age, gender, education, occupation, use of sunscreen, and supplements were collected via interview using structured pre-tested questionnaires. In this study 'no occupation' were students, pensioners, or housewives; 'service-related' comprised of labourers and factory and manufacturing workers.

Ethics

This study was carried out in accordance with the declaration of Helsinki, guided by the Council for International Organization of Medical Sciences Ethical Guidelines for Biomedical Research involving human subjects (CIOMS, 2008) and the National Guidelines for Biomedical/Behavioral Research (PCHRD-DOST, 2011). Only those who signed the informed consent form were

Table 1. Profile of participants characteristics by area (based on socio-economic, demographic and nutritional status)

Variables	*ALL (n=3409)*		*NCR (n=1867)*		*Cebu (n=864)*		*Davao del Sur (n=678)*		*p-value*
	n	*%*	*N*	*%*	*N*	*%*	*n*	*%*	
Age (Mean±SD)	40.1±14.8		40.0±14.8		41.1±15.3		39.4±13.7		
Age group (years)									0.010*
20-39	2162	56.3	1254	57.1	485	53.2	423	56.6	
40-59	1634	32.4	878	31.4	425	35.0	331	34.1	
≥60	659	11.3	379	11.5	173	11.8	107	9.3	
Gender									0.737
Male	2182	48.9	1223	48.8	527	48.9	432	49.8	
Female	2273	51.1	1288	51.2	556	51.1	429	50.2	
Total	4455	100	2511	100	1083	100	861	100	
Education									<0.001*
Elementary	1023	18.9	388	13.9	388	32.1	247	26.7	
High school	1728	40.0	1041	41.6	354	34.5	333	39.7	
College	1680	41.1	1071	44.5	331	33.4	278	33.6	
Occupation									<0.001*
Office worker	959	23.5	626	25.8	191	18.8	142	17.2	
Service related	1534	35.2	877	35.4	354	33.7	303	36.2	
Agriculture/ Fishery	235	3.5	10	0.4	133	10.9	92	10.0	
No occupation	1727	37.8	998	38.4	405	36.6	324	36.7	
BMI by age groups									
Underweight	433	9.9	181	9.4	88	10.1	75	10.8	
20-39 y	195	10.4	94	10.1	37	11.1	37	11.5	0.412
40-59 y	126	7.5	48	6.9	32	8.4	19	6.8	
≥60 y	112	14.8	39	13.5	19	11.4	19	21.5	
Normal	1599	37.7	641	35.0	346	40.3	297	44.6	
20-39 y	825	44.4	370	42.5	160	46.9	160	49.7	
40-59 y	517	29.3	176	24.7	126	33.1	103	38.3	0.003*
≥60 y	257	34.0	95	30.7	60	38.2	34	38.9	
Overweight/Obese	2122	52.3	1045	55.6	430	49.6	306	44.7	
20-39 y	784	45.2	402	47.5	136	42.0	121	38.9	
40-59 y	998	63.3	485	68.4	217	58.5	150	54.9	0.032*
≥60 y	340	51.1	158	55.8	77	50.4	35	39.6	
BMI (Mean±SD)	23.8±4.5		24.0±4.1		23.7±5.2		23.0±5.2		0.000*
Underweight	17.1±1.2		17.1±1.1		17.1±1.2		17.2±1.4		0.996
Normal	20.9±1.3		20.9±1.2		20.8±1.4		20.8±1.6		0.641
Overweight/Obese	27.1±3.4		27.1±3.13		27.4±4.1		26.7±3.8		0.067

Note: No Occupation (included Students, Pensioner and Housewife)
*Significant at p<0.05

included in the study. The conduct of the study was approved by the Food and Nutrition Research Institute (FNRI) Institutional Ethics Review Committee (FIERC-2013-008).

Statistical analysis

Descriptive statistics was used to describe the means, standard errors, confidence intervals and prevalence of vitamin D deficiency. Kolmogorov-Smirnov test was used to determine the normality of data. ANOVA was used to compare means of 25-OH vitamin D levels in the three areas. T-test was used to compare means of 25-OH vitamin D levels of the adults in the three areas who used sunscreen and supplements and those who did not. Chi-square test for association was used for categorical data across areas and gender to determine relationships between 2-3 variables. Logistic regression was conducted to determine which of the variables affects vitamin D deficiency. Variables included were age, sex, use of sunscreen, use of supplements, and BMI. STATA was used for all statistical analyses. Significance level considered in this study was $p<0.05$. Survey weights were applied in all anthropometric and all other data prior to analysis.

RESULTS

A total of 3,409 blood samples were collected from adult members aged ≥20 y (Mean = 40.1; SD = 14.8) from the sampled households: NCR (*n*=1867), Cebu (*n*=864) and Davao del Sur (*n*=678). Education and occupation were significantly different between groups. Elementary education was lowest in NCR but has the highest percentage of office workers (Table 1).

The prevalence of underweight was similar across all age groups ranging from 9.4% to 10.8%. However, the prevalence of overweight and obesity was significantly higher among the 40-59 y (63.3%) than in the other age groups, and was highest (68.4%) in NCR (Table 1).

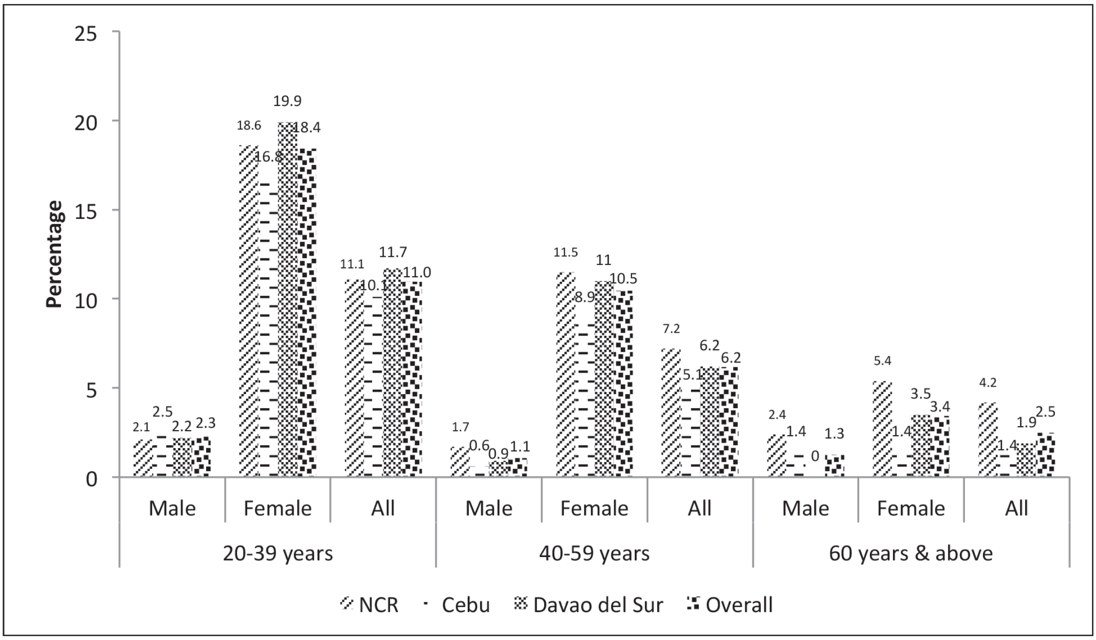

Figure 1. Percentage of adults using sunscreen by area, age and gender

Table 2. Mean of vitamin D levels and use of sunscreen by adults by area and age

Age (years)	National Capital Region			Cebu			Davao del Sur		
	Non-Sunscreen user	Sunscreen user	p-value†	Non-Sunscreen user	Sunscreen user	p-value†	Non-Sunscreen user	Sunscreen user	p-value†
	Mean±SE	Mean±SE		Mean±SE	Mean±SE		Mean±SE	Mean±SE	
20-39	71.7±1.6	65.1±3.9	0.075	84.2±2.9	59.5±4.7	<0.001*	97.7±3.4	78.0±4.2	0.002*
40-59	80.5±1.6	75.5±3.4	0.222	90.2±2.4	68.1±7.2	0.012*	105.1±4	82.1±2.9	0.016*
≥60	83.8±2.4	94.7±4.8	0.224	89.9±3.3	91.1±7.1	0.905	102.3±4	71.9±12	0.166
p-value‡	<0.001*	0.002*		0.210	0.062		0.112	0.851	

*Significant at $p<0.05$
†p-value for the difference between sunscreen user and non-sunscreen user by each age groups in each area (t-test)
‡p-value for difference between age groups who user sunscreen and who did not (ANOVA)

The use of sunscreen was more common among the 20-39 y (11.0%) while only 2.5% among the elderly participants. Among the 40-59 y, 6.2% used sunscreen. More female participants had used sunscreen than males and this was observed in all age groups and across the three areas (Figure 1). Among the 20-39 and 40-59 y who were sunscreen users in Cebu and Davao del Sur showed that, mean vitamin D levels were significantly lower than non-sunscreen users but this was not observed in NCR. Results also showed that in NCR the participants aged 20-39 y had significantly lower mean vitamin D levels than the other age groups (Table 2).

The study revealed that elderly participants (≥60 y) commonly used supplements (n=147; 24.3%) as compared with the 40-59 y (n=255; 19.2%) and in the 20-39 y (n=239; 16.3%). Comparing between areas in the elderly population, higher percentage of users were found in NCR (31.6%) than

Table 3. Mean serum vitamin D and percentage of vitamin D insufficiency by age, gender and area

Variables	Mean ± SE	Insufficiency†
	nmol/ml	N (%)
Over-all	81.1±1.1	1185(48.7)
Age group (years)		
20-39	76.1±1.5	579(55.5)
40-59	85.3±1.3	445(43.5)
≥60	87.4±1.9	161(38.1)
p-value	<0.001*	<0.001*
Gender		
Male	93±1.6	328(32.1)
Female	70.7±1.1	857(62.5)
p-value	<0.001*	<0.001*
Area		
NCR	76.2±0.9	755(54.1)
Cebu	85.7±2.0	260(43.8)
Davao del Sur	98.8±2.4	170(28.9)
p-value	<0.001*	<0.001*

*Significant at $p<0.05$
†Total of deficient and insufficient of vitamin D level

those from Cebu, (25.3%); and Davao del Sur (16.0%). Lowest percentage of supplement users was found among the 20-39 y with NCR having 19.4%, Cebu (13.0%) and Davao del Sur (16.4%). Males and female participants had almost similar percentage of users.

Mean vitamin D levels were highest among the participants from Davao del Sur (98.8±2.4 nmol/ml) and lowest was from the NCR (76.2±0.9 nmol/ml) while Cebu had 85.7±2.0 nmol/ml. The area with the highest proportion of deficient and insufficient levels was found among the participants in NCR (54.1%) and the lowest was from Davao del Sur (28.9%) while Cebu had 43.8% (Table 3).

Describing the population by age revealed that the prevalence of deficient and insufficient vitamin D was highest among the 20-39 y (55.5%); 40-59 y was 43.5%; and the lowest was among the elderly (38.1%). Females have a higher prevalence of deficiency and insufficiency (62.5%) as compared with males (32.1%) (Table 3).

The results of logistic regression analysis with vitamin D levels as dependent variable and sex, age, BMI, use of sunscreen, and use of supplement as independent variables showed that the determinant factors of vitamin D deficiency are gender, age and area. Females are 3.57 ($p<0.001$) times more likely to have vitamin D deficiency compared to the males. On the other hand, the adults aged 40-59 y (OR=0.62, $p=0.007$), and the elderly aged ≥60 y (OR=0.43, $p=0.001$), are less likely to have vitamin D deficiency compared to the younger adults. Adults in Cebu (OR=0.59, $p=0.001$) and Davao (OR=0.30, $p<0.001$) are less likely to have vitamin D deficiency compared to those in the NCR (Table 4).

Table 4. Multivariate logistic regression predicting the likelihood of being vitamin D insufficiency among Filipino adults in the NCR, Cebu and Davao

Determinants	*Adjusted OR*	*SE*	*95% CI*		*Wald*	*p-value*
			LL	*UL*		
Constant	0.79	0.1	0.6	0.9	-2.2	0.036
Sex						
Male (ref)						
Female	3.57	0.5	2.7	4.7	9.7	<0.001*
Age group (years)						
20-39 (ref)						
40-59	0.63	0.1	0.4	0.9	-2.9	0.007*
≥60	0.43	0.1	0.3	0.7	-3.7	0.001*
BMI						
<18.5	1.12	0.2	0.8	1.7	0.6	0.572
18.5-22.9 (ref)						
23.0-27.5	0.99	0.1	0.8	1.3	-0.1	0.958
>27.5	1.26	0.2	1	1.6	1.9	0.070
Sunscreen						
Do not use sunscreen (ref)						
Uses sunscreen	1.26	0.4	0.6	2.5	0.5	0.608
Supplement						
Do not take supplements (ref)						
Takes supplements	0.95	0.1	0.7	1.3	-0.3	0.740
Geographical location						
NCR (ref)						
Cebu	0.59	0.1	0.5	0.8	-3.8	0.001*
Davao	0.30	0.1	0.2	0.4	-6.6	<0.001*

DISCUSSION

Vitamin D is a prohormone that is essential for normal absorption of calcium from the gut. It is important to recognise that vitamin D is primarily made in the skin after exposure to ultraviolet radiation (UVR), and <10% is derived from dietary sources (Norris, 2001). Modern conditions of dress, lifestyle, and recommendations regarding sun avoidance to reduce risks of skin cancer may prevent a large proportion of the population from making healthy amounts of this vitamin.

Currently, there is no national data on mean vitamin D levels and prevalence of vitamin D deficiency in the Philippines. The 8th NNS conducted by the Department of Science and Technology – Food and Nutrition Research Institute (DOST-FNRI) in 2013 provided the opportunity to provide evidence on the vitamin D status of Filipino adults (20 to 59 y) and the elderly (≥60 y). However, this sub-study was conducted only in one highly urbanised city (NCR) and two provinces due to high cost of analysis. The NCR is located in Luzon, Cebu in Visayas and Davao del Sur in Mindanao.

The mean age of the participants was 40 y and overweight and obesity was very high across areas: ranging from 49.6% to 55.5%.

The present study revealed a very high prevalence of vitamin D insufficiency in the all the targeted areas especially in NCR, which had the highest prevalence. This may pose a health risk like osteomalacia, osteoporosis, diabetes, cardio vascular diseases and cancer (Lee *et al.*, 2018; Tangpricha *et al.*, 2002). In a vitamin D-deficient state, intestinal calcium absorption is only 10% to 15% and there is a decrease in the total maximal reabsorption of phosphate while in a vitamin D-sufficient state [25(OH)-D levels of <50 nmol/l (20 ng/ml)], net intestinal calcium absorption is up to 30%, although calcium absorption can reach 60% to 80% during periods of active growth (Misra *et al.*, 2008).

The Philippines is like other tropical countries with plenty of sunlight, and yet had shown high prevalence of vitamin D deficiency (Moy & Bulgiba, 2011; Harinarayan, 2005; Rahnavard *et al.*, 2010; Binkley *et al.*, 2007). In India, vitamin D deficiency was reported among 91% in healthy schoolgirls (Puri *et al.*, 2008) and in 78% of apparently healthy hospital staff (Arya *et al.*, 2004), using a cut-off level below 50 nmol/l. In Bangladesh, deficiency was 38% among women from high income group and 50% from low income group using a cut-off 37.5 nmol/l (Islam *et al.*, 2002). Prevalence of deficiency was 47% in Thailand, 49% in Malaysia, 90% in Japan and 92% in South Korea (Mithal *et al.*, 2009). Cut-off used for vitamin D insufficiency by these countries was <75 nmol/L.

This study revealed that the determinants of vitamin D level are age, gender and area. This study showed that the most vulnerable age group to having vitamin D insufficiency (<75 umol/L) are those in the 20-39 y. This high prevalence could be attributed to the use of sunscreens. The age group that has the high percentage of sunscreen users was mostly the females aged 20-39 y. In Cebu and Davao del Sur, the sunscreen users had lower vitamin D level compared to non-users. In the NCR, users and non-users have similar vitamin D levels. Sunscreen is used to avoid skin cancer due to exposure to sunlight and has become a common practice especially among young adult population. Sunscreen absorbs UV-B and some UV-A light and prevents it from reaching and entering the skin. A sunscreen with a sun protection factor (SPF) of eight can decrease vitamin D3 synthetic capacity by 95%, and SPF 15 can decrease it by 98% (Holick, 2004).

In adults who apply sunscreen properly (2 mg/cm2), the amount of vitamin D3 produced is decreased (95%). A previous study demonstrated lower vitamin D levels in people using SPF 15 sunscreens than in those not using sunscreen, however, these lower levels were not sufficient to cause PTH level elevations (Farrerons *et al.*, 1998). Sun exposure of the arms, legs, hands, or face for about 5 to 10 min for at least 2 or 3 times per week is enough for the production of vitamin D requirement.

The prevalence of vitamin D among the ≥60 y was 38%. It has been postulated that the older adult population is especially vulnerable to vitamin D deficiency due to a decreased capacity to synthesise vitamin D from sunlight (Parker *et al.*, 2010). Also, aging is associated with lower 7-dehydrocholesterol levels (Bischoff-Ferrari *et al.*, 2009), which is a precursor required for the synthesis of vitamin D in the skin. The mean vitamin D level of ≥60 y was significantly higher than the younger age groups maybe because of the high use of sunscreen among the younger population.

Moreover, the insufficient vitamin D was highest in NCR than in the other two areas despite its location in flat alluvial lands entirely within the tropics. It has been shown in previous studies that vitamin D production may be affected also by geography (Marks *et al.*, 1995). NCR is the centre of commerce, employment and education. The high percentage of vitamin D insufficiency in NCR is among the productive age groups of 20-59 y. This might be due to lesser time exposure to sunlight compounded by the high use of sunscreen. Increased urbanisation and increased time spent indoors at work may lead to decreased time spent outdoors and, therefore, decreased vitamin D synthesis. Shade reduces the amount of solar radiation by 60%, and windowpane glass blocks (UVR) ultraviolet radiation (Holick, 1995). For adequate vitamin D synthesis, exposure to the midday sun (between 1000 and 1500 hours) for 10-15 minutes in the spring, summer, and fall is considered sufficient for light-skinned people, providing 25% of the minimum erythema dose (MED) (Holick, 2003).

Another significant finding in this study is the higher odds of females to have vitamin D insufficiency than males. This is in congruent with the results of a previous study among in patients undergoing coronary angiography wherein gender significantly affected vitamin D status. Female gender was associated with lower vitamin D levels (14.5±10.9 vs. 15.9±9.5, p=0.007) and independently associated with severe vitamin D deficiency (41.9% vs. 30.4%, p<0.001; adjusted odds ratio (OR) (95% confidence interval (CI)=1.42 (1.08-1.87), p=0.01). The lower 25(OH)D levels observed in females, as compared to males, play a more relevant role in conditioning the severity of CAD (Verdoia *et al.*, 2015). Another study found contradicting results, male patients had significantly lower mean 25(OH)D concentrations than female patients 50.0 (22.0) nmol/l versus 53.6 (22.4) nmol/l (P=0.001) and a significantly (P=0.001) higher rate of vitamin D deficiency, 56% versus 47% (Johnson *et al.,* 2012). Another study found no significant association between vitamin D level and sex of the participants (Baradaran *et al.*, 2012). Different results might be due to different health conditions, lifestyle of respondents and time spent under the sun.

In previous studies, obesity was also associated with vitamin D deficiency (Wortsman *et al.*, 2000). The results of the study in Oslo, Norway showed the prevalence of vitamin D deficiency was highest in individuals with BMI ≥40 (Lagunova *et al.*, 2009). In this study, we did not find a significant role of BMI on vitamin D levels among the overweight and obese population because the mean BMI (23.8±4.5) might not be too high to cause a deficiency.

CONCLUSION

There was a high prevalence of vitamin D insufficiency among Filipino adults living in the three studied areas. Gender, age, and area were significant determinants of vitamin D level. More studies should be conducted to confirm the results of the present study before we can say that there are evident age, gender and area - specific determinants of vitamin D status. There is a need also to evaluate vitamin D status among younger age groups to prevent and control the long- and short – term effects of the deficiency at an early age.

Limitations

Interpretation of results of this study is not maximised because data on time of sun exposure including time of day and duration of exposure were not collected. Data on vitamin D intake was not computed because there is no vitamin D in the Philippine Food Composition Table at time of analysis of this survey.

Acknowledgement

This study was funded by DSM, Fonterra Philippines, and the Osteoporosis Society of the Philippines Foundation Incorporated (OSPFI). Mr. Keith Tanda has extended statistical guidance for this study.

Authors' contributions

IAA conceptualised and designed the study, analysed and interpreted the data, prepared the draft manuscript, provided critical revision and final approval of the revision to be published; LAP contributed in the design and write-up of the draft manuscript; MVC has contributed inputs in the draft manuscript.

Conflict of interest

The authors declare no conflict of interest.

References

Arya V, Bhambri R, Godbole MM & Nirthal A (2004). Vitamin D status and its relationship with bone mineral density in healthy Asian Indians. *Osteoporosis Int* 15:56-61.

Baradaran A, Behradmanesh S & Nasri H (2012). Association of body mass index and serum vitamin D level in healthy Iranian adolescents. *Polish Journal of Endocrinology* 63(1):29-33.

Binkley N, Novotny R, Krueger D, Kawahara T, Daida YG, Lensmeyer G, Hollis BW & Drezner MK (2007). Low vitamin D status despite abundant sun exposure. *J Clin Endocrinol Metab* 92:2130-2135.

Bischoff-Ferrari HA, Dawson-Hughes B, Staehelin HB, Orav JE, Stuck AE, Theiler R, Wong JB, Egli A, Kiel DP & Henschkowski J (2009). Fall prevention with supplemental and active forms of vitamin D: a meta-analysis of randomized controlled trials. *BMJ* 339:b3692.

DeLuca HF (2004). Overview of general physiologic features and functions of vitamin D. *Am J Clin Nutr* 80(suppl):1689S-96S.

Farrerons J, Barnadas M, Rodriguez J, Renau A, Yoldi B, Lopez-Navidad A & Moragas J (1998). Clinically prescribed sunscreen (sun protection factor 15) does not decrease serum vitamin D concentration sufficiently either to induce changes in parathyroid function or in metabolic markers. *Br J Dermatol* 139(3):422–427.

Harinarayan CV (2005). Prevalence of vitamin D insufficiency in postmenopausal south Indian women. *Osteoporosis Int* 16:397-402.

Holick MF (2014). Sunlight, ultraviolet radiation, vitamin D and skin cancer: how much sunlight do we need? *Adv Exp Med Biol* 810:1-16. 56.

Holick MF (2009). Vitamin D status: measurement, interpretation and clinical implication. *Ann Epidemiol* 19(2):73-78.

Holick MF & Chen TC (2008). Vitamin D deficiency: a worldwide problem with health consequences. *Am J Clin Nut* 87(4):1080S-1086S.

Holick MF (2004). Sunlight and vitamin D for bone health and prevention of autoimmune diseases, cancers, and cardiovascular disease. Am J Clin Nutr 80(suppl):1678S-88S.

Holick MF (2003). Vitamin D: A Millenium Perspective. *Journal of Cellular Biochemistry* 88:296-307.

Holick MF (1999). Evolution, biologic functions, and recommended dietary allowance for vitamin D. In Holick MF (ed). *Vitamin D: physiology, molecular biology and clinical applications*. Human Press, Totowa, New Jersey, pp 1-16.

Holick MF (1995). Environmental factors that influence the cutaneous production of vitamin D. *Am J Clin Nutr* 61(3 suppl):638S–645S.

Hyppönen E & Power C (2007). Hypovitaminosis D in British adults at age 45 y: nationwide cohort study of dietary and lifestyle predictors. *Am J Clin Nutr* 85:860-8.

Institute of Medicine Standing Committee on the Scientific Evaluation of Dietary Reference Intakes (1997). *Dietary Reference Intakes for Calcium Phosphorus, Magnesium, Vitamin D, and Flouride.* National Academy of Sciences, Washington, DC, USA.

Institute of Medicine (2011). *Dietary Reference Intakes: Calcium and Vitamin D.* Washington, DC: National Academy of Sciences.

Islam MZ, Lamberg-Allardt C, Karkkainen M, Outila T, Salamatullah Q & Shamim AA (2002). Vitamin D deficiency: a concern in premenopausal Bangladeshi women of two socio-economic groups in rural and urban region. *Eur J Clin Nutr* 56:51-56.

Johnson LK, Hofso D, Aasheim ET, Tanbo T, Holven KB, Andersen LF, Roislien J & Hjelmesaeth J (2012). Impact of gender on vitamin D deficiency in morbidly obese patients: a cross-sectional study. *European Journal of Clinical Nutrition* 66:83-90.

Kruger MC, Schollum LM, Kuhn-Sherlock B, Hestiantoro A, Wijanto P, Li-Yu J, Agdeppa IA, Todd JM & Eastell R (2010). The effect of a fortified milk drink on vitamin D status and bone turnover in post-menopausal women from South East Asia. *Bone* 46:759-767.

Lagunova Z, Porojnicu AC, Lindberg F, Hexeberg S & Moan J (2009). The Dependency of Vitamin D Status on Body Mass Index, Gender, Age and Season. *Anticancer Research* 29: 3713-3720.

Lee JH, O'Keefe JH, Bell D, Hensrud DD & Holick MF (2008). Vitamin D deficiency an important, common, and easily treatable cardiovascular risk factor? *J AmColl Cardiol* 52:1949–56.

Marks R, Foley PA, Jolley D, Knight KR, Harrison J & Thompson SC (1995). The effect of regular sunscreen use on vitamin D levels in an Australian population: results of a randomized controlled trial. *Arch Dermatol* 131(4):415–421.

McBeth J, Pye SR, O'Neill TW, Tajar A, Bartfai G, Boonen S, Bouillon R, Casanueva F, Finn JD, Forti G, Giwercman A, Han TS, Huhtaniemi IT, Kula K, Lean ME, Pendleton N, Punab M, Silman AJ, Vanderschueren D & Wu FC; EMAS Group (2010). Musculoskeletal pain is associated with very low levels of vitamin D in men: results from the European Male Ageing Study. *Ann Rheum Dis* 69:1448-1452.

Misra M, Pacaud D, Petryk A, Collet-Solberg PF & Kappy M (2008). Vitamin D Deficiency in Children and Its Management: Review of Current Knowledge and Recommendations. *American of Academy of Pediatrics Journals* 122.

Mithal A, Wahl DA, Bonjour JP, Burckhardt, Dawson-Hughes B, Eisman, JA, El-Hajji Fuleihan G, Josse RG, Lips P, Morales-Torres J on behalf of the IOF Committee of Scientific Advisors (CSA) Nutrition Working Group (2009). Global vitamin D status and determinants of hypovitaminosis D. *Osteoporos Int* 20:1807-1820.

Moy FM & Bulgiba A (2011). High prevalence of vitamin D insufficiency and its association with obesity and metabolic syndrome among Malay adults in Kuala Lumpur, Malaysia. *BMC Pub Hlth* 11:735.

Nimitphong H & Holick MF (2013). Vitamin D status and sun exposure in Southeast Asia. *Dermatoendocrinol* 5(1):34-37.

Norris JM (2001). Can the sunshine vitamin shed light on type 1 diabetes? *Lancet* 358(9292):1476-8.

Parker J, Hashmi O, Dutton D, Mavrodaris A, Stranges S, Kandala NB, Clarke A & Franco OH (2010). Levels of vitamin D and cardiometabolic disorders: Systematic review and meta-analysis. *Maturitas* 65(3):225-236.

Puri, S, Marwaha RK, Agarwal N, Tandon N, Agarwal R, Grewal K, Reddy DH & Singh S (2008). Vitamin D status of apparently healthy school-girls from two different socioeconomic strata in Delhi: relation to nutrition and lifestyle. *Br J Nutr* 99:876-882.

Rahnavard Z, Eybpoosh S, Rezaei-Homami M, Aghaei-Meybodi HR, Azemati B, Heshmat R & Larijani B (2010). Vitamin D deficiency in healthy male population: results of the Iranian multi-center osteoporosis study. *Iranian J Publ Hlth* 39:45-52.

Tangpricha V, Pearce EN, Chen TC & Holick MF (2002). Vitamin D insufficiency among free-living healthy young adults. *Am J Med* 112:659–62.

Verdoia M, Schaffer A, Barbieri L, Di Giovine G, Marino P, Suryapranata H & De Luca G (2015). Impact of gender differences on vitamin D status and its relationship with the extent of coronary artery disease. *Nutrition, Metabolism & Cardiovascular Diseases* 25(5):464-470.

World Health Organization (1995). *Physical status. The use of and interpretation of anthropometry.* WHO Technical Report Series No. 854. WHO, Geneva.

Wicherts IS, Van Schoor NM, Boek AJ, Visser M, Deeg DJH, Smit J, Knol DL & Lips P (2007). Vitamin D status predicts physical performance and its decline in older persons. *J Clin Endocrinol Metab* 92:2058-2065.

Wortsman J, Matsuoka LY, Chen TC, Lu Z & Holick MF (2000). Decreased bioavailability of vitamin D in obesity. *Am J Clin Nutr* 72:690-693.