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Vitamin D Status and Demographic and Lifestyle Determinants Among Adults in the United States (NHANES 2001-2006)

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Research Article

Vitamin D Status and Demographic and Lifestyle Determinants among Adults in the United States (NHANES 2001-2006)

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Abstract: This study looked at risk factors associated with vitamin D levels in the body among a representative sample of adults in the U.S., NHANES III (2001-2006) data were used to assess the relationship between several demographic and health risk factors and vitamin D levels in the body. The Baseline-Category Logit Model was used to test the association between vitamin D level and the potential risk factors age, education, ethnicity, poverty status, physical activity, smoking, alcohol, obesity, diabetes and total cholesterol with both genders. Vitamin D insufficiency and deficiency were significantly associated with age, race, education, physical activity, obesity, diabetes and total cholesterol level for both genders. Almost half of the adults sampled in these data had vitamin D levels lower than the recommended limits, with the highest frequency among the younger groups. Determining an individual's vitamin D level is very difficult without proper clinical testing. Many of those who have low vitamin D levels are unaware. With such a high prevalence of individuals with low vitamin D levels in the U.S. and a better understanding of characteristics associated with these lower levels, increased education and prevention efforts should be focused toward those with higher risk characteristics.

Keywords: Baseline category-logit model, diabetes, national health and nutrition examination survey, obesity, serum cholesterol levels, vitamin D deficiency, vitamin D insufficiency

INTRODUCTION

Vitamin D deficiency is a global health problem (Holick, 2007). It is well known that vitamin D is associated primarily with bone health; it is an essential factor for bone metabolism and skeletal health (Abrams *et al.*, 1999). Vitamin D deficiency can cause impaired calcium absorption which can lead to growth retardation and skeletal abnormalities and increases the risks of hip fractures (Holick, 2007). Adequate vitamin D is also important for optimal function of many organs and tissues throughout the body (Aloia *et al.*, 1998). Recent experiments have proven that Vitamin D deficiency is associated with increased risk of many chronic diseases, such as cancers, infectious diseases, cardiovascular diseases (Michael and Holick, 2007; Lips *et al.*, 1999; Looker *et al.*, 1998; Malabanan *et al.*, 1998), multiple sclerosis, autoimmune disease and metabolic syndrome (Marcelli *et al.*, 1998; Matsuoka *et al.*, 1995). Among the biologic effects of vitamin D are the regulation of inflammation, cellular proliferation, cellular differentiation, angiogenesis and apoptosis, which are key cancer-related mechanisms (Misra *et al.*, 2008). Vitamin D is also thought to play a role in regulating

the immune and renin-angiotensin systems, insulin secretion and thrombogenic activity (Gordon *et al.*, 2008; Forrest and Stuhldreher, 2011). It is critical to know the determinants of Vitamin D deficiency in order to reduce the health risks correlated with Vitamin D deficiency.

Vitamin D has 2 forms: vitamin D₂ and vitamin D₃. Vitamin D₂ is manufactured through the ultraviolet irradiation of ergosterol from yeast and vitamin D₃ through the ultraviolet irradiation of 7-dehydrocholesterol from lanolin (Holick, 2007). Vitamin D is derived from the skin and through an individual's diet and is metabolized in the liver to 25-hydroxy vitamin D (25 (OH) D). This 25-hydroxy vitamin D (25 (OH) D) is used to determine a patient's vitamin D status (Patience, 2013). (25 (OH) D) concentrations, which reflect both vitamin D intake and endogenous production, should be measured to clinically assess vitamin D status (Abrams *et al.*, 1999). Some conditions leading to vitamin D deficiency include lower vitamin D intake (decreased intake of vitamin rich foods and lack of fortified foods), lack of exposure to sunlight (especially in winter months), reduced skin synthesis (using sunscreens for prevention

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of skin cancer, or having elderly skin), nephritic syndromes; chronic renal disease, liver failure, mal-absorption and the use of medications increasing catabolism (steroids, anticonvulsants) (Holick, 2007).

A rapidly evolving knowledge indicates that vitamin D deficiency is much more prevalent than previously recognized. It is estimated that vitamin D deficiency is present in up to 50% of young adults and apparently healthy children (Forrest and Stuhldreher, 2011). The Third National Health and Nutrition Examination Survey (NHANES III) reported the prevalence of vitamin D deficiency in the U.S. to be between 25 and 57% of adults (Patience, 2013).

Research has demonstrated many different demographic and health status predictors that are associated with vitamin D levels in the body. Age is one common predictor that has been found to have a primarily negative association with vitamin D levels, where levels are found to decrease as age increases (Patience, 2013). Although the lowest vitamin D levels are predominantly found among the older populations, there has also been a resurgence of vitamin D deficient rickets among children (Mitchell *et al.*, 2012). Disparities have been seen among race and socioeconomic status and vitamin D levels in the body. Repeatedly, research has shown a significant association between those with darker pigmented skin, such as Hispanics and blacks and vitamin D deficiency (Patience, 2013; Moore *et al.*, 2005; Mathieu *et al.*, 2005). Socioeconomic status and education have both been determined to be significant predictors of vitamin D levels in the body. Those with lower income levels and lower educational attainment are also significantly more likely to have lower vitamin D levels in the body (Patience, 2013; Simonelli, 2005). Obesity and diabetes, two conditions that are often found together, have been found to be negatively associated with vitamin D levels in the body. Individuals who are obese and individuals who have diabetes have been significantly associated with insufficient and deficient vitamin D levels in the body (Weishaar and Vergili, 2013). In this study, we used a cross-sectional study design and the baseline-category logit model to examine the relationship between status of vitamin D and the potential risk factors, such as socio-demographics, behavioral variables and certain health conditions among US adults using NHANES III (2001-2006) data in U.S.

MATERIALS AND METHODS

We used the NHANES 2001-2002, NHANES 2003-2004 and NHANES 2005-2006 data to conduct this study. NHANES is an ongoing program that consists of a series of surveys conducted periodically by the National Center for Health Statistics (NCHS),

(Centers for Disease Control and prevention (CDC), 2003-2004) to assess the health and nutrition status of a large nationally representative sample of the civilian non-institutionalized U.S. population. NHANES employs a two-year stratified multistage probability sampling design and very similar across the three 2-year surveys; the methodology and full description of the sampling designs have been described in earlier studies (CDC). Data for the three surveys were collected during the following time periods-for NHANES 2001-02 were collected during January 2001-December 2002, for NHANES 2003-04 during January 2003-December 2004 and for NHANES 2005-06 during January 2005-December 2006, respectively including a total of 31,509 (2001-02: 11,309; 2003-04: 10,122; 2005-06: 10,348) participants aged ≥ 18 years older to 85 years of age (those aged >85 years were adjudicated to ≥ 85 years age). In addition, we excluded those who are pregnant during the study conduction.

The outcome variable in the study is the status of vitamin D. Similar to earlier studies; we used serum levels of 25 (OH) D as a biomarker to test the adequacy of vitamin D (Institute of Medicine, year). The National Center for Environmental Health, Atlanta, GA measured serum 25 OHD levels in the individuals who participated in the NHANES 2001-2006, using the DiaSorin Radioimmunoassay Kit (Stillwater, MN). Although a consensus regarding the optimal level of serum 25 (OH) D has not yet been established, consistent with earlier studies (Guillemant and Guillemant, 1996; Guillemant *et al.*, 1995; Michael and Holick, 2007; Bouillon, 2001) where optimal levels of vitamin D for health outcomes were underscored, we categorized the vitamin D status of an individual into three categories: Vitamin D deficient if serum level of 25 (OH) D was ≤ 20 ng/mL, insufficient if serum level of 25 (OH) D was 21 to 29 ng/mL and normal if serum level of 25 (OH) D ≥ 30 ng/mL.

Based on recently published research, the optimal concentration of serum 25 (OH) D levels for better health outcomes is at least 30 ng/mL (Bouillon, 2001).

Based on the existing literature (Guillemant and Guillemant, 1996; Guillemant *et al.*, 1995; Michael and Holick, 2007; Bouillon, 2001), we selected the following variables that could potentially influence the status of vitamin D in an individual: age, gender, race/ethnicity, education, family Poverty Income Ratio (PIR) (demographics), physical activity, smoking status, alcohol consumption (behavioral factors) and obesity, diabetes mellitus and serum cholesterol levels (health conditions). Age was collected as continuous variable by NHANES and we categorized into 18-29, 30-39, 40-49, 50-59, 60-69, ≥ 70 years age groups, respectively. Information on race/ethnicity was self-reported by the participants and recoded as either

Mexican-American or Hispanics, non-Hispanic White, non-Hispanic Black or other. Education was collected by NHANES as a continuous variable from zero to 17 years and we and 46.86% categorized into less than 11th grade, high school graduate or college/graduate and above, respectively. In addition, we defined obesity into two categories using Body Mass Index (BMI) as calculated by NHANES using the collected weight and height data: obese if BMI was ≥ 30 kg/m², otherwise, he/she was not obese. Similarly, we categorized adults by total serum cholesterol level into those who have high levels (≥ 200 ng/dL) and those who do not (< 200 ng/dL). All other variables are categorical in nature and characterized into two groups, including gender (males/females), physical activity (yes/no), smoking status (yes/no), alcohol consumption (yes/no), obesity (yes/no) and diabetes (yes/no), respectively.

Descriptive statistics were calculated using the statistical software SAS 9.2 and 95% confidence intervals were reported. The confidence intervals were estimated by conducting generalized linear models for continuous variables and using frequency tables and chi-square tests for categorical variables. Based on the score test for the proportional odds assumption, the null hypothesis was rejected and that all ordered log it coefficients are not equal across all the three level of

Vitamin D status ($p = 0.0289$). Therefore, we used the baseline-category log it model to test the associations of normal, deficient and insufficient levels of vitamin D with potential risk factors age, gender, education, ethnicity, obesity, diabetes, total cholesterol.

RESULTS AND DISCUSSION

Descriptive results: A total of 9946 adults were included in the study. Males had a higher mean 25 (OH) D concentration as compared with the females (21.51, 95% CI: 21.35-21.68 ng/mL vs. 20.89, 95% CI: 20.69-21.08 ng/mL, respectively; $p < 0.001$). Table 1 illustrates the bivariate analyses of predictors associated with vitamin D insufficiency and deficiency. Regardless of sex, vitamin D significantly varied by age, race, education, family Poverty Income Ratio (PIR), physical activity, obesity, diabetes and total cholesterol, except for alcohol consumption. Among females only, smoking significantly influenced 25 (OH) D concentrations (Table 1). Vitamin D deficiency existed in 52.35% of females of males. Lowest 25 (OH) D concentrations were observed in the 18~20s age group for males and in the 40~49 age group for females (males: 20.54 ng/mL; females: 19.87 ng/mL) (Fig. 1). Females had a higher prevalence of

Table 1: Bivariate analysis of factors associated with vitamin D insufficiency and deficiency among US adult males and females: NHANES 2001-2006, N = 9946

	Male				Female			
	≥ 30 ng/mL	20~30 ng/mL	< 20 ng/mL	p-value	≥ 30 ng/mL	20~30 ng/mL	< 20 ng/mL	p-value
Age (year)*								
18~29	14.00 (266)	31.68 (602)	54.32 (1032)	< 0.0001	18.31 (308)	24.26 (408)	57.43 (966)	
30~39	18.58 (196)	35.73 (377)	45.69 (482)		19.72 (195)	31.45 (311)	48.84 (483)	
40~49	16.03 (189)	38.51 (454)	45.46 (536)		14.53 (168)	29.67 (343)	55.80 (645)	
50~59	19.30 (172)	38.05 (339)	42.65 (380)		16.70 (146)	33.18 (290)	50.11 (438)	
60~69	14.77 (143)	38.12 (369)	47.11 (456)		14.31 (143)	32.53 (325)	53.15 (531)	
≥ 70	17.71 (234)	41.33 (546)	40.35 (541)		18.54 (238)	35.28 (453)	46.18 (593)	
Race (%)*				< 0.0001				
Hispanics	9.340 (170)	38.02 (692)	52.64 (958)		7.47 (127)	27.59 (469)	64.94 (1104)	
Non-hispanic whites	26.33 (946)	44.93 (1650)	28.73 (1055)		28.80 (1007)	39.04 (1365)	32.15 (1124)	
Non-hispanic blacks	2.50 (39)	16.75 (261)	80.74 (1258)		2.70 (41)	14.23 (216)	83.07 (1261)	
Other races	9.09 (24)	31.82 (84)	59.09 (156)		8.52 (23)	29.63 (80)	61.85 (167)	
Education (%)*				< 0.0001				
Less than 11 th grade	13.38 (212)	35.48 (562)	51.14 (810)		8.41 (121)	28.09 (404)	63.49 (913)	
High school graduate/GED	20.52 (253)	36.58 (451)	42.90 (810)		21.71 (259)	30.01 (358)	48.28 (576)	
College/graduate or above	17.44 (363)	40.85 (850)	41.71 (868)		21.43 (448)	33.24 (695)	45.34 (948)	
Family PIR*	2.98 (1.59)	2.79 (1.62)	2.46 (1.57)		< 0.0001	3.07 (1.62)	2.71 (1.62)	2.23 (1.55)
Obesity*				< 0.0001				
Yes	11.09 (219)	35.46 (700)	53.44 (1055)		8.05 (202)	24.65 (586)	66.85 (1589)	
No	18.64 (957)	37.33 (1920)	43.97 (2258)	22.13 (975)	33.82 (1490)	44.05 (1941)		
Diabetes*				< 0.0001				
Yes	10.16 (70)	32.80 (226)	57.04 (393)		10.06 (68)	23.67 (160)	66.27 (448)	
No	17.15 (1117)	37.13 (2419)	45.73 (2979)	18.05 (1120)	31.27 (1940)	50.68 (3145)		
Total CHL*				< 0.0001				
High	17.21 (527)	38.77 (1187)	44.02 (1348)		17.82 (572)	33.36 (1071)	48.82 (1567)	
Low	15.86 (673)	35.31 (1498)	48.83 (2072)	16.68 (624)	28.02 (1048)	55.29 (2068)		
Physical activity*				< 0.0001				
Yes	18.31 (845)	37.70 (1740)	43.99 (2030)		21.82 (894)	32.06 (1314)	46.12 (1890)	
No	13.23 (325)	35.30 (867)	51.47 (1264)	10.43 (268)	28.17 (724)	61.40 (1578)		
Alcohol				0.4275				
Yes	16.97 (319)	37.98 (714)	45.05 (847)		18.12 (79)	30.73 (134)	51.15 (223)	
No	17.31 (986)	38.11 (2171)	44.58 (2539)	19.21 (1081)	32.88 (1850)	47.91 (2696)		
Smoking*				0.0004				
Yes	17.75 (408)	33.23 (764)	49.02 (1127)		18.90 (251)	26.43 (351)	54.67 (726)	
No	16.04 (730)	39.45 (1795)	44.51 (2025)	17.18 (877)	32.06 (1637)	50.76 (2592)		

S.D.: Standard deviation; PIR: Poverty income ratio; p-value: Chi-square test; *: $p < 0.05$ for male and female

Table 2: Variables associated with 25 (OH) D concentrations (ng/mL) among NHANES adults in baseline-category logit model by gender

	Male			Female		
	Odds ratio (3/1 and 2/1)	95% CI (3/1 and 2/1)	p-value (3/1 and 2/1)	Odds ratio (3/1 and 2/1)	95% CI (3/1 and 2/1)	p-value (3/1 and 2/1)
Age (year)*						
30~39 vs. 18~29	0.579/0.668	(0.421, 0.797)/(0.491, 0.908)	0.0008/0.0100	0.864/1.330	(0.624, 1.195)/(0.624, 1.195)	0.3770/0.0782
40~49 vs. 18~29	0.591/0.831	(0.428, 0.814)/(0.611, 1.129)	0.0013/0.2365	1.434/1.801	(1.026, 2.005)/(1.291, 2.514)	0.0349/0.0005
50~59 vs. 18~29	0.549/0.744	(0.387, 0.779)/(0.535, 1.033)	0.0008/0.0778	1.332/2.022	(0.916, 1.937)/(1.409, 2.901)	0.1333/0.0001
60~69 vs. 18~29	0.655/0.951	(0.458, 0.937)/(0.678, 1.334)	0.0206/0.7723	1.444/1.861	(1.004, 2.078)/(1.301, 2.663)	0.0475/0.0007
≥70 vs. 18~29	0.798/0.943	(0.575, 1.107)/(0.692, 1.287)	0.1771/0.7134	1.368/1.714	(0.971, 1.927)/(1.228, 2.393)	0.0732/0.0015
Race (%)*						
Hispanics vs. whites	4.741/2.212	(3.622, 6.206)/(1.699, 2.879)	<0.0001/<0.0001	5.730/2.276	(4.281, 7.669)/(1.688, 3.069)	<0.0001/<0.0001
Blacks vs. whites	27.109/3.845	(17.562, 41.845)/(2.452, 6.03)	<0.0001/<0.0001	21.981/2.961	(13.874, 34.826)/(1.808, 4.849)	<0.0001/<0.0001
Other races vs. whites	6.843/1.945	(3.744, 12.508)/(1.031, 3.67)	<0.0001/0.0401	11.185/3.087	(5.503, 22.734)/(1.464, 6.509)	<0.0001/0.0031
Education (%)*						
Less than 11 th grade vs. college/graduate or above	0.606/0.747	(0.46, 0.797)/(0.573, 0.972)	0.0004/0.0301	1.295/1.187	(0.958, 1.749)/(0.877, 1.605)	0.0926/0.2672
High school graduate/GED vs. college/graduate or above	0.627/0.679	(0.493, 0.796)/(0.544, 0.849)	0.0001/0.0007	0.787/0.782	(0.616, 1.005)/(0.618, 0.991)	0.0551/0.0415
Family PIR*	0.888/0.963	(0.83, 0.952)/(0.903, 1.028)	0.0007/0.2578	0.875/0.901	(0.815, 0.939)/(0.841, 0.966)	0.0002/0.0033
Physical activity*						
Yes vs. no	1.439/1.275	(1.155, 3.670)/(1.033, 1.573)	0.0011/0.0235	1.916/1.609	(1.521, 2.413)/(1.281, 2.022)	<0.0001/<0.0001
Diabetes*						
Yes vs. no	1.742/1.249	(1.186, 2.557)/(0.855, 1.824)	0.0046/0.2502	1.133/0.934	(0.738, 1.742)/(0.605, 1.443)	0.5676/0.7578
Obesity*						
Yes vs. no	2.185/1.578	(1.728, 2.762)/(1.258, 1.978)	<0.0001/<0.0001	3.572/1.750	(2.790, 4.575)/(1.361, 2.249)	<0.0001/<0.0001
Total CHL*						
High vs. low	0.987/0.967	(0.809, 1.204)/(0.801, 1.166)	0.8980/0.7234	0.754/0.847	(0.609, 0.933)/(0.688, 1.042)	0.0095/0.1163
Smoking*						
Yes vs. no	1.080/0.931	(0.873, 1.336)/(0.759, 1.141)	0.4805/0.4894	1.272/0.957	(0.984, 1.645)/(0.741, 1.236)	0.0666/0.7365

Significant at alpha = 0.05 level; 3: Vitamin D deficient group; 2: Vitamin D insufficient group; 1: Vitamin D deficient group

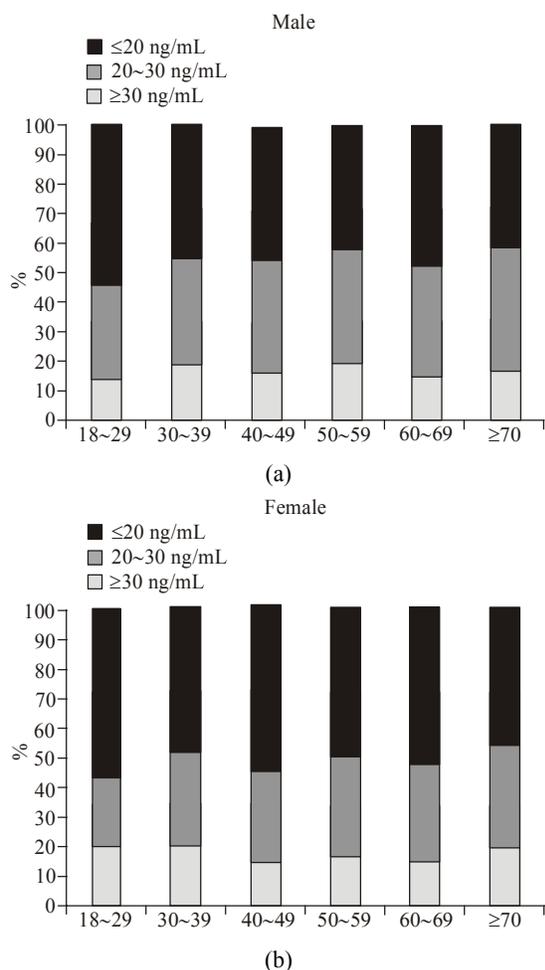


Fig. 1: Percentage of participants according to the status of the 25 (OH) D level by gender and age

Vitamin D deficiency (males: 54.32%; females: 57.43%) (Fig. 1). As age increased, the difference between males and females became more pronounced. The difference between sexes reached a maximum between the ages of 40 and 49 years. The prevalence of Vitamin D deficiency decreased with increasing age (males: 22.23 and 22.12 ng/mL; females: 22.82 and 22.39 ng/mL) and lower prevalence of Vitamin D deficiency (males: 45.73 and 43.99%; females: 50.68 and 46.12%) and 25 (OH) D concentration for the females were much higher than the males. In addition, 25 (OH) D levels among obese non-physically active females were worse than male counterparts (male: 19.82 and 20.55 ng/mL; female: 17.56 and 18.67 ng/mL). Males and females with diabetes had lower 25 (OH) D levels and higher Vitamin D deficiency (males: 19.45 ng/mL, 57.04%; females: 18.23 ng/mL, 66.27%) than those without diabetes (males: 21.74 ng/mL, 45.73%; females: 21.22 ng/mL, 50.68%). Also, 25 (OH) D levels and Vitamin D deficiency among females were worse than among males in both diabetes status. Males and females with high total cholesterol also had higher 25 (OH) D concentrations.

Multiple regression analysis results: Table 2 lists the results from the baseline-category logit model stratified by sex. The determinants for the males and females varied slightly. Being black (vs. white) and no physical activity (vs. physical activity) was associated with lower 25 (OH) D level, whereas obesity, lower education and lower family PIR were associated with a lower 25 (OH) D level in both sexes. Among males, diabetes was a predictor of lower 25 (OH) D

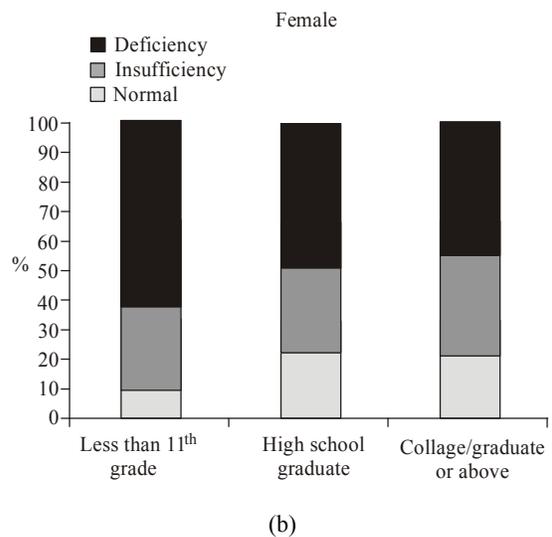
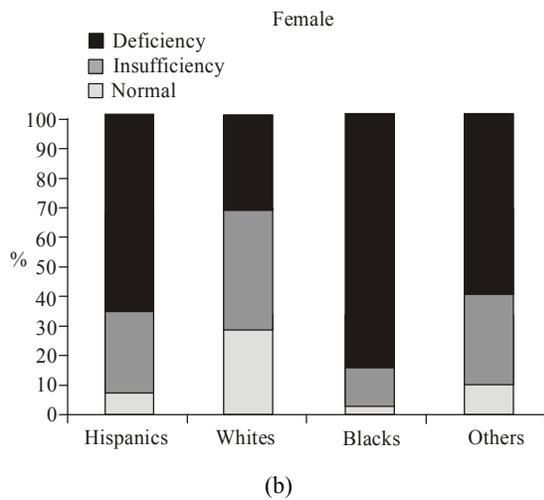
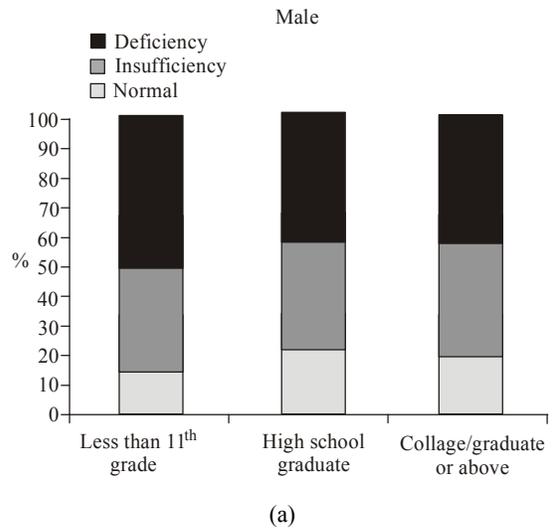
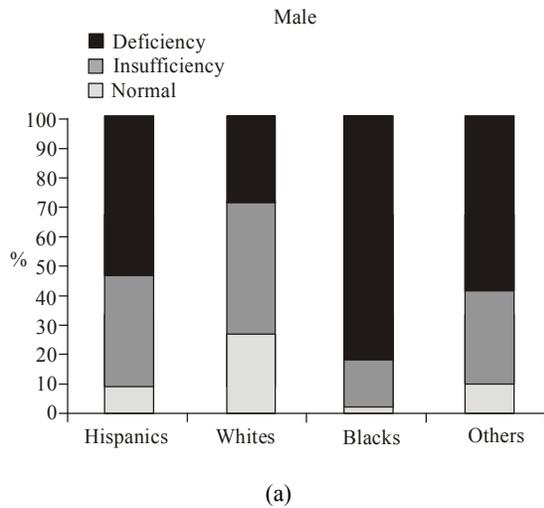


Fig. 2: Percentage of participants according to the status of the 25 (OH) D level by gender and race

Fig. 3: Percentage of participants according to the status of the 25 (OH) D level by gender and education

concentration (OR: 1.742, p-value: 0.0046), but this was not the case among females for both sexes.

Black subjects had the lowest 25 (OH) D concentration in Blacks for both sexes (males: 14.91 ng/mL; females: 14.07 ng/mL) and highest prevalence of Vitamin D deficiency (males: 80.74%; females: 83.07%) and whites had the highest 25 (OH) D concentration and lowest prevalence of Vitamin D deficiency among all race groups (Fig. 2). For different race groups, the females had more lower 25 (OH) D levels and higher prevalence of Vitamin D deficiency than males (Fig. 2). Subjects with less than an 11th grade education had the lowest 25 (OH) D (males: 20.69 ng/mL; females: 18.37 ng/mL) and highest prevalence of Vitamin D deficiency for both sexes (males: 51.14%; females: 63.49%). Male high school graduates and female college graduates had higher 25 (OH) D concentration (males: 22.64 ng/mL; females: 22.69 ng/mL). There was no significant difference in these

measures difference between those of either sex with high school diplomas and those with college/graduate educations (Fig. 3).

Those who were not obese or who reported physical activity showed higher 25 (OH) D ((OR: 1.133 (0.738, 1.742), p-value: 0.5676). Females smokers were more likely to have lower 25 (OH) D concentration (OR: 1.272 (1.186, 2.557), p-value: 0.0666), but smoking did not appear to affect the concentration among males (OR:1.08, p-value: 0.4805). Age had a significant positive relationship with Vitamin D status in our study. Among younger age groups, subjects were more likely to have Vitamin D deficiency and Vitamin D insufficiency. High total cholesterol was positively associated with Vitamin D status; subjects with high levels of total cholesterol were less likely to have Vitamin D deficiency.

Low levels of vitamin D are common among adults in the United States (Visser *et al.*, 2006; Mckenna, 1992). Nearly 48% of males and 53% of females show 25 (OH) D deficiency. Approximately 36% of males and 30% of females have 25 (OH) D insufficiency. Only 16.16% of males and 16.96% of females show 25 (OH) D sufficiency. In a NHANES study (2000-2004), the prevalence of 25 (OH) D deficiency was reported as 29 and 27% for males in the age categories of 20-49 and 70 years old, respectively and 35 and 34% for females in the age categories of 20-49 and 70 years old, respectively (Malabanan *et al.*, 1998). In this study, the prevalence of 25 (OH) D deficiency was 54.32, 45.69 and 40.35% for males and 57.43, 48.84 and 41.68% for females in the age categories of 18~29, 30~39 and above 70 years old, respectively. These figures are significantly higher than those reported in the NHANES study.

Although little is known about the exact genetic and environmental contributors to 25 (OH) D concentration, there are several plausible explanations for the high prevalence of 25 (OH) D deficiency among U.S. adults:

- Vitamin-D-fortified foods are less readily available
- Less direct sun exposure through use of sun screen and protective clothing, leading to absorption of lesser amounts of ultraviolet radiation
- Amount of vitamin D in supplements might be less than necessary

Although recommendations of daily vitamin D intake have been provided, studies have shown that higher-intakes required having preventive or treatment effects.

The mean 25 (OH) D concentration was significantly higher among the males than the females (21.51±8.47 vs. 20.89±9.73 nmol/L, respectively). The prevalence of 25 (OH) D deficiency was higher in the females than in the males (52.73 vs. 47.76%). Most, but not all, of the previous studies have shown higher 25 (OH) D levels among males than females (Malabanan *et al.*, 1998; Marcelli *et al.*, 1998; Mitchell *et al.*, 2012; Docio *et al.*, 1998). This sex difference might be due to differences in the amount of time spent outdoors or in use of sun-protective behaviors. Differences in overweight status between sexes has been suggested as a factor contributing to lower 25 (OH) D concentrations in females (Saintonge *et al.*, 2009).

In this study, males 18~29 years old and females 40~49 years old showed the lowest 25 (OH) D concentrations and the highest prevalence of 25 (OH) D deficiency, which conflicts with the current belief that the 25 (OH) D concentration declines with age (Marcelli *et al.*, 1998; Moore *et al.*, 2005; Mathieu *et al.*, 2005; Weishaar and Vergili, 2013). However, several studies have failed to substantiate a link between age and 25 (OH) D concentration (Holick, 2007; Gordon *et al.*, 2008; Simonelli, 2005; Guillemant

et al., 1995). A United States study showed that persons aged 70 or more years can synthesize enough vitamin D from daily outdoor activities to maintain sufficient levels (Visser *et al.*, 2006). In this study, those in their 70s showed a higher 25 (OH) D concentration. It could be that these individuals are more likely to be retired and thus spend more time outdoors than those who are younger.

Physical activity and alcohol consumption were positively correlated with 25 (OH) D concentration for both sexes in the previous study. The previous study has shown a positive association between physical activity and 25 (OH) D concentration which is consistent with the previous findings (McCullough *et al.*, 2010; VanDam *et al.*, 2007; Scragg and Camargo, 2008). But this study did not distinguish between outdoor and indoor physical activity, so this positive association might be the result of higher sun exposure during outdoor physical activity. There is no correlation between 25 (OH) D concentration and alcohol consumption in this study.

A previous study showed vitamin D deficiency was more common among those who had no college education (Institute of Medicine, year). This study showed people with high school education are less likely to have 25 (OH) D deficiency than people with college or graduate education or with less than 11th education. These people are more likely to have an outdoor job which leads to a higher 25 (OH) D concentration. Hispanics and blacks were more likely to have vitamin Deficiency and insufficiency than whites. Because populations with higher degree of skin pigmentation may decrease biosynthesis of vitamin D which leads to higher risk of low vitamin D level. Also, poverty is a significant risk factor of vitamin D deficiency. People with lower PIR may not have sufficient intake of vitamin-D-fortified foods such as fish, milk and so on.

Consistent with other work, this study also showed that diabetes was inversely correlated with the 25 (OH) D concentration for males (Pittas *et al.*, 2007). In prospective studies, 25 (OH) D was associated with an decreased risk of type 2 diabetes (Pittas *et al.*, 2010; Mattila *et al.*, 2007). Vitamin D is thought to influence the development of type 2 diabetes through defects in the pancreatic-cell function, insulin sensitivity and systemic inflammation (Pittas *et al.*, 2010; Mattila *et al.*, 2007). There was no significant relationship between 25 (OH) D concentration and diabetes for females in this study; the reason for this is not clear. Further investigation is required to identify differences in the role of vitamin D in diabetes prevention by sex.

Smoking was inversely correlated with 25 (OH) D concentration only among females in this study. Some previous studies have shown a significant inverse relationship between smoking and 25 (OH) D concentration (Lamberg-Allardt *et al.*, 2001; Knekt *et al.*, 2010; Brot *et al.*, 1999). Further investigation

should be conducted to show the gender difference between smoking and 25 (OH) D concentration.

The present study has some limitations. Firstly, detailed information on outdoor activity, sunscreen use, the dietary intake and supplementation of vitamin D were not collected, which could contribute greatly to difference in 25 (OH) D concentration. Supplement users had significantly higher serum 25 (OH) D concentrations compared to non-users. Secondly, season was strongly correlated with 25 (OH) D concentration in previous study. The prevalence of 25 (OH) D deficiency was higher during winter and spring than during summer and fall for males and females, respectively. But there is not season information in NHANES data, we cannot do relative analysis. Third, we did not have location information. It is known the serum 25 (OH) D concentrations has strong relationship with the location. People living in higher latitudes area are more likely to have seasonal vitamin D insufficiency because sunlight does not promote conversion of the vitamin D precursor in the skin in winter. We should do more research consider these factors further.

Furthermore, we found the that total cholesterol has a positive effect on vitamin D level, participants who had higher levels of total cholesterol were more likely to have higher vitamin D levels. This maybe because, in addition to its importance within cells, cholesterol also serves as a precursor for the biosynthesis of steroid hormones, bile acids and vitamin D. Therefore, we should increase the high-density lipoprotein cholesterol, or HDL-C, or the "good" cholesterol and reduce the low-density lipoprotein cholesterol, or LDL-C, or the "bad" cholesterol.

CONCLUSION

In conclusion, vitamin D deficiency was found to be a prevalent condition among U.S. adults. Despite the close link of vitamin D with human health, Vitamin D inadequacy is not widely recognized as a problem by physicians and patients. Greater awareness of the high prevalence of vitamin D inadequacy is required among researchers, clinician and patients. Physically inactive persons and highly educated persons were determined to be more likely to have lower 25 (OH) D concentrations in both genders. As vitamin D deficiency is related to an increased risk of many chronic diseases, it is important for health care professionals to know the determinants of the vitamin D level and to implement corrective intervention strategies. These research findings could help to identify persons who are at risk of 25 (OH) D deficiency.

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