THE PREVALENCE OF HYPOVITAMINOSIS D AMONG US ADULTS: DATA FROM THE NHANES III

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Objective: Several epidemiologic and mechanistic studies suggest that 25(OH) D_3 levels should be maintained above 70 nmol/L for a positive effect on the health of adults. Prior studies have noted low 25(OH) D_3 levels in subsets of minority populations. The objective of this study is to examine the prevalence of adequate 25(OH) D_3 levels among US adults.

Method: Using data from the third National Health and Nutrition Examination Survey (NHANES III), we evaluated serum levels of 25(OH) D_3 (nmol/L) among 15,390 adult participants ≥18 years of age. Racial/ethnic grouping was by self-identification as White, Black or African American, and Hispanic.

Results: The mean levels of 25(OH) D_3 were lower among the female than male participants (71.1 vs 78.7; $P=.003$) and among the elderly (≥65 years of age vs 40–59 and 18–39) than young participants. White men and women (83.0 and 76.0) had higher mean levels of vitamin D than Hispanic men and women (68.3 and 56.7; $P<.0001$) and than Black men and women (52.2 and 45.3; $P<.0001$), respectively. The prevalence of both mild-moderate and severe deficiency of vitamin D is higher among women ($P<.0001$) and minority populations ($P<.0001$). However, even among White men, 34% had low vitamin D levels.

Conclusion: Serum levels of 25(OH) D_3 are below the recommended levels for a large portion of the general adult population and in most minorities. Need exists for a critical review and probable revision of current recommendations for adult vitamin D intake to maintain adequate 25(OH) D_3 levels. (*Ethn Dis*. 2005;15 [suppl 5]:S5-97–S5-101)

Key Words: Hypovitaminosis D, Minority, Vitamin D

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INTRODUCTION

Adequate serum 25(OH) D_3 levels have been associated with a long list of health benefits including but not limited to blood pressure reduction, cardiovascular health, increased insulin sensitivity, and cancer prevention.[1–7] Several epidemiologic and mechanistic studies suggest that vitamin D intake should maintain a serum level of 25(OH) D_3 above 70 nmol/L for a significant positive effect on the health of adults.[8] Vitamin D intake of ≈20–25 μg per day would be required to maintain a serum level of 25(OH) D_3 above 70 nmol/L.[9] However, the recommendations for adult vitamin D intake in the US range only from 5 μg per day for adults to 15 μg per day for children.[10] The optimum requirement for vitamin D may therefore be much higher than the present official recommendations for vitamin D intake. The objective of this study is to examine the prevalence of vitamin D deficiency, defined as serum levels of 25(OH) D_3 below 70 nmol/L by using data from the third National Health and Nutrition Examination Survey (NHANES III).

METHODS

Study Sample

Our analysis used interview and laboratory data from 15,390 adult participants (age≥18 years) who were not taking vitamin D except what was contained in multivitamins. Racial/ethnic grouping for the purpose of this study was by self-identification as White, Black or African American, and Hispanic. Education was used as a surrogate for socioeconomic status (SES). Participants who self-identified as "other" were excluded from our analysis because of low sample size. Serum vitamin D levels were missing for 2937 participants. Supplements containing vitamin D were identified from the NHANES III. Participants receiving therapeutic doses of active vitamin D such as calcitriol, dihydrotachysterol, and ergocalciferol in vitamin D deficiency treatment doses (eg, 50,000 IU; $n=4$) were excluded. We also excluded pregnant women (they may receive special vitamin supplements; $n=171$), and participants with hypoalbuminemia (<3.0 g/L; $n=99$) and significant proteinuria (>3 g albumin/g creatinine; $n=349$) as surrogates of significant liver disease and nephrosis.

Survey

This study used data from NHANES III, a national probability survey conducted by the National Center for Health Statistics at 89 survey locations between 1988 and 1994. The survey is designed to estimate the prevalence of common chronic conditions and associated risk factors for disease control and prevention. The sample for the survey was obtained through a complex multistage cluster design with oversampling of persons ≥60 years of age, non-Hispanic Blacks, and Mexican Americans to enhance the precision of prevalence estimates in these groups.[11,12] Serum levels of 25(OH) D_3 were measured with an INCSTAR 25(OH) D_3 assay, with extraction of 25(OH) D_3 followed by radioimmunoassay with a 25(OH) D_3-specific antibody. The serum level of 25(OH) D_3 was used to classify the

Table 1. Characteristics of analysis sample

	Men	Women
Age, mean	42.81	44.43
Age (%)		
18–39	49.23	46.37
40–59	31.58	30.80
≥60	19.19	22.83
Race/ethnicity (%)		
White	82.75	82.13
Black	10.98	12.62
Hispanic	6.27	5.25
Education (%)		
<High school	24.73	22.90
High school	31.43	38.45
>High school	43.85	38.66
Weight status (%)		
BMI<25	40.27	50.03
25≤BMI<30	40.14	25.48
BMI≥30	19.59	24.49

Table 2. Mean Vitamin D levels (nmol/L) among participants

	Men		Women	
Group	*n*	Mean (SE)	*n*	Mean (SE)
All	7286	78.69 (0.34)	8104	71.07 (0.34)
Age				
18–39	3100	81.38 (0.57)	3499	77.01 (0.60)
40–59	1869	76.76 (0.64)	2117	67.55 (0.59)
≥60	2317	75.41 (0.52)	2488	64.54 (0.50)
Race/ethnicity				
White	3086	82.99 (0.51)	3602	75.95 (0.50)
Black	1999	52.22 (0.48)	2360	45.31 (0.43)
Hispanic	2201	68.31 (0.49)	2142	56.69 (0.48)
Education				
<High school	3116	78.15 (0.56)	3089	64.19 (0.50)
High school	2007	78.60 (0.66)	2771	69.90 (0.57)
>High school	2088	79.12 (0.62)	2207	76.28 (0.70)

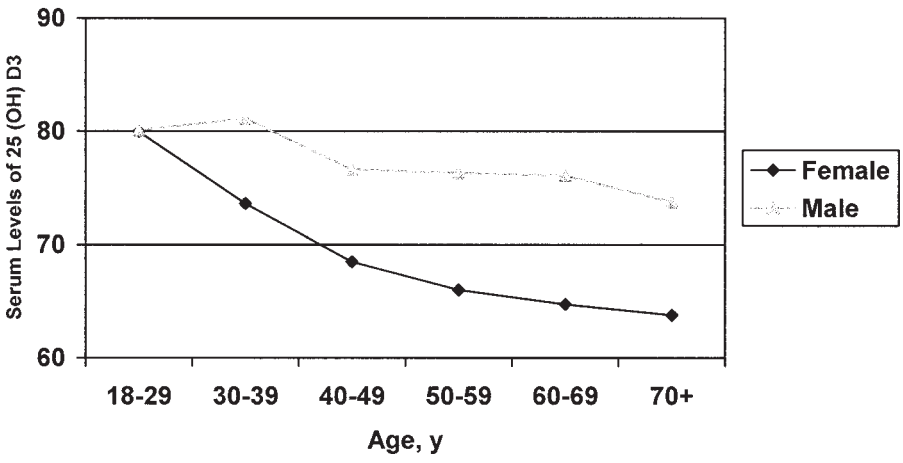

Fig 1. Serum levels of 25 (OH)D_3 (nmol/L) by age and gender

participants as vitamin D deficient (<70 nmol/L or 28 ng/ml) and severely vitamin D deficient (<25 nmol/L or 10 ng/ml).

Statistical Analysis

The analysis sample was stratified by age, gender, and race/ethnicity. Mean levels of serum 25(OH) D_3 were computed and compared between groups by using the two-tailed Student *t* test. Prevalence estimates and standard errors were calculated for the different groups. Data were weighted to account for oversampling, nonresponse bias, and poststratification population totals. Data analyses were conducted using the Statistical Analysis System (version 8.0, SAS Institute, Cary, NC) and SUDAAN version 8.0 (Research Triangle Institute, Research Triangle Park, NC). Statistical hypotheses were tested with a P value <.05 as the level of significance.

RESULTS

A total of 7,286 male and 8,104 female participants were in the final analysis sample. The characteristics of the participants are as shown in Table 1. Although most of the participants were White, the racial/ethnic minorities we chose to study were adequately represented in our analysis sample. The age and gender distributions are comparable across racial/ethnic groups. The mean levels of 25(OH) D_3 were lower among the female than male participants (71.07 vs 78.69; P=.003) and among the elderly (≥60 years of age) than young participants (Table 2 and Figure 1). The mean levels of 25(OH) D_3 by age, gender, ethnicity, and education are as shown in Table 2. White men and women had higher mean levels of 25(OH) D_3 (82.99 and 75.95) than Hispanic men and women (68.31 and 56.69; P<.0001) and than Black men and women (52.22 and 45.31; P<.0001) (Table 2, Figure 2).

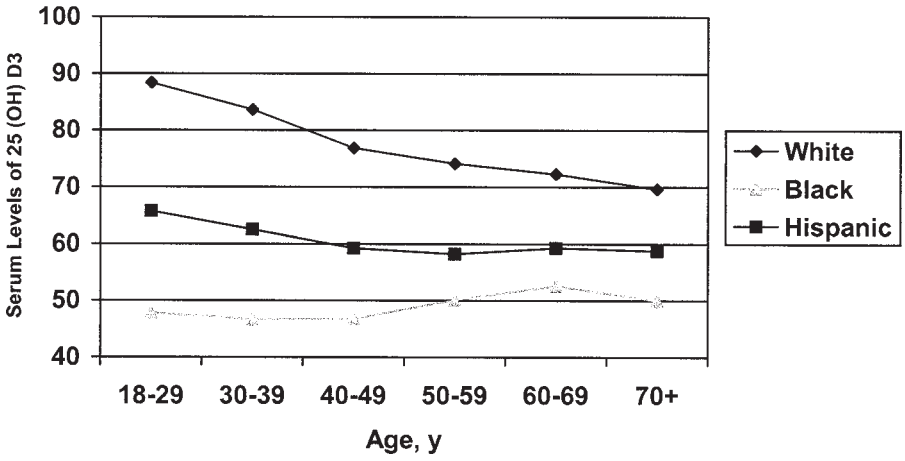

Fig 2. Serum levels of 25 (OH)D_3 (nmol/L) by age and race

Female participants with higher education had significantly higher levels of 25(OH) D_3, while no significant differences in the levels of 25(OH) D_3 across educational levels were seen among the male participants. The prevalence of both the mild-moderate and severe deficiency of vitamin D is higher among women and minority populations (Table 3). In a regression model adjusting for age, education, and body mass index, the relative risk of vitamin D deficiency remained greater for women in comparison with men and for minority populations in comparison with the White population (Table 4).

Table 3. Prevalence of mild-moderate and severe hypovitaminosis D

	Mild to Moderate 25–70 nmol/L		Severe < 25 nmol/L	
Group	**Men (%)**	**Women (%)**	**Men (%)**	**Women (%)**
All	40.29	50.73	1.12	2.65
Race/ethnicity				
White	34.39	45.22	0.50	1.27
Black	76.22	77.54	5.72	11.19
Hispanic	55.08	72.46	1.24	3.71
Age				
18–39	37.27	44.19	1.13	2.49
40–59	42.86	55.20	1.34	2.35
≥60	43.79	57.97	0.75	3.38
Education				
<High school	41.90	58.85	1.17	3.46
High school	39.41	52.06	1.27	2.68
>High school	40.01	44.47	0.98	2.12

Table 4. Odds ratios of hypovitaminosis D*

	Male		Female	
Race/Ethnicity	**OR (95% CI)**	***P*-value**	**OR (95% CI)**	***P*-value**
White	Referent		Referent	
Black	7.48 (6.51–8.58)	<.0001	8.24 (7.11–9.54)	<.0001
Hispanic	2.72 (2.40–3.08)	<.0001	3.29 (2.89–3.74)	<.0001

* Adjusted for age, education and body mass index.

DISCUSSION

Our findings indicate that vitamin D deficiency is highly prevalent among the general adult population in the United States, with a much greater preponderance among minority populations, the elderly, and female adults. The reasons for the pervasiveness of vitamin D deficiency are complex, and include but are not limited to reduced outdoor activities and associated reduction in sunlight exposure, low vitamin D intake, and possible low recommendations that lead to suboptimal intake of vitamin D even for those who follow the recommendations. With the exception of a few food items (eg, fish), the human diet does not provide enough vitamin D to prevent diseases like rickets and osteomalacia.[13,14] The solar synthesis of vitamin D in the skin and the variable degree of exposure to sunlight among humans deprives us of a reasonable reference point for dietary intake of vitamin D. A level of vitamin D intake associated with vitamin D deficiency in one population[15] has been implicated in vitamin D toxicity in another population.[16] Dietary recommended allowances for vitamin D for adults have generally erred more on the side of safety than adequacy.[17]

The circulating levels of serum 25(OH) D_3 have been suggested as the best objective method to assess vitamin D nutritional status.[18] Serum levels of 25(OH) D_3 greater than 70 nmol/L have recently been recommended for optimum bone health, and levels below 25 nmol/L have been associated with rickets and histologic evidence of osteomalacia.[2,19] Low vitamin D levels have been associated with other health problems as well, such as high blood pressure, cardiovascular disease, decreased insulin sensitivity, and cancer.[1–7] Our analysis is not sufficient to

determine if the lower levels of 25(OH) D_3 observed among racial/ethnic minorities in this study are due to reduced vitamin D intake, diminished exposure to sunlight, or delayed vitamin D synthesis in highly pigmented skin.[20,21] Ultraviolet light exposure and time spent outdoors are better predictors of 25(OH) D_3 levels than dietary vitamin D intake.[22] Also, dietary vitamin D intake correlates poorly with 25(OH) D_3 levels.[23] The timing of blood collections for NHANES participants appears to minimize the effect of seasonal variation from sunlight exposure on vitamin D levels as northern samples are collected during the warmer months, which suggests that NHANES sampling is appropriate for assessing vitamin D levels among the general population.[24]

The lower levels of 25(OH) D_3 observed with increasing age in this study are consistent with the existing body of literature[25] and may be due in part to the fact that aging decreases the capacity of human skin to produce vitamin D.[26] Low vitamin D levels in the elderly are of clinical relevance as they are associated with reduced lower-extremity function.[27] To our knowledge the lower levels of 25(OH) D_3 and the high prevalence of vitamin D deficiency among female participants with a lower level of education have not been reported previously, although low levels have been noted among women of reproductive age.[28] The recommendation that the serum level of 25(OH) D_3 should exceed 70 nmol/L for optimum bone health and osteoporosis prevention makes the high rate of vitamin D deficiency among the female participants particularly disturbing and should prompt the review and revision of the current adult female vitamin D intake recommendations. At the current level of adult vitamin D intake, ≈50% of adult Americans are vitamin D deficient. Abundant evidence shows that the daily intake of vitamin D in adults should be at least 800 IU (20 μg) with ≈1.2 g of elemental calcium. Lower levels of vitamin D intake may not be as effective, while higher levels of intake may cause hypercalcemia.[29–31] The daily multivitamin generally provides 400 IU of vitamin D along with minimum amounts of other vitamins. Inquiring about the use of additional dietary supplements is pertinent before prescribing extra doses of vitamin D. Although the level of intake at which vitamin D becomes toxic is unknown, hypercalcemia due to vitamin D intake is generally associated with serum levels of 25(OH) D_3 in excess of 220 nmol/L.

In conclusion, our study represents the first attempt (to our knowledge) to examine the prevalence of vitamin D deficiency across racial/ethnic subgroups from a representative sample of adults in the United States and to report high rates of vitamin D deficiency in a large, unselected group of minority adults. The high rate of severe vitamin D deficiency, particularly among minorities, is especially disturbing. Our findings highlight the magnitude of the problem of vitamin D deficiency and reiterate the need for a review and probable revision of current adult vitamin D intake recommendations and/or innovative strategies to implement existing recommendations.[13] The new recommendations should foster the efforts of the general public, clinicians, and public health professionals to effectively forestall vitamin D deficiency and its associated effects on the health of Americans.

ACKNOWLEDGMENTS

This research was supported in part by the NIH-NCRR/RCMI (RR03026, RR11145, RR14616, and RR019234), and DREW/UCLA Project EXPORT, NIH-NCMHD (MD00148).

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