Vitamin D insufficiency in southern Arizona[1–3]

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ABSTRACT

Background: Vitamin D deficiency or insufficiency has been observed among populations in the northern United States. However, data on the prevalence of vitamin D deficiency in areas of high sun exposure, such as Arizona, are limited.

Objective: The purpose of this study was to analyze serum 25-hydroxyvitamin D [25(OH)D] concentrations in residents of southern Arizona and to evaluate predictors of 25(OH)D in this population.

Design: Cross-sectional analyses of serum from participants in a colorectal adenoma prevention study were conducted to determine rates of vitamin D deficiency. Participants were categorized into 4 groups on the basis of serum 25(OH)D concentrations: <10.0 ng/mL, ≥10.0 ng/mL and <20.0 ng/mL, ≥20.0 ng/mL and <30.0 ng/mL, and ≥30.0 ng/mL.

Results: The mean serum 25(OH)D concentration for the total population was 26.1 ± 9.1 ng/mL. Of 637 participants, 22.3% had 25(OH)D concentrations >30 ng/mL, 25.4% had concentrations <20 ng/mL, and 2.0% had concentrations <10 ng/mL. Blacks (55.5%) and Hispanics (37.6%) were more likely to have deficient 25(OH)D concentrations (<20 ng/mL) than were non-Hispanic whites (22.7%). Sun exposure had a greater effect on 25(OH)D in whites than in blacks and Hispanics, whereas BMI appeared to be more important in the latter groups.

Conclusion: Despite residing in a region with high chronic sun exposure, adults in southern Arizona are commonly deficient in vitamin D deficiency, particularly blacks and Hispanics. *Am J Clin Nutr* 2008;87:608–13.

KEY WORDS Vitamin D deficiency, race-ethnicity, 25-hydroxyvitamin D, 25(OH)D, Arizona

INTRODUCTION

Currently, the recommended adequate intake of vitamin D is 200 IU for individuals aged <51 y and 400 IU for those aged 51–70 y (1), which represents the intake at which the deficiency diseases rickets and osteomalacia are prevented. Vitamin D deficiency has classically been defined as circulating concentrations of 25-hydroxyvitamin D [25(OH)D] < 10 ng/mL (2), but subsequent studies have indicated that concentrations <20 ng/mL are insufficient for blood parathyroid hormone (PTH) homeostasis (3). More recently, it was recommended that nutritional vitamin D deficiency be defined as concentrations of circulating 25(OH)D < 32 ng/mL, based on optimization of PTH concentrations, calcium absorption, and bone mineral density (4). Results from the third National Health and Nutrition Examination Survey (NHANES III) show that ≈42% of African American women and 4.2% of white women had serum 25(OH)D concentrations <15 ng/mL (5). Other studies in the United States, generally conducted in northern latitudes, have found that up to 30% of healthy, noninstitutionalized adults had vitamin D insufficiency, with higher rates in those with darkly pigmented skin (reviewed by Hanley and Davison; 6). However, few studies have been conducted in regions of the southern United States, where ultraviolet (UV) exposure is relatively high (5, 7, 8), and less is known about the vitamin D status of that population. Because the ability to synthesize vitamin D endogenously is dependent on several factors, including age, skin color, and geographic location, vitamin D status may vary in different locations of the United States. Recently, there has been renewed interest in revising recommendations for vitamin D intake (4, 9). It is especially imperative to consider the contribution of regional differences in sunlight exposure and race-ethnicity to vitamin D status when evaluating these guidelines. Therefore, the objective of this work was to determine whether serum 25(OH)D concentrations are adequate in a sun-replete southern Arizona adult population and to assess whether there were differences in 25(OH)D by self-reported race-ethnicity. Additionally, in an attempt to clarify the correlates of 25(OH)D in a population in a sun-replete location, we constructed a model to determine the variables that contributed to circulating serum 25(OH)D concentrations.

SUBJECTS AND METHODS

Study population and design

Data were available from participants in the Ursodeoxycholic Acid Trial—a double-blind, randomized, placebo-controlled

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trial designed to assess the effect of ursodeoxycholic acid treatment (8–10 mg · kg^{-1} · d^{-1}) for 3 y on the risk of colorectal adenoma recurrence (10). Participants were aged 40–80 y and resided in Tucson (latitude 32° 7' N; elevation 2480 feet, or ≈744 m) or Phoenix (latitude 33° 26' N; elevation 1122 feet, or ≈337 m) AZ, and had had one or more adenomas removed within the 6 mo before randomization (10). A total of 619 participants were randomly selected for analyses of serum concentrations of 25(OH)D. To enrich the population with participants with darker skin pigmentation, the remaining available samples from all participants who reported their race-ethnicity as black, Hispanic, or Native American were analyzed, which yielded a total of 637 participants of the 1192 who completed the Ursodeoxycholic Acid Trial for the current study. The study was approved by the University of Arizona Human Subjects Committee and local hospital committees, and written informed consent was obtained from each participant before study enrollment.

Analysis of serum 25(OH)D

Serum samples were assessed for 25(OH)D concentrations at the laboratory of Bruce Hollis at the Medical University of South Carolina. Acetonitrile extraction was performed, and [^{125}I]vitamin D derivative was added to the assay tubes (11). After incubation with primary antibodies, 0.5 mL of the second-antibody complex was added, incubated, and counted with a gamma well-counting system. The CV for the analyses was <7.0% (11).

Exposure variables

Dietary data were collected using the Arizona Food Frequency Questionnaire (AFFQ), a self-administered, semi-quantitative, scannable instrument with 113 items (12). The AFFQ was completed at baseline, where study participants were asked to report their usual intake of foods for the prior 12-mo period (10).

Sun exposure was evaluated by using the Arizona Physical Activity Questionnaire (APAQ). The APAQ was modified from the Minnesota Leisure Time Physical Activity Questionnaire (13), which is a self-administered questionnaire designed to assess physical activity in the previous month. The frequency and average time spent on any physical activity (including sleeping and living tasks) were reported by the participants at the beginning of the study, summed, and expressed as metabolic equivalents (METs). To estimate sun exposure, a "0" for indoor or a "1" for outdoor was assigned to individual activities. The amount of time in the sun was calculated by multiplying the time spent performing each activity by the sun exposure variable and then summing the amount of sun exposure from each activity and summarizing an average amount of sun exposure per week.

At baseline, participants completed a questionnaire for various demographic data. On the questionnaire, participants selected one race category from the following choices: white, black, Native American, Asian, and other. They then self-reported their Hispanic ethnicity. Participants reporting "other" or those with missing data were excluded from the race-ethnicity-specific analyses ($n = 22$).

Study participants were categorized on the basis of 4 cutoffs of serum 25(OH)D concentrations: <10.0 ng/mL, 10.0–19.9 ng/mL, 20.0–29.9 ng/mL, and ≥30.0 ng/mL. The first cutoff was based on the classic definition of vitamin D deficiency (2); the second on the concentration at which homeostasis of blood PTH is proposed to be achieved (3), and which more recently has been proposed to classify a deficient state; the third on optimal PTH regulation, calcium absorption, and bone mineral density (4); and the fourth on 25(OH)D concentrations proposed for optimal health (4). Although there is some controversy regarding the best cutoff to define optimal status based on 25(OH)D concentrations, we used 30.0 ng/mL given recent publications and our own work in this area (4). With regard to the season when blood was drawn, winter was designated as December 1 to February 28, spring was from March 1 to May 30, summer was from June 1 to August 31, and fall was from September 1 to November 30.

Statistical analyses

All analyses were conducted by using the STATA statistical software package (version 9.0; Stata Corporation, College Station, TX). Means and standard deviations were used to describe baseline characteristics by vitamin D status and by race-ethnicity. P values were calculated by using ANOVA for categorical variables and linear regression for continuous variables. Percentages were calculated for the number of participants in each category of vitamin D status by race-ethnicity, sex, and season. Comparisons of serum 25(OH)D concentrations by race-ethnicity and sex were performed by using Student's t test. P values < 0.05 were considered to be statistically significant.

The model for predicting serum 25(OH)D concentrations was constructed by using the methods of Giovannucci et al (14). Each of the variables that were significant in the preliminary analysis of baseline characteristics by 25(OH)D concentration was included in the linear regression model; serum 25(OH)D was the outcome variable. Any variable that remained statistically significant ($P < 0.05$) in the multivariate linear regression model was included in the final prediction model. Predictors of 25(OH)D were then evaluated separately by race-ethnicity using the same methods.

RESULTS

Baseline characteristics of the study population by category of 25(OH)D concentration are shown in **Table 1**. A total of 13 (2.0%) participants had 25(OH)D concentrations <10.0 ng/mL, 149 (23.4%) had concentrations >10.0 ng/mL or <20.0 ng/mL, 333 (52.2%) had concentrations between 20.0 and 29.9 ng/mL, and 142 (22.3%) had concentrations ≥30 ng/mL. In general, participants in the highest category of serum 25(OH)D were more likely to be male, to be white, to have a lower body mass index, to spend more time in the sun, and to consume more energy, calcium, and dietary vitamin D than those with concentrations <10 ng/mL.

Baseline characteristics of participants by self-reported race/ethnicity are shown in **Table 2**. Whites were significantly older than Hispanics and blacks. Hispanics consumed significantly more energy and total fat than did whites and also reported a significantly higher intake of calcium than did blacks. Dietary vitamin D intake was significantly lower and physical activity was significantly higher among blacks than among whites. Hispanics, blacks, and Native Americans all reported significantly higher sun exposure than whites.

The results of predictive models of serum 25(OH)D in the total population and by race-ethnicity are shown in **Table 3**. The R^2 values of the model for the total population, for whites, and for blacks and Hispanics combined were 0.16, 0.17, and 0.55, respectively (data not shown). Sun exposure and dietary vitamin D

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TABLE 1
Baseline characteristics by serum 25-hydroxyvitamin D [25(OH)D] concentrations

Characteristic	Serum 25(OH)D <10.0 ng/mL (n = 13; 2.0%)	10.0–19.9 ng/mL (n = 149; 23.4%)	20.0–29.9 ng/mL (n = 333; 52.2%)	≥30.0 ng/mL (n = 142; 22.3%)	P for trend
Age (y)	61.6 ± 9.3[1]	65.4 ± 8.6	66.2 ± 8.4	64.7 ± 8.9	0.78
Males [n (%)]	6 (46.2)	73 (49.0)	235 (70.6)	101 (69.2)	0.008
White [n (%)]	8 (72.7)	114 (88.4)	287 (93.8)	130 (95.6)	0.000
Current smoker [n (%)]	3 (23.1)	22 (14.8)	37 (11.1)	21 (14.4)	0.85
BMI (kg/m^2)	30.2 ± 7.9	28.0 ± 5.4	27.7 ± 4.5	26.6 ± 4.0	0.000
Energy (kcal/d)	2376.7 ± 1283.4	1832.6 ± 838.3	2026.5 ± 792.2	2087.1 ± 824.4	0.04
Total fat (g/d)	80.9 ± 48.9	60.6 ± 35.4	66.6 ± 32.2	67.4 ± 31.3	0.28
Calcium (mg/d)	928.4 ± 475.3	864.3 ± 423.9	985.3 ± 460.5	1039.2 ± 510.8	0.000
Dietary vitamin D (IU/d)	98.6 ± 78.6	111.1 ± 84.3	138.9 ± 100.7	150.2 ± 100.9	0.02
Supplemental vitamin D (IU/d)	285.7 ± 406.5	218.9 ± 280.4	259.0 ± 228.0	253.8 ± 233.9	0.25
Physical activity (kcal/d)	2642.7 ± 306.4	2317.7 ± 595.9	2472.0 ± 650.9	2448.0 ± 729.4	0.41
Sun exposure (min/wk)	1.6 ± 1.6	4.9 ± 7.0	6.8 ± 10.6	8.2 ± 9.5	0.001

[1] $\bar{x}$ ± SD (all such values).

intake had a larger effect on circulating 25(OH)D concentrations among whites than among blacks and Hispanics, whereas sex appeared to be a more important factor for the latter group. Although there was no statistically significant race × sex interaction (P = 0.10), a statistically significant race × sex × season interaction (P = 0.03) was observed (data not shown).

As shown in **Table 4**, differences in circulating 25(OH)D concentrations by race-ethnicity were observed. The mean (±SD) concentration in whites was 26.7 ± 9.1 ng/mL; concentrations were significantly lower in for Hispanics (22.4 ± 7.3 ng/mL; $P < 0.01$) and blacks (18.2 ± 7.5 ng/mL; $P < 0.001$). The mean value for Native Americans (28.2 ± 8.6 ng/mL) was not significantly different from that of whites ($P < 0.63$). A total of 24.1% of whites had optimal concentrations of 25(OH)D (≥30 ng/mL), compared with 12.5% of Hispanics, 11.1% of blacks, and 40.0% of Native Americans. Conversely, only 1.5% of whites were found to have circulating 25(OH)D concentrations <10 ng/mL compared with 6.3% of Hispanics, 11.1% of blacks, and 0.0% of Native Americans. With respect to sex, men were more likely than women to have 25(OH)D concentrations ≥30 ng/mL (24.3% compared with 19.9%, respectively), whereas women were twice as likely to have concentrations <10 ng/mL (3.1% compared with 1.5%, respectively). Overall, serum 25(OH)D concentrations were significantly lower in women (24.8 ± 10.3 ng/mL) than in men (26.8 ± 8.3 ng/mL; $P < 0.01$).

Because of the high level of sunlight exposure in southern Arizona, we assessed whether the proportion of individuals in each category of 25(OH)D concentration changed by season (**Table 5**). Mean concentrations of serum 25(OH)D varied by season; the highest values were observed in summer (29.3 ± 9.3 ng/mL) and the lowest values in winter (24.1 ± 8.8 ng/mL). In the summer and fall, 33.3% and 29.0% of participants, respectively, had vitamin D concentrations ≥30 ng/mL; proportions were lower in the winter (15.0%) and spring (17.5%). Likewise, the proportion of participants with 25(OH)D concentrations <20 ng/mL was greater in the winter (35.6%) and spring (32.5%) than in the summer (11.7%) and fall (15.5%).

TABLE 2
Baseline characteristics by race-ethnicity

Characteristic	Race-ethnicity White (n = 539)	Hispanic (n = 48)	Black (n = 18)	Native American (n = 10)
Age (y)[1]	66.2 ± 8.5[2]	62.6 ± 8.5[3]	60.9 ± 9.8[3]	63.4 ± 5.8
Male [n (%)]	346 (64.2)	31 (64.6)	12 (66.7)	7 (70.0)
Current smoker [n (%)]	67 (12.7)	7 (14.6)	2 (11.8)	2 (20.0)
BMI (kg/m^2)	27.4 ± 4.6	28.5 ± 5.2	29.3 ± 5.7	28.6 ± 5.7
Energy (kcal/d)[1]	1963.0 ± 775.7	2459.7 ± 933.5[3]	1997.1 ± 1124.1	1606.1 ± 643.0
Total fat (g/d)[1]	63.3 ± 30.3	90.4 ± 47.9[3]	70.3 ± 41.1	54.3 ± 25.9
Calcium (mg/d)[1]	968.3 ± 464.2	1079.7 ± 426.1[4]	716.7 ± 388.2	742.8 ± 358.3
Dietary vitamin D (IU/d)[1]	137.0 ± 96.7	130.0 ± 101.5	76.7 ± 65.0[3]	100.1 ± 91.4
Supplemental vitamin D (IU/d)	253.3 ± 247.2	157.1 ± 243.8	142.9 ± 189.5	NA
Physical activity (kcal/d)[1]	2404.0 ± 629.7	2564.3 ± 829.7	2961.9 ± 910.5[3]	2732.2 ± 1207.6
Sun exposure (min/wk)[1]	5.3 ± 5.8	18.1 ± 23.4[3]	12.6 ± 9.4[3]	27.3 ± 25.3[3,4]

[1] $P < 0.05$ (ANOVA).
[2] $\bar{x}$ ± SD (all such values).
[3] Significantly different from whites, $P < 0.05$ (Tukey-Kramer test).
[4] Significantly different from blacks, $P < 0.05$ (Tukey-Kramer test).

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TABLE 3
Predictive models of changes in serum 25-hydroxyvitamin D [25(OH)D] concentrations in the total population and by race-ethnicity[1]

Baseline characteristic	Change in 25(OH)D (ng/mL) Total population (n = 637)	White (n = 539)	Black or Hispanic (n = 66)
Race, white	5.6 (0.000)	NA	NA
Sex, male[2]	1.4 (0.10)	0.4 (0.65)	6.2 (0.002)
BMI (kg/m^2)	−0.3 (0.001)	−0.23 (0.01)	−0.68 (0.00)
Sun exposure (min/wk)	0.2 (0.000)	0.42 (0.000)	0.05 (0.26)
Dietary vitamin D intake (IU/d)	0.01 (0.01)	0.01 (0.03)	0.01 (0.21)
Season[3]			
Winter	Referent	Referent	Referent
Spring	0.9 (0.34)	1.0 (0.40)	−0.2 (0.91)
Summer	5.6 (0.000)	6.0 (0.000)	0.6 (0.82)
Fall	3.5 (0.001)	3.3 (0.003)	5.3 (0.03)

[1] All values are β-coefficients; P values in parentheses. NA, not available. All coefficients and P values were calculated with multivariate linear regression models.
[2] An interaction term for race × sex was not statistically significant in the model (P = 0.10).
[3] An interaction term for race × sex × season was statistically significant in the model (P = 0.03).

DISCUSSION

This study was conducted to assess whether circulating 25(OH)D concentrations are adequate in southern Arizona, a region of the United States with high sun exposure. We observed that deficiency, recently defined as a 25(OH)D concentration <20 ng/mL, was present in ≈25% of our adult population; higher rates were observed in Hispanics, blacks, and women. When the classic cutoff for deficiency (< 10 ng/mL) was used, the same differences across race-ethnicity and sex were observed. In addition, despite the relatively high UV exposure in southern Arizona throughout the year, seasonal variation in serum 25(OH)D concentrations was detected.

In the current study, lower concentrations of circulating 25(OH)D were more commonly observed in women and in those with a higher BMI. Men spent almost twice as much time in the sun and consumed more dietary vitamin D, which might have contributed to the sex differences observed; however, women had a slightly higher intake of supplemental vitamin D (data not shown). The inverse association between BMI and circulating 25(OH)D has been hypothesized to be related to sun avoidance in those with a higher BMI or to sequestration of 25(OH)D in adipose tissue (15, 16).

In our study, 25% of the study participants were found to be in a deficient state, based on serum 25(OH)D concentrations <20 ng/mL. This percentage is lower than that observed by Levis et al (7) in a study of residents in south Florida (39%). One potential reason for the higher rates of vitamin D deficiency in the south Florida population was the greater proportion of women (63.7%) than in the current study (35.3%). As noted earlier, the women in our study had lower serum 25(OH)D concentrations than did the men; this finding was also evident in the south Florida population.

In a study based on data from NHANES III, Looker et al (8) assessed the 25(OH)D status of adolescents and adults of both sexes in the United States. In that study, vitamin D deficiency and insufficiency were defined as serum 25(OH)D concentrations of <17.5 nmol/L (7.0 ng/mL) and 62.5 nmol/L (25.0 ng/mL), respectively. The rates of deficiency were <1%, whereas up to 58% of the total population had insufficiency (8). Direct comparisons with the current work are difficult because of the unique

TABLE 4
Distribution of participants by ethnicity, sex, and category of serum 25(OH)D concentration

	Mean 25(OH)D concentration	Serum 25(OH)D <10.0 ng/mL	10.0–19.9 ng/mL	20.0–29.9 ng/mL	≥30.0 ng/mL
Race-ethnicity[1]	*ng/mL*	*n (%)*			
White (n = 539)	26.7 ± 9.1	8 (1.5)	114 (21.2)	287 (53.3)	130 (24.1)
Hispanic (n = 48)	22.4 ± 7.3[2]	3 (6.3)	15 (31.3)	24 (50.0)	6 (12.5)
Black (n = 18)	18.2 ± 7.5[3]	2 (11.1)	8 (44.4)	6 (33.3)	2 (11.1)
Native American (n = 10)	28.2 ± 8.6[4]	0 (0.0)	2 (20.0)	4 (40.0)	4 (40.0)
Sex[5]					
Men (n = 412)	26.8 ± 8.3	6 (1.5)	73 (17.6)	235 (56.6)	101 (24.3)
Women (n = 225)	24.8 ± 10.3[6]	7 (3.1)	76 (33.6)	98 (43.4)	45 (19.9)

[1] P = 0.004 chi-square test for ethnicity by category of serum 25(OH)D.
[2,3] Significantly different from white (Student's t test): [2] $P < 0.01$, [3] $P < 0.001$.
[4] Not significantly different from white, $P < 0.63$ (Student's t test).
[5] P = 0.001 chi-square test for sex by category of serum 25(OH)D.
[6] Significantly different from men, $P < 0.01$ (Student's t test).

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TABLE 5
Distribution of participants by season and by category of serum 25(OH)D concentration

Season	Mean 25(OH)D	25(OH)D concentration <10.0 ng/mL	10.0–19.9 ng/mL	20.0–29.9 ng/mL	≥30.0 ng/mL
	ng/mL	*n (%)*			
Winter (*n* = 180)	24.1 ± 8.8	3 (1.7)	61 (33.9)	89 (49.4)	27 (15.0)
Spring (*n* = 154)	25.0 ± 9.0	2 (1.3)	48 (31.2)	77 (50.0)	27 (17.5)
Summer (*n* = 120)	29.3 ± 9.3	3 (2.5)	11 (9.2)	66 (55.0)	40 (33.3)
Fall (*n* = 155)[1]	27.7 ± 8.7	3 (1.9)	21 (13.6)	86 (55.5)	45 (29.0)

[1] $P = 0.001$ chi-square test for season by category of serum 25(OH)D.

design of NHANES III. Because NHANES includes data from participants across the United States, it might be expected that the inclusion of those in the northern United States would result in higher rates of vitamin D insufficiency. However, NHANES data are collected in the southern United States during the winter and in the northern United States during the summer (8), which results in higher 25(OH)D concentrations than might otherwise be expected.

In another study that used NHANES data to assess 25(OH)D concentrations among women of reproductive age, Nesby-O'Dell (5) reported rates of insufficiency of 4.2% for white women and 42.4% for black women using a cutoff of <15.0 ng/mL (5). Given the lower cutoff used to classify insufficiency, lower rates than those observed by Looker et al (8) and in our study are evident. When the cutoff of <5.0 ng/mL was applied to the data for our study, 15.0% of the white women and 66.7% of the black women were classified as deficient—higher proportions than those reported by Nesby-O'Dell et al, possibly because the rates of overweight (42.2%) and obesity (27.1%) in the current study were higher than those reported in NHANES (22.5% and 24.2%, respectively) (5). It must be noted that difficulties exist when results are compared across studies of 25(OH)D concentrations. The fact that different methods are sometimes used to assess 25(OH)D concentrations and that different cutoffs are used to classify different levels of status (eg, deficient, insufficient, and optimal) creates challenges in this field. One step forward would be to come up with terminology and agreed on cutoffs for various states of vitamin D status.

The finding of lower concentrations of serum 25(OH)D observed among blacks and Hispanics in our study is consistent with the known effect of skin pigmentation on endogenous synthesis of vitamin D (17). Furthermore, the exploratory modeling of the predictors of serum 25(OH)D by race-ethnicity showed that the factors with the greatest effect on serum 25(OH)D concentrations may vary by degree of skin pigmentation. For example, sun exposure appeared to have less of an effect on circulating 25(OH)D concentrations in Hispanics and blacks than in whites, whereas body mass index and sex had a greater effect on serum concentrations in the former group than in the latter group. We did not observe significantly different serum 25(OH)D concentrations between whites and those reporting Native American race. The Native Americans in our study spent more time in the sun, which may have negated the effect of skin pigmentation in the Native Americans in this population. However, these data must be interpreted with caution because of the small numbers of Native Americans in the current study. Additionally, only one choice could be made for race on the demographic questionnaire, which cannot account for complexities introduced by mixed ancestry. The ability of self-reported race-ethnicity to describe skin phototypes is controversial, although those with more pigmented skin types have shown stronger correlations with physician-diagnosed skin phototypes (18). Nonetheless, a limitation to this study was the use of race-ethnicity as a proxy for skin pigmentation (15, 19).

The observed differences in serum 25(OH)D by season are similar to what was observed by Levis et al (7) in the south Florida population, where higher concentrations were shown during the summer months. This finding indicates that, despite the relatively high sunshine exposures in southern Arizona and Florida, deficiency is more common in the winter months than in the summer months.

Limitations in the current study must be considered, including the relatively small number of participants reporting black and Native American race-ethnicity and the measure of sun exposure, which was derived from a physical activity questionnaire by characterizing activities as "indoor" or "outdoor." Values for sun exposure per week ranged from 0 to 100 min, with a mean of 6.6 min/wk. This estimate is far lower than what might be expected in a population in southern Arizona; however, significant differences in circulating 25(OH)D concentrations were observed relative to sun exposure. This finding indicates that, whereas the measure of UV exposure per week may underestimate the actual amount of time spent in the sun, it is able to differentiate between groups with higher and lower UV exposure. The strengths of this study included the use of a validated measure of serum 25(OH)D and the availability of data for factors that have been linked to 25(OH)D, including dietary and supplemental vitamin D intakes, physical activity, and race-ethnicity.

In summary, although classic vitamin D deficiency (<10 ng/mL), which leads to rickets and osteomalacia, is uncommon in this population, recent work has associated suboptimal concentrations of circulating 25(OH)D with a number of diseases, including cancer, diabetes, and heart disease (2, 20). Furthermore, the differences in 25(OH)D by race-ethnicity may contribute to some of the variation in disease incidence and outcomes between groups and warrant further study.

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interpret the data; BWH: conducted the analyses of serum 25(OH)D and helped interpret the manuscript; ZY: conducted the literature searches and helped prepare the manuscript; and MEM: collaborated in the planning and analysis of the study and helped prepare the manuscript. All authors reviewed the final manuscript before submission, and none had a conflict of interest with regard to this work.

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