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Vitamin D Insufficiency and Hyperparathyroidism in a Low Income, Multiracial, Elderly Population*

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ABSTRACT

This report examines the wintertime vitamin D and PTH status of 308 participants in the Boston Low Income Elderly Osteoporosis Study of noninstitutionalized low income elderly men and women (age, 64–100 yr) living in subsidized housing in Boston, MA. Twenty-one percent of the 136 black subjects and 11% of the 110 whites had very low plasma 25-hydroxyvitamin D (25OHD) concentrations (<25 nmol/L), and 73% of the blacks and 35% of the whites had 25OHD concentrations less than 50 nmol/L. The mean 25OHD levels of the smaller Hispanic and Asian subsets were generally similar to those of the white subjects. In addition to race, significant predictors of 25OHD included vitamin D intake (positive association) and smoking (inverse association), but not sex or age. Low 25OHD concentrations were associated with increased PTH and reduced serum calcium. The PTH level in the black subjects was substantially higher than that in the white subjects, and this difference was only partially explained by the racial difference in 25OHD. Elderly individuals who live in northern areas, particularly African-Americans, should be strongly encouraged to increase their vitamin D intake, especially in winter. (*J Clin Endocrinol Metab* **85:** 4125–4130, 2000)

VITAMIN D DEFICIENCY is common in the institutionalized elderly (1, 2), and it is becoming increasingly clear that the vitamin D status of some free-living populations may not be ideal (3, 4). Urban, low income, elderly adults who live in northern cities such as Boston may be at a high risk for vitamin D deficiency compared with other older adults because of more limited sun exposure and lower dietary vitamin D intakes. In Boston, a high proportion of the low income population is African-American, a group at even higher risk because of reduced skin synthesis of vitamin D precursors (5–8). Most population-based studies of vitamin D status in the elderly have involved relatively affluent subjects (9–12), only one has involved black women (12), none has involved black men, and few have examined subjects in the winter when, at northern latitudes, vitamin D deficiency is most common (9, 13).

Low vitamin D intakes and blood levels of 25-hydroxyvitamin D (25OHD), the metabolite that best reflects vitamin D status, are clearly linked to bone loss (14) and fracture (15, 16), and there is more limited evidence that vitamin D reduces the risk of hypertension (17, 18), cardiovascular disease (19), diabetes (19), and some cancers (20, 21). Vitamin D deficiency can be reversed easily and inexpensively through vitamin D supplementation and exposure to UV light. The identification of at-risk subsets of the U.S population is necessary to design and target appropriate interventions that have the potential to reduce the incidence of common and debilitating chronic diseases.

This report examines the wintertime vitamin D and PTH status of participants in the Boston Low Income Elderly Osteoporosis Study (BLEOS) of noninstitutionalized low income elderly men and women living in subsidized housing in Boston, Massachusetts.

Experimental Subjects

All of the 702 men and women born before 1935 (and therefore at least 64 yr old) who lived in any of the 14 subsidized housing units operated by the Boston Housing Authority in the Boston neighborhoods of Dorchester, Mattapan, and Jamaica Plain were invited to participate in the study. Of them, 349, or 50%, were enrolled. Reasons for nonparticipation included being away from the building on the day of measurements (some eligible subjects were in the hospital or under short-term nursing home care), being bed-bound or unable to come to the common room, and an unwillingness to participate. The mean age of participants (75 ± 8 yr) was similar to that of nonparticipants (75 ± 7 yr), as was the percentage of females (63% and 62% in the participants and nonparticipants, respectively). The protocol was approved by the research board of the Carney Hospital and the human investigation review committee at Tufts University, and written informed consent was obtained from all participants. Of the 349 enrolled, 15 did not have any blood drawn, and an additional 24 did not have enough blood drawn for determinations of 25OHD, PTH, and serum calcium, and they are not included in this paper. An additional 2 subjects, both black men, were excluded from these analyses because of severe hypercalcemia (serum calcium, >2.8 nmol/L), of unknown origin in 1 case and consistent with primary hyperparathyroidism in the other.

Materials and Methods

Measurements

A measurement team, led by Dr. Soteriades, went to each of the 14 housing units on 1 or 2 mornings in February or March of 1999 and

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collected nonfasting blood samples; made physical measurements, including height and weight; and administered a questionnaire about health-related conditions and behaviors. Translators were available to assist non-English-speaking residents. Laboratory measurements were made in the USDA Human Nutrition Research Center on Aging Nutrition Evaluation Laboratory at Tufts University. Plasma 25OHD was measured by the competitive protein binding method of Chen *et al.* (22), without the optional chromatography step, and the intra- and interassay coefficients of variation (CVs) were 5.0% and 7.3%, respectively. The laboratory reference range for 25OHD is 20–137 nmol/L. Serum intact PTH was measured with Allegro intact RIA kits from Nichols Institute Diagnostics (San Juan Capistrano, CA), and the intra- and interassay CVs were 5.6% and 6.6%. The reference range for PTH is 1.1–6.9 pmol/L. Serum total calcium was measured with a Nova 7 calcium analyzer (Nova Biochemical, Waltham MA), and the intra- and interassay CVs were 1.2% and 3.0%. The reference range for serum calcium is 2.08–2.56 nmol/L.

The questionnaire included questions related to vitamin D and calcium intakes, medication use, southern travel, smoking, and demographics. Variables describing vitamin D and calcium intakes were constructed from responses to categorical questions about milk consumption, consumption of other dairy products, and use of vitamin D (including multivitamins) and calcium supplements. An 8-oz serving of milk contains 100 IU vitamin D and 300 mg calcium. One serving of other dairy products contains no vitamin D and 300 mg calcium. Total vitamin D intake was defined as low (<8 oz/day of milk and no vitamin D supplement use), medium (≥8 oz/day of milk and/or less than daily vitamin D supplement use), or high (daily vitamin D supplement use regardless of milk intake). Similarly, total calcium intake was defined as low (less than two servings per day of dairy products and no calcium supplement use), medium (two or more servings per day of dairy products and/or less than daily calcium supplement use), or high (daily calcium supplement use regardless of dairy product intake). No information was collected about nondairy, nonsupplement sources of calcium and vitamin D or other nutrients.

Statistical analysis

Characteristics of black and white subjects were compared with two-tailed t tests for two independent samples and with the χ^2 test for differences in proportion. Group means were adjusted and compared with analysis of covariance (ANCOVA), and possible interactions were investigated by including interaction terms in the ANCOVA models. Linear associations were investigated and described with Pearson correlation coefficients and multivariable linear regression. ANCOVA and regression analyses were conducted with the General Linear Models procedure (SPSS, Inc., Chicago, IL). $P < 0.05$ was considered to indicate statistical significance.

Results

Twenty-seven subjects had traveled south of New England during the 6 months preceding their study measurements, and their mean 25OHD concentrations were both higher on the average ($P = 0.006$) and more variable than those of the nontravelers. The mean concentrations were 60 ± 10 (±SE) nmol/L in 14 black travelers, 76 ± 16 in 8 white travelers, and 100 ± 17 in 5 Hispanic travelers. Means in the nontravelers are described below. The travelers were excluded from further analyses because the heterogeneity of their trip destinations and durations did not allow for adequate adjustment for travel effects. Of the remaining 281 subjects, 27 were Hispanic and 8 were Asian, compared with 136 black and 110 white subjects. We begin with analyses for the 246 black and white subjects and then report more limited descriptive information about the smaller Hispanic and Asian subsets.

The ages of the black and white subjects ranged from 64–100 yr. On the average, the women were older than the men (Table 1; $P < 0.02$), but age did not differ significantly by race. The characteristics of the 246 black and white nontraveling subjects are shown in Table 1. As expected, many white subjects (42%) and even more black subjects (71%) had not graduated from high school. The majority of subjects were nonsmokers, but smoking was more common in men than in women ($P < 0.01$). About half of the subjects consumed less than one glass of milk per day, and consumption of other dairy products was also low. Reported milk consumption did not differ significantly by race. Regular (daily) use of vitamin D supplements, predominantly multivitamins, ranged from 15% in black men to 46% in white women and was significantly more common in white than in black subjects. Some, but not all, other measures of vitamin D and calcium-related intakes also differed by race in men and/or women (Table 1).

The distributions of plasma 25OHD concentrations by race and sex are shown in Fig. 1 and demonstrate a clear racial difference in 25OHD distributions, but similar sex distributions within race. The mean plasma 25OHD was about 20 nmol/L lower in black compared with white subjects, or about 30% lower (Table 2). Some of this difference was explained by race differences in factors related to vitamin D, especially differences in smoking and vitamin D intake, but differences of 17 nmol/L in men and 14 nmol/L in women remained after multivariate adjustment (Table 2).

In ANCOVA models that included the independent variables listed in Table 2 (adjusted models) as well as race, the significant predictors of 25OHD included only smoking status ($P = 0.010$) and total vitamin D intake ($P < 0.001$). Smoking was associated with a 9.2 nmol/L lower mean 25OHD concentration compared with nonsmoking ($P = 0.010$).

The association of higher vitamin D intakes with higher 25OHD concentrations is shown in Fig. 2 and demonstrates that the greatest differences occurred between the highest intake category (defined by daily vitamin D supplement use) and the lower two intake categories. In a further ANCOVA model, total vitamin D intake was replaced with separate variables for milk consumption and vitamin D supplement use, and both of these were independently associated with 25OHD ($P = 0.027$ and $P < 0.001$, respectively).

There were no significant interactions of race with any predictors of 25OHD, and it is therefore not surprising that when the analyses were conducted separately for each of the racial groups, the significant determinants of vitamin D status were the same in both groups.

A total of 14 women and no men reported the use of prescription medications to treat osteoporosis in the past 3 months (6 black and 2 white women used hormone replacement therapy, 1 black and 4 white women used alendronate, and 1 white woman used calcitonin). Exclusion of these women had little effect on the estimated racial differences in 25OHD.

Mean PTH was significantly higher in black than in white subjects (Table 2) both before and after adjustment for covariates. Mean PTH tended to be higher in the women than in the men ($P = 0.095$ for the group overall), but differences within race subsets were not statistically significant. About 23% of the overall population had PTH values above the reference range, and this percentage was 39% in black men, 43% in black women, 13% in white men, and 22% in white

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TABLE 1. Characteristics of 246 black and white subjects in the BLEOS population

	Men			Women			All		
	Black	White	*P*	Black	White	*P*	Black	White	*P*
No.	52	32		84	78		136	110	
Mean ± SE									
Age (yr)	73.0 ± 0.9	73.5 ± 1.2	0.717	76.4 ± 0.9	77.5 ± 0.9	0.412	75.1 ± 0.7	76.3 ± 0.7	0.225
BMI (kg/m^2)	25.8 ± 0.7	28.7 ± 1.2	0.022	30.4 ± 0.8	28.7 ± 0.8	0.105	28.6 ± 0.6	28.7 ± 0.6	0.044
%									
High school graduate			0.077			<0.001			<0.001
No	63.5	43.8		76.2	41.0		71.3	41.8	
Yes	36.5	56.3		23.8	59.0		28.7	58.2	
Smoke			0.399			0.323			0.099
No	59.6	68.8		84.5	89.7		75.0	83.6	
Yes	40.4	31.3		15.5	10.3		25.0	16.4	
Walk outside			0.837			0.053			0.156
0 days/week	13.5	9.4		26.2	38.5		21.3	30.3	
1–2 days/week	25.0	28.1		40.5	23.1		34.6	24.8	
3–7 days/week	61.5	62.5		33.3	37.2		44.1	45.0	
Milk intake			0.403			0.753			0.866
<1 glass/day	50.0	59.4		51.2	48.7		50.7	49.3	
≥1 glass/day	50.0	40.6		48.8	51.3		51.8	48.2	
All dairy intake			0.813			0.347			0.460
<2 serving/day	45.2	46.9		40.5	33.3		41.9	37.3	
≥2 servings/day	54.8	53.1		59.5	66.7		58.1	62.7	
Vitamin D supplement use			0.060			0.030			0.003
None	76.9	59.4		69.0	48.7		72.1	51.8	
Irregular	7.7	3.1		2.4	5.1		4.4	4.5	
Regular (daily)	15.4	37.5		28.6	46.2		23.5	43.6	
Calcium supplement use			0.161			0.079			0.012
None	96.2	84.4		79.8	66.7		86.0	71.8	
Irregular	1.9	9.4		15.5	19.2		10.3	16.4	
Regular (daily)	1.9	6.3		4.8	14.1		3.7	11.8	
Vitamin D intake[a]			0.041			0.054			0.004
Low (<100 IU/day)	38.5	37.5		35.7	23.1		36.8	27.3	
Medium	46.2	25.0		35.7	30.8		39.7	29.1	
High (daily supplement)	15.4	37.5		28.6	46.2		23.5	43.6	
Calcium intake[b]			0.584			0.112			0.047
Low (<600 mg/day)	42.3	40.6		34.5	28.2		37.5	31.8	
Medium	55.8	53.1		60.7	57.7		58.8	56.4	
High (daily supplement)	1.9	6.3		4.8	14.1		3.7	11.8	

[a] From milk and supplements: low, less than 8 oz/day milk and no vitamin D supplement use; medium, 8 oz/day or more milk and/or irregular vitamin D supplement use; high, daily vitamin D supplement use (regardless of milk intake).

[b] From dairy products and supplements: low, less than two servings per day of dairy and no calcium supplement use; medium, two or more servings per day of dairy and/or irregular calcium supplement use; high, daily calcium supplement use (regardless of dairy intake).

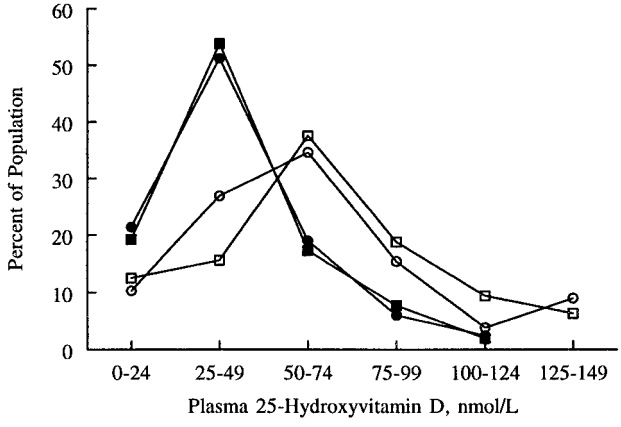

FIG. 1. Distributions of plasma 25OHD concentrations in 52 black men (■), 84 black women (●), 32 white men (□), and 78 white women (○).

women. Serum calcium concentrations were normal in all but one of these individuals, a black woman whose serum calcium concentration was just over the upper normal limit.

PTH was inversely correlated with 25OHD in the group as a whole ($r = -0.30$; $P < 0.001$), and this association is shown by race in Fig. 3 (*top*). Although higher 25OHD concentrations were associated with lower PTH concentrations in both blacks and whites, blacks had higher PTH levels at each 25OHD concentration. There was no evidence of a PTH plateau with higher 25OHD in whites, and the apparent plateau in blacks is based on only 12 subjects who had 25OHD concentrations as high as 75 nmol/L (compared with 33 whites). The association of 25OHD with PTH was further examined in an ANCOVA model that included 25OHD, race, sex, age, and calcium intake as independent variables. Predictors of higher PTH included lower 25OHD ($P < 0.001$), black race ($P = 0.004$), and higher age ($P = 0.012$).

Mean serum calcium did not differ by race (Table 2) and, as described above, was in the normal range for all but one subject. Serum calcium was positively correlated with 25OHD in the group as a whole ($r = 0.25$; $P < 0.001$), and this association is illustrated separately by race in Fig. 3 (*bottom*).

Selected descriptive information for the two smaller race subsets of the BLEOS population is shown in Table 3. Overall,

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TABLE 2. Biochemical characteristics of 246 black and white subjects in the BLEOS population

	Men			Women			All		
	Black	White	*P*	Black	White	*P*	Black	White	*P*
No.	52	32		84	78		136	110	
25-Hydroxyvitamin D (nmol/L)									
Mean ± SE, unadjusted	45.0 ± 2.8	65.9 ± 5.5	<0.001	45.3 ± 2.4	64.6 ± 3.8	<0.001	45.2 ± 1.8	65.0 ± 3.1	<0.001
Mean ± SE, adjusted[a]	54.0 ± 5.4	70.6 ± 5.6	0.004	41.0 ± 4.2	54.2 ± 4.1	0.001	45.3 ± 3.1	59.6 ± 3.1	<0.001
% <25 nmol/L	19.2	12.5	0.421	21.4	10.3	0.053	20.6	10.9	0.041
% <50 nmol/L	73.1	28.1	<0.001	72.6	37.2	<0.001	72.8	34.5	<0.001
PTH (pmol/L)									
Mean ± SE, unadjusted	6.24 ± 0.42	4.33 ± 0.35	0.002	7.54 ± 0.58	5.25 ± 0.38	0.001	7.04 ± 0.40	4.98 ± 0.29	<0.001
Mean ± SE, adjusted[a]	6.28 ± 0.67	4.50 ± 0.68	0.010	8.06 ± 0.75	5.89 ± 0.74	0.003	7.26 ± 0.50	5.11 ± 0.50	<0.001
Serum calcium (mmol/L)									
Mean ± SE, unadjusted	2.39 ± 0.02	2.39 ± 0.02	0.820	2.41 ± 0.01	2.41 ± 0.01	0.686	2.40 ± 0.01	2.41 ± 0.01	0.742
Mean ± SE, adjusted[a]	2.40 ± 0.03	2.38 ± 0.03	0.525	2.42 ± 0.02	2.42 ± 0.02	0.880	2.41 ± 0.01	2.41 ± 0.01	0.996

[a] Adjusted for age, body mass index, smoking, vitamin D intake, calcium intake, and, in the All analyses, for sex.

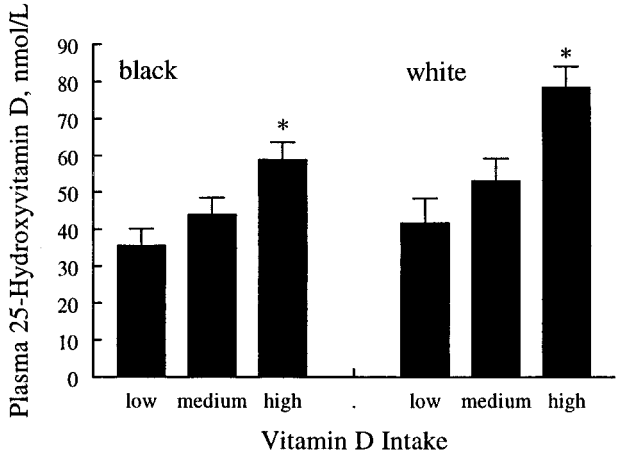

FIG. 2. Mean plasma 25OHD concentrations by category of total vitamin D intake from milk and vitamin supplements: low, less than 100 IU/day from diet and no supplements; medium, 100 IU/day or more and/or less than daily supplement use; and high, daily supplement use, usually 400 IU/day, regardless of diet. Adjusted within race for age, body mass index, sex, smoking, and total calcium intake. *Error bars* show SEMs. Sample sizes from low to high intake are 50, 54, and 32 in blacks and 30, 32, and 48 in whites. *, differs from lower intake categories, $P < 0.005$.

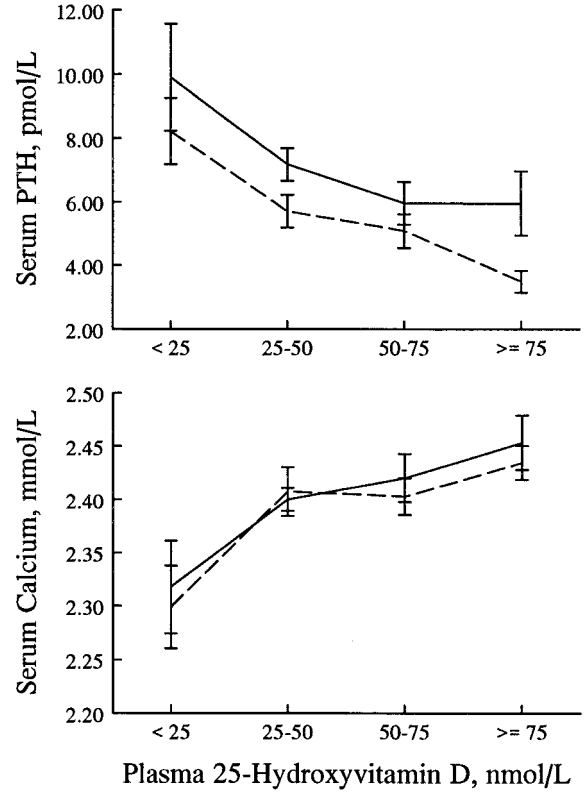

FIG. 3. Mean serum PTH and serum calcium concentrations by category of plasma 25OHD concentration in black (*solid line*) and white (*dashed line*) adults. The number of subjects from lowest to highest 25OHD category is 10, 89, 25, and 12 in blacks and 7, 31, 39, and 33 in whites.

mean 25OHD and PTH levels in these two groups were similar to those in the white subjects. The small number of Asian women had relatively low 25OHD and high PTH, perhaps because of their low vitamin D and calcium intake. Forty-eight percent of the Hispanic and 50% of the Asian subjects had 25OHD concentrations below 50 nmol/L.

Discussion

Currently, there is no consensus for a specific 25OHD concentration that defines vitamin D deficiency, and designating such a value may not be possible because 25OHD determinations differ across assay methods (23). Nevertheless, the 21% of black and 11% of white low income elderly subjects who had wintertime 25OHD concentrations below 25 nmol/L would be considered very low or deficient by most standards. Notably, none of the subjects who reported daily use of a vitamin D supplement (predominantly multivitamins containing 400 IU vitamin D) had concentrations below 25 nmol/L. The number of subjects who did report daily vitamin D supplement use was surprisingly high, 24% of blacks and 44% of whites, with higher percentages among women than men in each race. Although it is possible that subjects overreported their supplement use, the more than 30 nmol/L higher 25OHD concentrations in daily users *vs.* nonusers provides support for these estimates.

An optimal 25OHD concentration has also not been defined, but increases to 50 nmol/L or higher have been associated with increased suppression of PTH (24, 25) and reductions in bone loss and fracture (16). Too few of the

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TABLE 3. Selected characteristics in 35 Hispanic and Asian subjects in the BLEOS population

	Men		Women		All	
	Hispanic	Asian	Hispanic	Asian	Hispanic	Asian
No.	19	4	8	4	27	8
Mean ± SE						
Age (yr)	74.2 ± 1.5	67.0 ± 1.2	72.4 ± 2.5	74.8 ± 5.0	73.6 ± 1.3	70.9 ± 2.8
BMI (kg/m^2)	27.4 ± 1.1	23.4 ± 1.6	27.8 ± 1.7	21.5 ± 0.9	27.5 ± 0.9	22.4 ± 0.92
25-Hydroxyvitamin D (nmol/L)	62.9 ± 7.2	86.7 ± 15.8	55.5 ± 12.6	48.7 ± 3.9	60.7 ± 6.2	67.7 ± 10.4
% <25 nmol/L	5.3	0.0	12.5	0.0	7.4	0.0
% <50 nmol/L	47.4	25.0	50.0	75.0	48.1	50.0
PTH (pmol/L)	4.73 ± 0.45	3.34 ± 0.40	4.28 ± 0.72	5.62 ± 2.21	4.60 ± 0.38	4.48 ± 1.13
Serum calcium (mmol/L)	2.40 ± 0.02	2.36 ± 0.04	2.37 ± 0.01	2.31 ± 0.08	2.39 ± 0.01	2.34 ± 0.04
%						
Smoke						
Yes	15.8	25.0	12.5	0.0	14.8	12.5
No	84.2	75.0	87.5	100.0	85.2	87.5
Vitamin D intake						
Low (<100 IU/day)	42.1	25.0	50.0	75.0	44.4	50.0
Medium	36.8	75.0	37.5	25.0	37.0	50.0
High (daily supplement)	21.1	0.0	12.5	0.0	18.5	0.0

BLEOS subjects had 25OHD concentrations sufficiently high to identify the point at which PTH concentrations are maximally suppressed. Although there does appear to be some leveling off between 50 and 75 nmol/L in black subjects, this apparent plateau is based on too few people to provide compelling evidence that 50 nmol/L is an optimal 25OHD concentration in blacks or that there is a racial difference in the plateau level. The BLEOS data do demonstrate that in terms of suppressing PTH, 25OHD concentrations of at least 50 nmol/L, if not higher, are desirable in both blacks and whites. Whereas 65% of whites achieved this concentration in winter, only 27% of black subjects did. Although only a small number of Hispanic and Asian subjects were studied, low 25OHD concentrations appear to be prevalent in these groups as well (48% of the Hispanics and 50% of the Asians).

This is the first study of vitamin D status in an exclusively low income population of elderly Americans. Although there may be other low income populations at higher risk, the mean wintertime vitamin D concentrations of the white men and women in BLEOS were about the same as those in the relatively affluent Framingham cohort (9) and in members of a Michigan health maintenance organization (12). Age over a range similar to that of the BLEOS subjects (64–100 yr) has been reported by others to be associated with 25OHD concentrations (9), but we did not observe a similar association. This may result from the fact that age-related declines in skin synthesis of vitamin D (26) do not influence 25OHD concentrations in winter to the extent that they do in other seasons. Sex was also not a significant determinant of 25OHD concentrations in this study, and this is consistent with previous reports that at Boston's latitude, men have higher 25OHD concentrations in summer but not in winter (3, 9). Our finding of lower 25OHD concentrations in smokers is consistent with a previous report in humans (27) and may be an effect of nicotine (28).

Low 25OHD concentrations clearly contributed to reduced serum calcium and increased PTH in both blacks and whites and also explained some of the racial difference in PTH. Mean PTH concentrations of both young (5, 8) and older black adults (12, 29) have been reported to be higher than those of whites, and PTH increases more rapidly with age in black than in white adults (29). The parathyroid glands of healthy blacks are larger than those of healthy whites (30), and this difference is not explained by differences in body size. We have demonstrated that the PTH difference is not entirely due to differences in current vitamin D status, but our data do not provide an explanation for the residual difference. It may be due to a relatively lower skeletal sensitivity to the resorptive effects of PTH in blacks (5, 32, 33) or to racial differences in calcium and sodium intake and handling (29). Another interesting suggestion has been that long-term vitamin D deficiency may cause parathyroid hyperplasia that results in elevated PTH even after vitamin D status has been improved (34, 35). It will be important to test these theories because elevated PTH has been linked not only to bone loss, but also to hypertension, a condition that is highly prevalent in elderly blacks (36).

In conclusion, suboptimal vitamin D status is common in Boston's low income elderly. Although a problem in all race groups, it is most serious in African-Americans, 73% of whom were found to have low vitamin D concentrations in winter. Increased use of vitamin D supplements, fortified milk, and other foods can effectively improve wintertime vitamin D status in Northern areas and should be strongly promoted by clinicians, educators, and public health policymakers.

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