Vitamin D, Sunlight Exposure, and Bone Density in Elderly African American Females of Low Socioeconomic Status

Sally P. Weaver, PhD, MD; Cindy Passmore, MA; Ben Collins; Eugene Fung, MD

Background and Objectives: *Darker skin pigmentation and aging are known factors influencing the body's ability to synthesize adequate amounts of vitamin D (25OHD). The objective of this study is to determine the 25OHD insufficiency in elderly African American females of low socioeconomic status (SES) in a southern latitude during springtime sun exposure.* Methods: *Patients ≥ 70 years old who did not have disorders that might affect vitamin D and calcium absorption/metabolism were enrolled at a community health center. Serum calcium, 25OHD, and intact parathyroid hormone were measured and repeated 6–8 weeks later. Bone mineral density (BMD) scan results were obtained from clinic records.* Results: *Most subjects (86.4%) had inadequate 25OHD levels < 32ng/mL, and no clinically significant rise in levels was seen after 6–8 weeks of sun exposure. A quarter of subjects had truly deficient 25OHD levels ≤ 15ng/mL. 25OHD levels were positively correlated with BMD only at the lumbar spine. Fifty-two percent of subjects were osteopenic, and 9% were osteoporotic.* Conclusions: *25OHD insufficiency is common among low SES elderly African American women, and springtime sunlight exposure does not cause significant increases in 25OHD. Additionally, this population has low calcium and vitamin D intake from diet, and more women than expected had reduced BMD.*

(Fam Med 2010;42(1):47-51.)

It is becoming increasingly evident that suboptimal vitamin D (25OHD) serum levels are a common health problem. This is especially true in the elderly population where lower 25OHD levels in industrialized countries are associated with greater risks for myopathies,[1-3] falls,[1-3] fractures,[1,4,5] nursing home admissions,[6] secondary hyperparathyroidism,[7] and reduced bone mineral density (BMD).[7]

Older adults have an increased probability of lower 25OHD levels due to atrophic skin changes that lead to a diminished capacity to generate vitamin D via ultraviolet light exposure.[8] Diminished renal function with aging also leads to decreased renal conversion to 1,25OH2D, a precursor to the active form of vitamin D, 25OHD.[9] Additional factors that may influence 25OHD production from the skin include intensity of sun exposure (due to season, latitude, time of day, cloudiness, clothing, etc) and skin pigmentation.[10]

There is no clear consensus on how much sun exposure is needed for a given individual due to differences in skin color, renal function, age, and living latitude. It takes weeks of increased ultraviolet (UV) light exposure to see increases in serum 25OHD levels in non-elderly subjects.[11-14] Lucas[11] showed a lag of 1–2 months in seasonal 25OHD fluctuations closely paralleling UV dose variations in non-elderly, light-skinned women. Pasco[12] showed that seasonal variations in 25OHD levels lagged 4 weeks behind UV exposure in women ≥55 years old. Armas[13] found that 25OHD levels in a group of younger men and women had a median rise of 10.64nmol/L at the end of 4 weeks of 3x/week exposure to UV-B in a light booth. Finally, van der Mei[14] showed that the lag time from adequate sun exposure to appropriate 25OHD rises ranged 21 days to 7.5 weeks depending on latitude and study population in Australian men and women <60 years old. No one has yet investigated changes in 25OHD in response to

From the McLennan County Medical Education and Research Foundation, Family Medicine Residency Program, Waco, Tex (Dr Weaver); Faculty Development Center, Waco, Tex (Dr Passmore); Baylor University, Waco, Tex (Mr Collins); and private practice, Waco, Tex (Dr Fung).

seasonal sun exposure in older persons, especially those with darker pigmentation of the skin.

The study reported here was conducted in a sample of independent older African American women of low socioeconomic status (SES) living in central Texas. The aim was to determine whether community dwelling African-American women ages 70 years and older demonstrated increasing serum levels of 25OHD during a time of year with increasing chance for UV exposure while controlling for vitamin D supplementation.

Methods

This is a prospective cohort study of 44 non-Hispanic African American women ages ≥ 70 years old who did not have medical conditions that might affect vitamin D levels (see exclusionary criteria below). All subjects were recruited from a community health center with more than 46,000 active patients and considered to be of low socioeconomic status (SES). Factors defining low SES included residential zip code, not completing high school, and a household annual income of <$25,000.[15] Over a period of 8 weeks in late winter 2006, staff physicians and mid-level providers recruited potential subjects from elderly African American women with office visits.

Women who were homebound or institutionalized were excluded from the study. Additional exclusion criteria included decompensated hepatic insufficiency, renal insufficiency with an estimated glomerular filtration rate < 30ml/min, gastrointestinal disorders affecting vitamin D absorption (eg, celiac disease, Crohn's disease, gastric bypass surgery history), metabolic bone disease, and thyroid disorders. Electronic chart review and personal interviews were used to identify exclusionary criteria for each subject.

This study was conducted in Waco, Texas, latitude 31.5º N. Subjects had two office visits: one in mid to late April 2006 and the second visit approximately 6 to 8 weeks later. This is a time of year when there is ample sunlight in central Texas but not so hot as to stop the elderly from going outdoors. Data were collected via personal interviews conducted at the time of the initial study visit. Information obtained during these interviews included personal history of fractures, history of known osteoporosis, activity level as a young adult, usual daily/weekly sun exposure in the spring in central Texas, medications, and nutritional supplements. Fracture history included documentation of fracture site, age at time of fracture, osteoporotic fracture (if known), and whether the fracture was related to a motor vehicle collision. High activity level as a 15–30 year old was defined as self-described high activity or having played high school athletics. For sun exposure, subjects were asked "How much time daily (in minutes a day and days per week) do you spend outdoors on average this time of year?" Using a detailed dietary interview with food models, nutrition history for the past 1 month was obtained with attention to intake of calcium, vitamin D, and magnesium. Height and weight were measured at the first office visit, and a body mass index (BMI) was calculated for each subject.

Each patient received a bottle of tablets containing 1,000 mg calcium with 400 international units (IU) of vitamin D to take one daily during the study without making any change in diet or sun exposure recommendations. This replaced any other calcium/vitamin D supplement they were taking to control for supplement use in a population with varied calcium/vitamin D supplement use. This study received Institutional Review Board approval from the McLennan County Medical Society.

Laboratory Tests

Blood samples were analyzed for serum 25OHD, calcium, and ionized parathyroid hormone (iPTH). For assessment of vitamin D, we chose to measure 25OHD levels since they are most predictive of true circulating vitamin D. 25OHD was measured by radioimmunoassay. We defined 25OHD insufficiency as levels <32ng/mL (<80nmol/L) and deficiency as 25OHD levels <20ng/mL (<50nmol/L) based on emerging data that suggest these are the appropriate cutoffs to use.[16-19] A "clinically significant" change would be insufficient 25OHD levels increasing to ≥32ng/mL and deficient levels increasing to ≥20ng/mL. If international units were not the original unit of measure, they are noted in parentheses. Normal serum calcium levels are 8.6–11.0 mg/dL (2.15–2.75nmol/L) and for iPTH 10–60 pg/mL (10–60 mg/L).

Bone Density Measurements

Following patient consent, BMD test results from the 12 months prior to the start of the study were obtained from the clinic's electronic health record. All study subjects except one had a documented BMD test within the past year. The high rate of BMD measurements is likely due to the fact that the clinic obtained a bone density scanner in 2005, and there was a campaign to get all women >65 years old (without a BMD in the past 2 years) tested. For these tests, BMD was measured at the lumbar spine (L1-L4), left femoral neck, and left total hip using dual-energy X-ray absorpitometry (DEXA) (Prodigy DXA System, Madison, Wis). The software for this equipment is Encore 2006. All scans were performed by the same two experienced DEXA technicians. The results of these studies are expressed as a T-score (the standard deviation from the mean value of young Caucasian adult) or a Z-score (the standard deviation from the mean value of a similarly aged Caucasian woman). World Health Organization definitions of osteoporosis (T-score at or below -2.5 SD), osteopenia (T-score between -1 and greater than

-2.5 SD) and normal (T-score at or above -1 SD) BMD were used.

Dietary Nutritional Analysis

Dietary intake was assessed using a food frequency questionnaire to determine intake of all foods over the past 1 month. Food models were used during interviews to help participants more accurately report the amount of food eaten. Food information was entered into the Diet Analysis Plus computer program, and dietary intake of vitamin D, calcium, and magnesium was recorded using the information from this program.

Statistical Analysis

The main outcome of interest is serum 25OHD levels. Secondary outcomes include other serum lab values. For each potentially influential factor, analysis was performed as follows: relationships between continuous measures (BMI, sun exposure) and the primary outcome were evaluated by Pearson Correlation Coefficients. Statistical differences between levels of categorical factors (fracture and activity histories) and primary or secondary outcomes were determined via Student's *t* tests. A significance level of $P<.05$ was used for all statistical tests.

A one-sample paired *t* test was used to compare the mean change in serum 25OHD levels between the first and second office visits. The achieved sample size (n=36) was large enough to detect a 3.02 increase in the serum 25OHD levels with 73% power at the 0.05 significance level.

Results

Baseline characteristics of the study subjects are summarized in Table 1. Thirty eight of 44 subjects completed the study. Of the six patients not completing the study, one was hospitalized at the time of follow up, two had been admitted to nursing homes, one declined continued study participation, one did not keep follow up appointments, and one had incorrect contact information.

Most participants were overweight, with 80% having a BMI > 25. Of the nine subjects reporting a personal history of fracture, all fractures were reported as non-motor vehicle collision related, non-vertebral, or non-hip fractures. Average age at time of fracture was 55 years old, and no one reported an osteoporotic fracture.

Ninety-six percent of subjects reported some weekly sun exposure (Table 1). Two subjects reported no sun exposure on a daily or weekly basis. The amount of self-reported sun exposure was not correlated with 25OHD levels or BMD measurements. Women who reported daily sun exposure did not have different 25OHD levels from women who reported less than daily sun exposure.

Table 1

Demographic and Dietary Data

Variable	*Mean (Range)*
Age (years)	75.7 (70–88)
Body mass index (kg/m^2)	32.7 (16.8–49)
Household annual income <$25,000	96.4%
Low SES zip code	100%
Completed high school or greater	34.5%
Fracture history	20.5%
Usual sun exposure (minutes/day)	109 (0–360)
Dietary calcium intake (mg/d)	700mg (98–2,171)
Dietary vitamin D intake (IU/d)	145 IU (0–967)
Dietary magnesium intake (mg/d)	188 mg (13–645)

SES—socioeconomic status

According to chart reviews, 27 (96%) of subjects with osteopenia and osteoporosis had been told to take calcium with vitamin D; however, a little more than half of study subjects (54.5%) reported not taking any calcium or vitamin D supplements prior to the study. Of the remaining subjects, seven reported taking vitamin D either alone or in combination with calcium, and five subjects reported taking a daily multivitamin (containing between 200 IU and 400 IU of vitamin D). At follow-up, all subjects stated they were taking a minimum of 400 IU vitamin D supplement most days of the week. The mean daily dietary intake of calcium, vitamin D, and magnesium are listed in Table 1. On average, most women were receiving only about 545 IU of vitamin D daily including diet and supplements. Vitamin D from diet and supplements was not significantly correlated with serum 25OHD.

At the beginning of the study, 86.4% of subjects had 25OHD levels <32ng/mL with a mean of 21.05ng/mL (Table 2). A total of 22.7% of subjects had 25OHD levels ≤ 15ng/mL. Six-week follow-up 25OHD levels increased by a mean of 3ng/mL ($P=.023$). Changes in 25OHD levels ranged from a loss of 10ng/mL to a gain of 19ng/mL. Subjects with the lowest initial 25OHD levels tended to show the highest gains. There was no significant difference in 25OHD levels between patients with a fracture history and those without such a history. Mean serum calcium and iPTH levels were within normal parameters initially and did not change significantly over time (Table 2).

Sunlight exposure was not correlated with any regional or collective BMD measure. 25OHD levels, however, were significantly and positively correlated with both T-scores and Z-scores, but only at the lumbar spine ($P<.05$). The lowest regional BMD was found

Table 2

Laboratory Test Results

Laboratory Test	*Initial Result Values*	*Follow-up Result Values*	P *Value*
25OHD (ng/mL)	21.05 (range 5–45)	24.24 (range 8–45)	.02*
Calcium (mg/dL)	9.21 (range 8.7–10.1)	9.43 (range 8.8–11.2)	.06
iPTH (pg/mL)	34.4 (range 23.2–72.5)	31.9 (range 13.1–64.0)	.98

* statistically significant
iPTH—intact parathyroid hormone

at the left femoral neck with a mean T-score of -1.23 (Table 3). The incidence of normal BMD versus osteopenia or osteoporosis is shown in Table 4. At the lumbar spine 30% of subjects had lower than desirable BMD (osteopenia or osteoporosis), as did 66% at the left femoral neck and 51% at the total left hip. When using the lowest regional BMD measurement for each individual patient, below normal BMD was found in 61% of subjects (52% were osteopenic and 9% were osteoporotic). Six subjects with a history of osteoporosis and prescriptions for treatment told interviewers they did not have osteoporosis.

Increasing BMI was positively correlated with T-scores, but not Z-scores at the lumbar spine, left femoral neck and total left hip. Women without a history of a fracture had significantly higher lumbar spine Z-scores (p=0.038) but not T-scores (p=0.154). 66% of subjects reported high exercise levels in their youth. Of these, 33 women played high school sports, primarily basketball. BMD was no different in this high activity group than in the rest of the subjects.

Discussion

Our data suggest that sun exposure in the spring is inadequate for increasing serum 25OHD to sufficient levels in older African American women. A statistically significant increase in 25OHD of 3 ng/mL during the study period was not clinically significant because 25OHD levels remained <32ng/mL. Two studies have specifically looked at 25OHD status at the end of winter at latitudes supposedly close enough to the equator for year-round vitamin D photosynthesis. The first such study had a high degree of 25OHD insufficiency at the end of winter in Miami (25.46 degrees N) but found that serum 25OHD was similar between African Americans and whites with a mean of 22.4ng/mL.[20] Vitamin D data analyzed from the third National Health and Nutrition Examination Survey (NHANES III) found 25OHD insufficiency in 69% of African American women > 60 years (mean 25OHD level 18.8ng/mL) in the winter in the south (latitude 25N to 34.9N).[21] Additionally, 43% of African American women had 25OHD levels truly deficient at <15.1ng/mL. Being at a similar latitude, our population had a lower incidence of true 25OHD deficiency with 23% having levels ≤ 15ng/mL but a higher incidence of overall inadequacy (84%).

Like previous researchers[7] who showed that seasonal serum 25OHD levels correlate with femoral neck BMD, we found a significant correlation between BMD and 25OHD levels but not springtime sun exposure. Osteopenia and osteoporosis at the femoral neck were relatively high in our study population at 56% and 10%, respectively. Cauley et al[22] showed the same rate of osteoporosis at the left femoral neck (9.8%) in a similarly aged African-American female population (n=58) as our study but a much lower rate of osteopenia (39.6%, personal communication with author).

Our study population had inadequate dietary intake of both calcium and vitamin D (even when accounting for supplements) which is a known issue among African American women.[16] We found no correlation between daily vitamin D intake and serum 25OHD levels, but this is likely related to such low daily intake of vitamin D in our population. Based on our results, on average, elderly African American women need to be minimally taking an additional 400IU of vitamin D supplement daily to get close to realizing the recommended 600–800 IU/d for maintaining good bone health.[23]

Limitations

This study has limitations that should be considered when interpreting the results. Our cohort of women was small, but power analysis suggests that sample size was adequate to have detected important differences had they been present. There is also the issue of geographic limitations, but sun exposure should be similar at this latitude worldwide. Additionally, we did not measure skin pigment density; however, none

Table 3

Bone Mineral Density Findings

Region	*Mean*	*Range*
L1-L4 T-score	-0.165	-3.3 to +2.4
L1-L4 Z-score	+ 0.28	-2.2 to +2.5
Left femoral neck T-score	-1.23	-3.2 to +1.3
Left femoral neck Z-score	-0.533	-1.9 to +2.2
Left total hip T-score	-0.69	-2.3 to +1.5
Left total hip Z-score	-0.46	-1.9 to +1.3

Table 4

Reduced Bone Mineral Density (BMD) Findings

BMD Site	*Normal*	*Osteopenia*	*Osteoporosis*
Lumbar spine	70% (26)*	27% (10)	3% (1)
Left femoral neck	33% (13)	56% (22)	10% (4)
Total left hip	49% (19)	51% (20)	0% (0)
Any site	39% (17)	52% (23)	9% (4)

* Number in parenthesis indicates number of subjects.

of our subjects were especially light-skinned, which might alter vitamin D synthesis from sun exposure. There was no correlation of prior sun exposure with intervention sun exposure.

We used dietary recall for the past month of foods eaten rather than prospective food diaries to document calcium and vitamin D but attempted to get accurate information by using an extensive interview with many food models. Finally, we tracked subjects for only 6–8 weeks and may not have followed them long enough to see a rise in 25OHD in an elderly, dark-skinned population.

Conclusions

In summary, we found 25OHD insufficiency to be common in elderly African-American women of low SES living at relatively low latitude, and serum 25OHD levels did not increase adequately during 6 weeks of sun exposure (with 400 IU of supplementary vitamin D) to be clinically significant. Additionally, our population of African-American women is somehow different than previously studied populations of older African-American women in that their BMD is much lower with a greater incidence of osteopenia. Whether our population is therefore prone to higher fracture rates in the future has yet to be shown. Following our cohort for fractures would be the next step in analyzing this population.

Acknowledgments: Financial support provided through a regional grant from Proctor & Gamble Pharmaceuticals.

The content of this manuscript was presented at the 2007 North American Primary Care Research Group Annual Meeting and at the 2008 Texas Academy of Family Physicians Annual Session.

The authors would like to thank Charlotte Litton and Margaret Weaver for their expertise as DEXA technicians and Elaine Holt for her assistance with patient recruitment. We also thank Jennifer Marquez and Russenda Jones for their assistance with interviewing patients and documenting dietary histories and Dr Suzy Weems for her analysis of dietary intake.

Corresponding Author: Address correspondence to Dr Weaver, 1600 Providence Drive, Waco, TX 76707. 254-750-8214. Fax: 254-759-3549. SallyWeaver@me.com.

References

1. Lips P. Vitamin D deficiency and secondary hyperparathyroidism in the elderly: consequences for bone loss and fractures and therapeutic implications. Endo Rev 2001;22(4):477-501.
2. Bischoff-Ferrari HA, Dawson-Hughes B, Willett WC, et al. Effect of vitamin D on falls: a meta-analysis. JAMA 2004;291(16):1999-2006.
3. Stein MS, Wark JD, Scherer SC, et al. Falls relate to vitamin D and parathyroid hormone in an Australian nursing home and hostel. J Am Geriatr Soc 1999;47(10):1195-1201.
4. Cummings SR, Browner WS, Bauer D, et al. Endogenous hormones and the risk of hip and vertebral fractures among older women. Study of Osteoporotic Fractures Research Group. N Engl J Med 1998;339(11):733-8.
5. Jackson RD, LaCroix AZ, Gass M, et al. WHII. Calcium plus vitamin D supplementation and the risk of fractures. N Engl J Med 2006;354(7):669-83.
6. Visser M, Deeg DJH, Puts MTE, et al. Low serum concentrations of 25-hydroxyvitamin D in older persons and the risk of nursing home admission. Am J Clin Nutr 2006;84:616-22.
7. Melin A, Wilske J, Ringertz H, et al. Seasonal variations in serum levels of 25-hydroxyvitamin D and parathyroid hormone but no detectable change in femoral neck bone density in an older population with regular outdoor exposure. J Am Geriatr Soc 2001;49:1190-6.
8. Holick MF, Matsuoka LY, Wortsman J. Age, vitamin D, and solar ultraviolet. Lancet 1989;2(8671):1104-5.
9. Lau KH, Baylink DJ. Vitamin D therapy of osteoporosis: plain vitamin D therapy versus active vitamin D analog (D-hormone) therapy. Calcif Tissue Int 1999;65(4):295-306.
10. Holick MF. Environmental factors that influence the cutaneous production of vitamin D. Am J Clin Nutr 1995;61(suppl):638S-645S.
11. Lucas JA, Bolland MJ, Grey AB, et al. Determinants of vitamin D status in older women living in a subtropical climate. Osteoporosis Int 2005;16:1641-8.
12. Pasco JA, Henry MJ, Kotowicz MA, et al. Seasonal periodicity of serum vitamin D and parathyroid hormone, bone resorption, and fractures: the Geelong Osteoporosis Study. J Bone Miner Res 2004;19:752-8.
13. Armas RP, Heaney MJ, Barger-Lux C, et al. The effects of UV-B light on serum vitamin D levels in humans. J Bone Miner Res 2007;22(suppl 1):S215.
14. Van der Mei IAF, Ponsonby A-L, Englesen O, et al. The high prevalence of vitamin D insufficiency across Australian populations is only partly explained by season and latitude. Environ Health Perspect 2007;115(8):1132-9.
15. Centers for Disease Control and Prevention. Socioeconomic status of women with diabetes—United States, 2000. JAMA 2002;287(19):2496-7.
16. Holick MF. Vitamin D: importance in the prevention of cancers, type 1 diabetes, heart disease, and osteoporosis. Am J Clin Nutr 2004;79:362-71.
17. Dawson-Hughes B, Heaney RP, Holick MF, Lips P, Meunier PJ, Vieth R. Estimates of optimal vitamin D status. Osteoporosis Int 2005;16(7):713-6.
18. Dawson-Hughes B. Racial/ethnic considerations in making recommendations for vitamin D for adult and elderly men and women. Am J Clin Nutr 2004;80(6 Suppl):1763S-1766S
19. Hollis BW. Circulating 25-hydroxyvitamin D levels indicative of vitamin D insufficiency: implications for establishing a new effective dietary intake recommendation for vitamin D. J Nutr 2005;135(2):317-322.
20. Levis S, Gomez A, Jimenez C, et al. Vitamin D deficiency and seasonal variation in an adult South Florida population. J Clin Endocrinol Metab 2005;90(3):1557-62.
21. Looker AC, Dawson-Hughes B, Calvo MS, et al. Serum 25-hydroxyvitamin D status of adolescents and adults in two seasonal subpopulations from NHANES III. Bone 2002;30(5):771-7.
22. Cauley JA, Lui LY, Ensrud KE, et al. Bone mineral density and the risk of incident nonspinal fractures in African-American and white women. JAMA 2005;293(17):2102-8.
23. Institute of Medicine. Dietary reference intakes: calcium, phosphorus, magnesium, vitamin D, and fluoride. Washington, DC: National Academy Press, 1997.