

Vitamin D Deficiency Is Associated With Worse Cognitive Performance and Lower Bone Density in Older African Americans

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Background: Vitamin D deficiency is common in older adults and is more prevalent among persons with darker pigmented skin. The detrimental effects of vitamin D deficiency on the bone are widely known; however, recent data suggest that vitamin D deficiency may contribute to other disorders, including low mood, cognitive impairment, and impaired mobility.

Objective: The purpose of this study was to determine whether nonskeletal diseases such as depression, cognitive impairment, and physical disability, which have been associated with vitamin D deficiency, are more commonly seen in older African Americans.

Design: In a cross-sectional study of 60 older adults (30 African Americans and 30 European Americans), vitamin D status, cognitive performance, physical performance, and bone mineral density (BMD) were assessed. Differences between groups and differences between those with vitamin D deficiency and those with normal vitamin D levels were tested.

Results: African Americans had a lower mean 25-hydroxyvitamin D level (17.98 ng/ml; SD, 6.9) compared to European Americans (25.20 ng/ml; SD, 7.0; $p < .0001$). Participants with vitamin D deficiency performed worse on a measure of cognitive performance, the Short Blessed Test (10.87 vs 6.31; $p = .016$); the Physical Performance Test (PPT) (27.00 vs 28.96; $p = .039$); and had lower BMD (0.823 vs 0.914; $p = .005$) and t scores (-1.29 vs -0.72; $p = .008$) of the hip. Among African Americans, vitamin D deficiency was associated with worse cognitive performance and lower BMD of the hip.

Conclusions: Vitamin D deficiency in older African Americans was associated with worse cognitive performance and lower BMD of the hip.

Keywords: vitamins and minerals ■ African Americans ■ cognitive functioning ■ bone

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INTRODUCTION

The prevalence of vitamin D deficiency is common in elderly, affecting up to 50% of older adults.¹⁻³ African Americans have a higher prevalence of vitamin D deficiency across all age groups, mostly due to differences in cutaneous synthesis of vitamin D following ultraviolet light exposure.⁴

The deleterious effects of vitamin D deficiency on the bone are widely accepted;^{5,6} however, recent data suggest that vitamin D deficiency may play a role in other conditions, including neurological and cardiovascular disorders.⁷ There is a growing body of literature to support a role for vitamin D in brain function and development,⁸ including identification of vitamin D receptors in the brain,⁹⁻¹¹ neuroprotection by vitamin D in vitro,¹²⁻¹⁴ and downregulation of vitamin D receptors in hippocampal cells in Alzheimer's disease.¹⁵ Additionally, treatment with vitamin D for both 8 and 12 months resulted in a higher density of neurons in the rat hippocampus.¹⁶ A recent study from our group found that older adults with vitamin D deficiency had more depressive symptoms and worse cognitive performance compared to those with normal vitamin D levels.¹⁷

Although numerous studies have found that African Americans have lower vitamin D levels,¹⁸⁻²⁰ little attention has been given as to whether these levels of vitamin D are associated with clinical manifestations of vitamin D deficiency in older African Americans. The most commonly observed consequence of vitamin D deficiency—osteopenia/osteoporosis—is thought to be less common in African Americans. Now that vitamin D deficiency has been associated with nonskeletal diseases such as depression, cognitive impairment, and physical disability, it is important to determine whether these effects of

vitamin D deficiency are seen with greater prevalence in African Americans. To explore these associations, we compare the vitamin D status, cognitive performance, physical performance, presence of mood disorder and bone mineral density (BMD) in a group of community-dwelling, ambulatory older African Americans and European Americans.

SUBJECTS AND METHODS

Participants

This is a cross-sectional study of older adults participating in studies of cognitive and functional aging at the Alzheimer's Disease Research Center (ADRC) at Washington University in St Louis, Missouri. The ADRC recruits cognitively healthy and demented older adults from the greater metropolitan St Louis area (population 2.5 million).^{21,22} Participant recruitment occurs through public service announcements (radio, television, and print media); requests to private physicians and organizations; and word of mouth. Inclusion criteria for this study were age greater than 55, ability to ambulate independently, ability to complete all assessments, and willingness to provide serum. Participants were either cognitively normal or had only mildly impaired cognition. Persons with moderate or severe cognitive impairment, history of stroke, renal failure, Parkinson's disease, who use osteoporosis medications and use prescription vitamin D supplements or nonprescription vitamin D supplements greater than 800 IU daily were excluded.

Sixty participants (30 African Americans and 30 European Americans) were recruited and assessed between October 2003 and January 2005. Each African American who enrolled in the study was matched with a European American by Clinical Dementia Rating (CDR). Informed consent was obtained from all participants and the study was approved by the Human Research Protection Office at Washington University.

Clinical and Cognitive Assessments

The clinical evaluation included obtaining past medical, social, and family history from a reliable informant, usually a spouse or adult child. Information regarding possible cognitive change in comparison with previously obtained levels of function that was sufficient to interfere with accustomed activities was obtained by a clinician from semistructured interviews with the informant and separately with the participant. For example, the clinician may have asked whether the participant had a decline in the ability to handle financial and business affairs as opposed to asking if the participant could handle business affairs. The interview with both the participant and informant were useful in assigning the CDR. Included in the clinical assessment protocol were the items from the Mini-Mental State Examination (MMSE)²³ and the Short Blessed Test (SBT).²⁴ The

MMSE is an 11-item tool that assesses memory, orientation, attention, and visual-spatial function. The MMSE has a maximum score of 30, with a higher score indicating better performance. The SBT is a 6-item cognitive assessment tool that evaluates memory, orientation, and attention. The SBT has a maximum score of 28 and uses a weighted-error score, with a higher score indicating worse performance and 0 indicating no errors. Although the MMSE and SBT are highly correlated ($r = 0.91$), the SBT is superior for detecting mild dementia and sub-threshold impairments.²⁵

Each participant was assigned a CDR, which determined the presence or absence of dementia and, when present, rates its severity.²⁶ Using the complete clinical evaluation, the clinician used the CDR to rate cognitive performance in each of 6 categories: memory, orientation, judgment and problem solving, community affairs, home management and hobbies, and personal care. A CDR of 0 indicated no dementia; a CDR of 0.5 indicated very mild dementia; and CDRs of 1, 2, and 3 indicated mild, moderate, and severe dementia, respectively.²¹

The clinician used the depressive features inventory, a 9-item administered survey that has been previously used for diagnosis of depression²⁷ to determine the presence or absence of an active mood disorder. This inventory uses questions based on the 9 symptoms for major depression from the *Diagnostic and Statistical Manual of Mental Disorders* (Fourth Edition).²⁸

Physical Assessment

Following the general physical and neurological examination, the physical performance test (PPT) was administered by a trained research nurse. Scores on the original PPT instrument (developed by Reuben and Siu^{29,30}) correlate with degree of disability, loss of independence, and mortality.^{31,32} We modified the PPT by substituting the chair rise and Progressive Romberg test of standing balance for the stair-climbing tasks.³² Performance on these 2 tasks, which have been included in other modifications of the original PPT,^{31,33} has been associated with self-reported disability, nursing home placement, and mortality.³² Specific tasks in our modified PPT are writing a sentence; simulated eating (ie, spooning beans into a container); lifting a book; simulated dressing (ie, putting on and taking off a jacket); picking up a penny from the floor; turning in a complete circle (ie, steadiness and continuity of steps); walking 50 ft; the chair rise (ie, sitting in and rising from a chair 5 times); and the Progressive Romberg test of standing balance (ie, standing with feet in tandem, semitandem and side-by-side positions). Most of the tasks in our PPT were scored on a 5-point scale: 0, 1, 2, 3, and 4. The total PPT score, a simple summation of the individual item scores, is a composite measure of frailty. The maximum (ie, best) total score was 36, with a decreasing score, indicating increasing frailty.

Vitamin D Assessment

Serum was collected at the time of the clinical assessment and PPT. The 25-hydroxyvitamin D levels were determined using a competitive radioimmune protein binding assay (Diasorin, Stillwater, Minnesota). Subjects were divided into 2 subgroups: normal vitamin D (serum 25-hydroxyvitamin D ≥ 20 ng/mL) and deficient (serum 25-hydroxyvitamin D < 20 ng/mL). Vitamin D deficiency is defined as less than 20 ng/mL based on the laboratory reference range for the 25-hydroxyvitamin D assay utilized in this study. No other biochemical assessments were performed, and vitamin D was assessed on only 1 occasion.

Bone Mineral Density Assessment

BMD of the lumbar spine and proximal femur was measured using dual-energy x-ray absorptiometry (Delphi 4500-W; Hologic Corp, Waltham, Massachusetts).

BMD of the lumbar spine was performed using the anteroposterior projection and was calculated as the mean BMD of vertebrae L1-L4. The coefficient of variation for this technique at our center was 1.1% for the lumbar spine and 1.2% for the proximal femur. *T* scores and *z* scores were generated.

Statistical Analysis

Descriptive statistics were expressed as number, percentage, mean, and standard deviation (SD). Unadjusted differences between African Americans and European Americans in demographic characteristics and clinical and neuropsychological measures were tested using unpaired *t* tests for quantitative variables. Similarly, unadjusted differences between those with vitamin D deficiency (25-hydroxyvitamin D levels < 20 ng/ml) and those with normal vitamin D levels were tested using unpaired *t* tests for quantitative variables. Vitamin D

Table 1. Characteristics of the Participants

Characteristics	All (n = 60)	African Americans (n = 30)	European Americans (n = 30)	P Value
	Mean (SD)	Mean (SD)	Mean (SD)	
25-hydroxyvitamin D (ng/ml)	21.59 (7.8)	17.98 (6.9)	25.20 (7.0)	<.0001
Age, y	74.99 (8.2)	73.39 (7.9)	76.60 (8.2)	.130
Education, y	15.00 (2.9)	14.37 (2.8)	15.63 (3.0)	.097
Weight, kg	76.05 (15.8)	77.3 (13.3)	74.7 (17.9)	.392
Short Blessed Test	8.67 (7.4)	9.57 (8.0)	7.77 (6.7)	.351
Mini-Mental State Exam	25.23 (4.4)	25.70 (4.0)	24.77 (4.8)	.418
Physical performance test	27.93 (3.5)	27.07 (3.6)	28.75 (3.3)	.079
Bone mineral density, hip	0.867 (0.13)	0.876 (0.12)	0.859 (0.14)	.614
Bone mineral density, spine	1.018 (0.22)	1.039 (0.20)	0.997 (0.23)	.461
<i>t</i> score hip	-1.019 (0.85)	-1.031 (0.78)	-1.007 (0.92)	.914
<i>t</i> score spine	-0.515 (1.72)	-0.479 (1.5)	-0.550 (1.9)	.875
Active mood disorder ^a	15 {25%}	7 {23%}	8 {27%}	.770
Depression features score	0.83 (1.32)	0.80 (1.45)	0.87 (1.20)	.847

^a Reflects number of subjects and percentage of each group in { }.

Table 2. Comparison Between Normal and Vitamin D-Deficient Participants

Characteristics	Vitamin D Deficient ^a (n = 31)	Normal Vitamin D ^b (n = 29)	P Value
	Mean (SD)	Mean (SD)	
25-hydroxyvitamin D (ng/ml)	15.57 (3.2)	28.01 (5.8)	<.0001
Age, y	72.66 (8.7)	77.49 (6.9)	.021
Education, y	14.29 (2.7)	15.76 (3.0)	.053
Weight, kg	77.8 (13.3)kg	74.2 (17.9)	.392
Short Blessed Test	10.87 (7.5)	6.31 (6.7)	.016
Mini-Mental State Exam	25.39 (3.9)	25.07 (4.9)	.783
Physical performance test	27.00 (3.8)	28.96 (2.9)	.039
Bone mineral density, hip	0.823 (0.10)	0.914 (0.14)	.005
Bone mineral density, spine	0.980 (0.22)	1.058 (0.21)	.169
<i>t</i> score hip	-1.294 (0.67)	-0.724 (0.92)	.008
<i>t</i> score spine	-0.818 (1.70)	-0.191 (1.71)	.160
Active mood disorder	8 (26%)	7 (24%)	.618
Depression features score	0.68 (1.09)	0.97 (1.49)	.399

^a Eight Caucasians, 23 African Americans

^b Twenty-two Caucasians, 7 African Americans.

deficiency and normal vitamin D groups were also compared for both races separately.

Regression models were used to test whether vitamin D status was associated with SBT score, PPT score, and BMD (hip), while adjusting for the effects of age and race in all models, education in the SBT model, weight in BMD and PPT models, and gender in the BMD only. Preliminary models tested the interaction of vitamin D category with each of the other independent variables. Interactions that were significant in preliminary models were included in the final model.

RESULTS

The sample characteristics at the time of serum collection used for vitamin D determination are shown in Table 1, with group means for African Americans and European Americans. Slightly more than half (52%) of the participants had abnormal vitamin D levels. African Americans had a lower mean vitamin D level (17.98 ng/mL; SD = 6.9) compared to European Americans (25.20 ng/mL; SD = 7.0; *p* < .0001). No other statistically significant differences were seen between the 2 groups.

Comparing all subjects with respect to vitamin D status, subjects with vitamin D deficiency had worse SBT (10.87 vs 6.31; *p* = .016) and PPT (27.00 vs 28.96; *p* = .039) scores and lower BMD (0.823 vs 0.914; *p* = .005) and *t* scores (-1.29 vs -0.72; *p* = .008) of the hip (Table 2). No differences were found in the MMSE, presence of mood disorder, or BMD of the spine (Table 2). Those with vitamin D deficiency were also younger (72.66 vs 77.49; *p* = .021).

In the analyses adjusted for age, race, education, weight, and gender (Table 3), vitamin D deficiency remained significantly associated with the SBT score, BMD of hip, and PPT score.

Seventy-six percent of the African Americans and 27% of the European Americans were vitamin D deficient. Among African Americans (Table 4), those with vitamin D deficiency had worse performance on the MMSE and SBT, higher CDR scores, and lower BMD of the hip compared to African Americans with normal vitamin D despite being younger (71.18 [6.3] years vs 80.67 [9.1]; *p* = .004).

Table 3. Regression Analyses. Models Test Whether Vitamin D Status Was Associated With Short Blessed Test Score, Bone Mineral Density (Hip), and Physical Performance Test Score^a

	Short Blessed Test Score				Bone Density, Hip				Physical Performance Test Score			
	Unstandardized		Standardized		Unstandardized		Standardized		Unstandardized		Standardized	
	β	SE	β	p	β	SE	β	p	β	SE	β	p
Overall model	14.80	1.19	-	.0001	0.577	0.259	-	.030	420.12	7.72	-	.0001
Vitamin D deficient	2.51	1.17	0.171	.036	-0.103	0.033	-0.401	.003	-20.25	1.01	-0.320	.031
Age, y	0.029	0.062	0.032	.640	0.002	0.002	0.136	.336	-0.106	.067	-242	.120
African American	0.895	1.12	0.061	.429	0.254	0.265	0.152	.322	-10.087	1.103	-0.155	.329
Education	0.202	0.176	0.080	.255	-	-	-	-	-	-	-	-
Weight	-	-	-	-	0.001	0.001	0.274	.081	-0.015	.017	-0.147	.397
Gender	-	-	-	-	0.071	0.038	0.269	.065	-	-	-	-

^a Model adjusts for the effects of, age, race, education (Short Blessed Test), weight (bone mineral density and physical performance test) and gender (bone mineral density only).

Table 4. Comparison of Vitamin D Status in African Americans

Characteristics	African Americans (n = 30)		p
	Normal (n = 7)	Deficient (n = 23)	
	Mean (SD)	Mean (SD)	
25-hydroxyvitamin D (ng/ml)	26.53 (9.46)	15.37 (2.8)	< .0001
Age, y	80.67 (9.1)	71.18 (6.3)	.004
Education, y	15.29 (2.9)	14.08 (2.5)	.289
Weight, lbs	155.43 (38.4)	171.48 (28.6)	.240
Short blessed test	2.29 (2.4)	11.78 (7.9)	.004
Mini-Mental State Exam	29.14 (0.9)	24.65 (4.1)	.008
Physical performance test	29.33 (1.6)	26.43 (3.7)	.080
Bone mineral density, hip	1.01 (0.09)	.83 (0.10)	.0001
Bone mineral density, spine	1.13 (0.10)	1.01 (0.22)	.161
<i>t</i> score hip	-0.414 (0.78)	-1.22 (0.69)	.014
<i>t</i> score spine	-0.061 (0.80)	-0.607 (1.7)	.417
Active mood disorder ^a	0 {0%}	7 {30%}	.143
Depression features score	0.14 (0.38)	1.22 (1.6)	.086

^a Reflects number of subjects and percentage of each group in { }.

DISCUSSION

In this study of older Americans, vitamin D deficiency was associated with worse physical performance and lower BMD of the hip. Among African Americans, vitamin D deficiency was associated with worse performance on the MMSE and SBT, both measures of cognitive performance. This study also found that more than half of the participants had vitamin D levels below the sufficient range. This finding is similar to prior reports of the prevalence of vitamin D deficiency in older adults,^{1,34} but lower than a report by Sato et al of vitamin D deficiency in persons with Alzheimer's disease.³⁵

As reported elsewhere,¹⁷ African Americans were more likely to be vitamin D deficient, with three-quarters of the African Americans in the study having abnormally low vitamin D levels. African Americans with vitamin D deficiency had worse cognitive performance despite being younger than African Americans who had normal vitamin D levels. This significant finding suggests that African Americans may be at a particular increased risk for cognitive impairment as a result of their vitamin D deficiency. As expected, those participants with vitamin D deficiency had lower bone density in the hip. The African Americans with vitamin D deficiency had similarly low bone density compared to European Americans with vitamin D deficiency.

Although this study did find important associations between vitamin D deficiency and nonskeletal conditions in older African Americans, the small sample size limits the ability to apply the results to all African Americans. The mean educational level of the African Americans in the study is higher than the average older American and, therefore, is not representative of the population. However, including participants with higher educational achievement in the study may limit erroneously attributing differences in cognitive performance to race.

This study provides additional support for the hypothesis that vitamin D deficiency is associated with impaired cognitive and physical function in older adults. Identifying contributors to cognitive impairment, especially potentially reversible contributors, is increasingly important as the prevalence of dementia and the excess disability associated with dementias continues to increase. African Americans are particularly vulnerable to vitamin D deficiency and some studies report higher rates of Alzheimer's disease and other dementias in African Americans.^{36,37}

Larger prospective studies are needed to confirm this report, and clinical trials will be necessary to determine whether appropriate vitamin D therapy can remediate the effects of vitamin D deficiency. Because vitamin D deficiency may be a common factor contributing to both cognitive and physical impairments, more aggressive and systematic screening of the older adult population is warranted with a particular emphasis on the African American community.

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