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Reduced Sun Exposure Does Not Explain the Inverse Association of 25-Hydroxyvitamin D with Percent Body Fat in Older Adults

Short Title: Body fat, sun exposure and 25(OH)D

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ABSTRACT

Context: Greater adiposity is associated with lower blood levels of 25-hydroxyvitamin D [25(OH)D]. The extent to which this results from reduced sun exposure among heavier individuals is unknown.

Objective: This analysis was conducted to determine whether sun exposure habits differ according to percent body fat (%FAT) in older adults and to what extent they explain the inverse association of adiposity with 25(OH)D in that population.

Design: Cross-sectional analysis of baseline data from a randomized trial of calcium and vitamin D supplementation to prevent bone loss.

Setting: Metabolic Research Unit at the USDA Jean Mayer Human Nutrition Research Center on Aging at Tufts University.

Participants: 381 generally healthy male and female volunteers age 65 and older. Exclusion criteria included vitamin D and calcium supplement use, and medical conditions and medications known to affect bone metabolism.

Intervention: None. Measurements for this analysis were made before participants received trial supplements.

Main Outcome Measures: Plasma 25(OH)D, an indicator of vitamin D status.

Results: Sunscreen use, hours per week spent outside and percent of skin exposed did not differ across quartiles of %FAT ($P>0.43$). 25(OH)D decreased across %FAT quartiles ($P<0.05$) and was about 20% lower in the highest compared with the lowest quartile of %FAT after adjustments for age, sex, season and vitamin D intake. Further adjustment for sun exposure habits had little effect on estimates of 25(OH)D.

Conclusions: In older adults, sun exposure habits do not vary according to adiposity and do not appear to explain lower 25(OH)D concentrations with increasing adiposity.

INTRODUCTION

Greater adiposity is associated with lower blood levels of vitamin D (1) and its liver metabolite, 25(OH)D (2-5). Several potential explanations for this have been proposed and examined to varying degrees (1, 3, 6, 7). The most likely explanations, and they are not mutually exclusive, are 1) that fat tissue may limit bioavailability of vitamin D by reducing its entry into the circulation (1, 6) and 2) that fatter individuals receive less sun exposure because they spend less time outside and/or expose less skin when they do go out. This analysis was conducted to examine the latter possibility.

SUBJECTS AND METHODS

The subjects were participants in the baseline visit of a three-year trial of calcium and vitamin D supplementation to reduce bone loss in men and women aged 65 years and older (8). Use of vitamin D or calcium supplements were exclusions for the study, and no subjects were taking vitamin D or calcium supplements, including multivitamins, at the time the measurements for the present analysis were made. Other exclusion criteria included medical conditions and medications known to affect bone metabolism. The study was approved by the Investigational Review Board at Tufts University and written informed consent was obtained from all participants. Of the 445 subjects enrolled in the supplement trial, five were excluded from the present analysis due to missing measurements of 25(OH)D, % body fat, or sun exposure. Fifteen were excluded due to non-Caucasian race because of prior evidence that the association of adiposity with 25(OH)D differs by race (9) and 44 were excluded because they had traveled south of latitude 35°N in the month preceding the study visit.

All measurements used in this analysis were made at the baseline visit of the supplement trial. Sun exposure habits over the three-month period preceding the study visit were assessed by questionnaire. Separate questions addressed the number of hours per week the subjects usually spent outside during the period (not including time spent in vehicles), the amount of skin that was usually exposed (e.g. face only, face and hands, etc.), and whether they wore sunscreen during any of the time they spent outside. Season of sun exposure was designated according to the middle month of each subject's three-month sun exposure recall period as November through April (Nov-Apr), when sun exposure is too weak to stimulate vitamin D production (10, 11), or May through October

(May-Oct). Dietary vitamin D intake was estimated with a short food frequency questionnaire developed in this laboratory (11). Heights and weights were measured with a stadiometer and digital scale respectively. Body fat was measured by dual-energy x-ray absorptiometry with a DPX-L scanner (Lunar Radiation, Madison, WI). %FAT was calculated from body fat weight and total weight and divided into quartiles. Plasma 25(OH)D and 1,25 dihydroxyvitamin D [$1,25(OH)_2D$] were measured by competitive protein-binding methods having interassay CVs of 7.3% and 7.7% respectively (12, 13).

Analyses were conducted with SPSS version 14.0 (SPSS Inc., Chicago). P values less than 0.05 were considered to indicate statistical significance. Analysis of covariance (ANCOVA) was used to compute regression coefficients (β) and adjusted means and standard errors of the mean (SEM) of sun exposure and 25(OH)D values across quartiles of percent body fat. Potential interactions among predictor variables were examined in preliminary analyses, and none was identified.

RESULTS

Mean age of the 381 subjects (173 men and 208 women) was 71±5 (SD) and mean vitamin D intake was 4.6±2.6 μg/d (185±105 IU/d). Mean %FAT was 34±9 and, as expected, was lower in men (28±6) than women (39±7, P<0.001). There was a significant inverse correlation of %FAT with vitamin D intake (r=0.15, P=0.003) but not with age (r=-0.09, p=0.077).

Predictors of Sun Exposure Habits

Only 16% of subjects (10% of men, 21% of women) reported that they had used any sunscreen when they were outside, and %FAT did not differ by sunscreen use in the group as a whole (P=0.771) or in the subjects measured in either season (P>0.800).

We examined sex, age, season, and %FAT as predictors of hours per week spent outside. The results were similar whether %FAT was included as a continuous variable or categorized into quartiles. When all four potential predictors were considered simultaneously in ANCOVA models, sex was a significant predictor (mean±SEM hours per week was 21±1 for men vs. 15±1 for women, P<0.001) and season was a significant predictor (Table 1, P<0.001), but age and %FAT were not. Mean hours per week spent outside are shown by quartiles of %FAT in Table 1. Subset analyses indicated that, although hours per week spent outside were higher in May-Oct than Nov-Apr, they did not differ across %FAT quartiles in either season (Table 1).

We conducted similar analyses of age, sex, season and %FAT as predictors of the amount of skin that was typically exposed. The percent of skin that was exposed was higher in May-Oct than Nov-Apr (P<0.001) but did not differ across %FAT quartiles (Table 1).

25(OH)D, Percent Body Fat and Sun Exposure

25(OH)D decreased significantly across quartiles of %FAT before and after adjustment for sex, age, season and vitamin D intake (Table 2). After adjustment for sex, age, season and vitamin D intake, hours per week spent outside (β=0.138, P=0.017) and percent of skin exposed (β=0.151, P=0.001) but not sunscreen use (P=0.095) were significantly and positively associated with 25(OH)D. However, adjustment for these variables had little effect on estimates of 25(OH)D across the %FAT quartiles (Table 2). In contrast to 25(OH)D, $1,25(OH)_2D$ did not differ across %FAT quartiles (P=0.654). The means±SEM for $1,25(OH)_2D$ from the lowest to the highest %FAT quartiles were: 34.2±0.9, 35.3±0.9, 35.7±0.9, 35.3±0.9.

DISCUSSION

In this group of older men and women, those in the highest %FAT quartile (over about 40% fat) had 20% lower 25(OH)D concentrations than those in the lowest quartile (under about 28% fat) after adjustment for potential confounders including sex, age, season and vitamin D intake. Further adjustment for sun exposure habits had little effect on the estimates, indicating that differences in sun exposure do not explain the inverse association of 25(OH)D with adiposity in older people. Evidence from this and prior studies suggests that two other potential explanations are also unlikely. First, it does not appear that adiposity influences the skin synthesis of previtamin D_3 or its conversion

to vitamin D_3 (6). Second, it has been proposed that elevated $1,25(OH)_2D$ in obesity may reduce 25(OH)D via negative feedback on its hepatic production (7). However, this mechanism does not explain the inverse association of 25(OH)D with adiposity in this study or that of Parikh et al.(3), neither of which observed an increase in $1,25(OH)_2D$ with increasing adiposity. If differences in sun exposure can be ruled out, the most likely explanation for the association seems to be that vitamin D is sequestered in fat tissue, reducing its entry into the circulation (1, 6). This explanation is consistent with the fact that adiposity is inversely associated with increases in vitamin D_3 after skin irradiation (6) and increases in vitamin D (6) and 25(OH)D after treatment with vitamin D supplements (14). It is also supported by the observation that directly measured adipose tissue is more strongly inversely associated with 25(OH)D than are other anthropometric measures that reflect body size as well as adiposity (4). There is some evidence that subcutaneous fat stores may influence blood levels of 25(OH)D more than visceral fat stores do (4), but further studies are needed to characterize the specific mechanisms by which adipose tissue of varying types contributes to reduced 25(OH)D concentrations in overweight and obese individuals.

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Table 1. Mean±SEM sun exposure habits by quartiles of percent body fat (%FAT)

%FAT	<27.5	27.5-33.8	33.9-40.2	≥40.3	P
N	95	96	95	95	
Hours/wk spent outside					
All subjects[a]	18.9±1.3	18.3±1.2	16.3±1.2	17.5±1.4	0.519
Nov-Apr subset[b]	13.1±1.5	13.2±1.3	11.8±1.3	13.1±1.7	0.842
May-Oct subset[b]	24.2±2.1	23.4±1.9	20.8±2.0	22.2±2.2	0.705
Usual % of skin exposed					
All subjects[a]	19.3±1.6	21.2±1.5	20.9±1.5	20.1±1.7	0.799
Nov-Apr subset[b]	10.1±0.5	11.0±0.4	10.3±0.4	10.9±0.6	0.431
May-Oct subset[b]	28.6±3.1	31.4±2.7	31.8±2.9	29.6±3.2	0.826

[a] adjusted for age, season and sex.
[b] adjusted for age and sex.

Table 2. Mean±SEM 25-hydroxyvitamin D (ng/ml)[a] by quartiles of percent body fat (%FAT)

%FAT	<27.5	27.5-33.8	33.9-40.2	≥40.3	P
N	95	96	95	95	
Unadjusted	34.1±1.4	36.2±1.5	29.4±1.4	25.3±1.2	<0.001
Adjusted for sex, age, season, and vitamin D intake	32.6±1.4	31.7±1.3	30.1±1.3	25.9±1.6	0.024
Adjusted for sex, age, season, vitamin D intake, sunscreen use, hours per week outside and percent of skin exposed	33.2±1.5	32.3±1.4	30.9±1.5	26.7±1.7	0.030

[a]Multiply ng/ml by 2.496 to get nmol/l.