Serum 25-hydroxyvitamin D status of vegetarians, partial vegetarians, and nonvegetarians: the Adventist Health Study-2[1–4]

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ABSTRACT

Background: Vegans and other vegetarians who limit their intake of animal products may be at greater risk of vitamin D deficiency than nonvegetarians, because foods providing the highest amount of vitamin D per gram naturally are all from animal sources, and fortification with vitamin D currently occurs in few foods.

Objective: We assessed serum 25-hydroxyvitamin D [s25(OH)D] concentrations and factors affecting them in vegetarians, partial vegetarians, and nonvegetarians in a sample of calibration study subjects from the Adventist Health Study-2.

Design: Food-frequency questionnaires and sun-exposure data were obtained from 199 black and 229 non-Hispanic white adults. We compared s25(OH)D concentration, dietary and supplemental vitamin D intake, and sun exposure in the different dietary groups.

Results: We found no significant difference in s25(OH)D by vegetarian status for either white or black subjects. Among whites, dietary vitamin D intake and sun behavior were different between vegetarian groups, but there was no difference in skin type distribution. Among blacks, no significant differences were observed for any of these variables between vegetarian groups. The mean (±SD) s25(OH)D was higher in whites (77.1 ± 10.33 nmol/L) than in blacks (50.7 ± 27.4 nmol/L) ($P < 0.0001$).

Conclusions: s25(OH)D concentrations were not associated with vegetarian status. Other factors, such as vitamin D supplementation, degree of skin pigmentation, and amount and intensity of sun exposure have greater influence on s25(OH)D than does diet. *Am J Clin Nutr* 2009;89(suppl):1686S–92S.

INTRODUCTION

The diseases associated with low concentrations of serum 25-hydroxyvitamin D [s25(OH)D; the measure of vitamin D adequacy] now extend beyond rickets and osteoporosis. They include the big killers—heart disease, cancers, and diabetes—as well as autoimmune diseases, depression, and chronic pain (1). Foods providing the highest amount of vitamin D per gram naturally are all from animal sources: cod liver oil, finfish, and shellfish (2). The only naturally occurring plant sources of vitamin D are certain types of mushrooms in which it is present in small amounts (2). Fortification of foods is limited both in amount and distribution. Does this mean that vegetarians, who choose to limit their intake of animal products because it has been associated with better overall health (3), are at greater risk than nonvegetarians of vitamin D deficiency and its accompanying diseases? The Adventist Health Study-2 (AHS-2) is an ideal cohort to examine these questions because its subjects range from vegans to omnivores, with 4.2% vegan, 31.6% lactoovo-vegetarian, 11.4% pescovegetarian (include fish with their otherwise vegetarian diet), 6.1% semivegetarian (eat meat <1 time/wk), and 46.8% nonvegetarians (4).

STUDY POPULATION AND METHODS

Parent study

The AHS-2 has been described in detail elsewhere (4). In brief, it is a prospective epidemiologic study of 96,000 Seventh-day Adventists designed to examine the relation of lifestyle (particularly soy, calcium, vitamin D, and fat intakes) to risks of prostate, breast, and colon cancers. Enrollment to AHS-2 occurred between 2001 and 2007. More than 26,000 of the enrollees are black, and study members live in every state and province of the United States and Canada. Every 2 y, a questionnaire designed to gather information about all hospitalizations is mailed. The second of these questionnaires included additional detailed questions about sun exposure.

Study population

Subjects included in this report are members of the AHS-2 calibration study. Details of the calibration study methods have been described elsewhere (5). Briefly, calibration subjects (n = 1007) were randomly selected from among the 97,000 enrollees to the AHS-2. They were required to attend a clinic during which weight and height were measured, and fasting blood samples were collected. These clinics were held from November 2003 to May 2007 (none were held during February, June, or July because of weather or vacation time). The detailed method of the clinic portion of the calibration study is similar to that of the pilot clinics that have been described elsewhere (6). Cali-

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bration subjects also provided three to six 24-h telephone diet recalls, completed a food-frequency questionnaire (FFQ) within 1–3 mo of blood sample collection, and provided detailed sun exposure information for the 2 mo before their clinic attendance. The subjects of this report are limited to 199 blacks and 229 non-Hispanic whites (whites) who were enrolled in the calibration study as of June 2006, and who completed $\geq$3 diet recalls and a FFQ within 1–3 mo of their clinic visit. Clinic sites for subjects of this report were scattered across the United States.

Biochemical methods

Blood collected at clinics from calibration study subjects was sent on frozen gel packs overnight to reach the processing laboratory at Loma Linda University, CA, within 30 h of sample collection. Plasma and red blood cells were separated by centrifuge at the clinic sites. S25(OH)D was measured with the use of a 2-step radioimmunoassay procedure (DiaSorin, Stillwater, MN). The selected samples were couriered from the Loma Linda laboratory to the Reproductive Endocrine Research Laboratory, Department of Obstetrics and Gynecology, University of Southern California Keck School of Medicine on dry ice and stored again in liquid nitrogen until time of assay. Assay was performed in 3 batches. Typical intra- and interassay CVs at this laboratory are 10% and 16%, respectively.

Dietary and supplemental vitamin D intakes

Vitamin D intake was assessed by the AHS-2 FFQ that was moderately correlated against 24-h telephone recalls. Validity coefficients were 0.61, 0.59, and 0.63 in all, black, and white subjects, respectively. Dietary vitamin D included D_2 (plant source, ergocalciferol) and D_3 (animal source, cholecalciferol) obtained from foods, both naturally occurring and fortified. The vitamin D content of foods included the amount reported in the NUTRITIONAL DATA SYSTEMS (NDS) database (version 5.03; Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN), plus amounts from fortification not included in the NDS. The latter values for foods such as cereals, yogurt, margarines, liquid diet foods, health bars, and soy milk were determined by contacting the manufacturers or consulting relevant websites. Supplemental vitamin D included vitamin D taken in the form of pills or liquid. Subjects were asked to name all pills and supplements they were consuming, including brand names, and amounts. Values for vitamin D from supplements were also verified from manufacturers' websites. No differentiation was made for D_2 or D_3 for either food or supplemental sources because it could not always be determined.

Dietary vitamin D was adjusted for energy intake with the use of the residual method (7). Supplemental intake was not energy adjusted. Total vitamin D intake was the sum of the population mean dietary intake, the energy-adjusted residual, and supplemental intake.

Definition of vegetarian groups

Approximately 43% of whites and 26% of blacks in this study group were vegetarian. We based the vegetarian categories on the frequency of self-reported intake of fish, meat, dairy, and eggs. Vegans consumed any animal product $<$1 time/mo. Lactoovovegetarians were those who ate meat and fish $<$1 time/mo, and dairy or eggs $\geq$1 time/mo. Semivegetarians ate meat and fish $\leq$1 time/wk. Pescovegetarians ate meat $<$1 time/mo, and fish $\geq$1 time/mo. Nonvegetarians ate meat and fish totaling $\geq$1 time/wk (4). Because there were relatively few vegans and semivegetarians in this substudy, vegans were combined with lactoovovegetarians to form the "vegetarian" group, and semi- and pescovegetarians were combined to form the "partial vegetarian" group.

Skin type

Categories according to Fitzpatrick sun-reactive skin types I through VI (8) were defined according to response to prolonged sun exposure: types I: no tan; II: tan very lightly; III: tan moderately; IV: tan darkly; V: already brown; and VI: already black. Types I and II were collapsed for both blacks and whites because so few reported skin type I, and types V and VI were collapsed because of similar response to vitamin D production by sun exposure.

Statistical analysis

Differences between the white and black ethnic groups for selected continuous and categorical baseline characteristics were calculated with Student's *t* test and Pearson's chi-square test, respectively. Analysis of variance and estimated means adjusted for age and sex were used to determine the levels and significance of relations between various vegetarian categories and s25(OH)D for selected variables known to affect s25(OH)D. A chi-square test for independence was used to determine the percentage categorized as sufficient, insufficient, or deficient for s25(OH)D concentrations, by vegetarian group and ethnicity. Dietary vitamin D was adjusted for energy intake with the residual method (7). Supplemental intake was not energy adjusted. Total vitamin D intake was the sum of the population mean dietary intake, the energy-adjusted residual, and supplemental intake. Analyses were conducted using S-PLUS software, version 7.0 (Insightful, Seattle, WA).

RESULTS

The wide geographic distribution of subjects of this report is shown in **Table 1**. s25(OH)D and selected baseline characteristics (1) that might affect the s25(OH)D concentration by ethnic group

TABLE 1
Number of subjects and clinics, by ethnicity and geographic region

	No. of subjects		
Geographic region	Black	Non-Hispanic whites	No. of clinics
Northwest Mountain	6	69	20
Western Pacific	48	75	35
Great Lakes	31	32	17
Central	18	18	7
Southwest	18	17	8
Southern	50	16	20
Eastern	28	2	10
New England	0	0	0
Total	199	229	117

are shown in **Table 2**. Mean s25(OH)D was 52% higher among whites than among blacks. The white subjects were older, had lower body mass index (in kg/m^2), and had a higher proportion of males. Distributions of vegetarian status and skin type were significantly different between ethnic groups. The proportion of vegetarians and nonvegetarians was almost equal among whites, whereas there were twice as many nonvegetarians compared with vegetarians among blacks. The proportion of partial vegetarians was the same for both ethnic groups. None among the whites reported skin type V or VI, whereas 44% of blacks belonged to these skin types. Variables that did not differ significantly between ethnic groups included vitamin D intake (dietary, supplemental, and total), time spent in the sun, amount of body exposed, and exposure factor, the product of the last 2 variables.

The estimated means for selected variables affecting s25(OH)D according to vegetarian status adjusted for age and sex are shown in **Table 3**. The means are those estimated for a population with mean age and equal numbers of males and females. The mean age was 63 y for white and 58.3 y for blacks. In white subjects, no significant difference in s25(OH)D was observed between vegetarian groups, although dietary vitamin intake increased significantly from vegetarians to partial vegetarians to nonvegetarians. No significant difference was observed in supplemental vitamin D intake, total vitamin D intake, or time spent in the sun among the dietary groups. However, the product of duration and percentage of body exposed to the sun (9), exposure factor, was significantly higher in partial vegetarians than in nonvegetarians and total vegetarians.

For blacks, the estimated means for s25(OH)D did not vary significantly between vegetarian groups (range: 48.65–51.51 nmol/L). Unlike the white subjects, no significant differences were observed between the vegetarian groups for any of the personal characteristics or nutritional or sun exposure behaviors.

The proportion of subjects who are sufficient, insufficient, and deficient in s25(OH)D by vegetarian status within each ethnic group is shown in **Table 4**. The distribution of s25(OH)D status was not significantly associated with vegetarian status for either ethnic group. In general, ethnicity had a far greater effect on s25(OH)D than did diet. Blacks have ≥3 times higher percentage in the deficient category than whites for all dietary groups.

TABLE 2

Selected baseline characteristics of the study group according to ethnicity

Characteristic	Non-Hispanic whites (n = 229)	Blacks (n = 199)	P[1]
Serum 25-hydroxyvitamin D (nmol/L)[2]	77.1 ± 10.33[3]	50.7 ± 27.4	<0.0001
Categories of serum 25-hydroxyvitamin D concentrations [n (%)]			<0.0001
Deficient (<50 nmol/L)	35 (15.2)	116 (58.3)	
Insufficient (50 to 74.9 nmol/L)	74 (32.3)	50 (25.1)	
Sufficient (≥75 nmol/L)	120 (52.4)	33 (16.6)	
Males [n (%)]	85 (37.1)	51 (25.6)	0.02
Age (y)	62.9 ± 14.0	58.0 ± 12.5	0.0002
BMI (kg/m^2)	26.9 ± 5.1	30.3 ± 6.7	<0.0001
Dietary vitamin D intake (IU)[4]	140 ± 96	132 ± 96	0.33
Supplemental vitamin D intake (IU)[5]	244 ± 316	224 ± 296	0.39
Total vitamin D intake (IU)[6]	388 ± 249.2	352 ± 312	0.22
Vegetarian status [n (%)]			0.003
Vegetarian[7]	98 (42.8)	52 (26.1)	
Partial vegetarian[8]	35 (15.3)	31 (15.6)	
Nonvegetarian[9]	96 (41.9)	116 (58.3)	
Skin type [n (%)][10]			<0.0001
Type I, no tan or freckles	19 (8.3)	1 (0.5)	
Type II, tans lightly	75 (32.8)	31 (15.6)	
Type III, tans moderately	97 (42.4)	32 (16.1)	
Type IV, tans darkly	38 (16.6)	41 (20.6)	
Type V or VI, skin brown or black	0	85 (42.7)	
Unknown type	0	9 (4.5)	
Time spent in the sun daily (min)	89.6 ± 83.0	88.3 ± 86.1	0.73
Percentage of body exposed to sunshine[11]	9.3 ± 6.5	8.7 ± 6.9	0.31
Exposure factor[12]	913.9 ± 1251.3	952.0 ± 1467.9	0.62

[1] Student's t test or chi-square test difference of means or percentages.
[2] Assayed by 2-step radioimmunoassay procedure (DiaSorin, Stillwater, MN).
[3] Mean ± SD (all such values).
[4] Adventist Health Study-2 food-frequency questionnaire collected within 1–3 mo of blood sample. Calorie adjusted by residual method (7).
[5] Adventist Health Study-2 food-frequency questionnaire collected within 1–3 mo of blood sample.
[6] Sum of the population mean dietary, energy-adjusted residual, and supplemental intakes.
[7] Ate meat and/or fish <1 time/mo.
[8] Ate meat and fish <1 time/wk or ate meat <1 time/mo and fish ≥1 time/mo.
[9] Ate meat and fish totaling ≥1 time/wk.
[10] Fitzpatrick sun-reactive skin types I through VI (8).
[11] According to Wachtel's burn chart, modified (9).
[12] Product of time in the sun and percentage of body exposed to sunshine because only one side of body faces sun at any one time.

TABLE 3
Estimated means for selected variables affecting serum 25-hydroxyvitamin D concentrations by vegetarian status, adjusted for differences in age and sex

	Non-Hispanic white				Black			
	n	Estimated mean	SE	*P*[1]	*n*	Estimated mean	SE	*P*[1]
Serum 25-hydroxyvitamin D (nmol/L)[2]				0.87	199			0.77
Vegetarian[3]	98	76.76	2.62		52	48.65	3.98	
Partial vegetarian[4]	35	77.25	4.36		31	52.63	5.08	
Nonvegetarian[5]	96	78.64	2.65		116	51.51	2.78	
Dietary vitamin D intake (IU)[6]				0.005	172			0.32
Vegetarian[3]	93	119.46	10.0		43	150.56	15.2	
Partial vegetarian[4]	34	143.12	16.4		26	114.66	19.2	
Nonvegetarian[5]	88	165.32	10.0		103	135.77	10.0	
Supplemental vitamin D intake (IU)[7]				0.91	181			0.21
Vegetarian[3]	94	227.39	32.4		48	257.51	44.0	
Partial vegetarian[4]	34	208.99	53.6		29	148.92	55.6	
Nonvegetarian[5]	91	236.14	32.8		104	180.18	31.2	
Total vitamin D intake (IU)[8]				0.51	161			0.38
Vegetarian[3]	93	350.60	34.0		39	375.06	51.6	
Partial vegetarian[4]	34	351.97	56.0		26	265.55	62.8	
Nonvegetarian[5]	88	402.90	34.8		96	327.46	34.4	
Time spent in the sun (min/d)				0.30	170			0.97
Vegetarian[3]	87	88.48	8.35		44	101.93	13.07	
Partial vegetarian[4]	32	113.31	13.68		25	103.35	16.80	
Nonvegetarian[5]	83	93.86	8.53		101	105.41	8.79	
Percentage of body exposed to sunshine[9]				0.11	195			0.43
Vegetarian[3]	90	8.36	0.68		51	8.79	1.01	
Partial vegetarian[4]	32	10.69	1.14		31	7.15	1.27	
Nonvegetarian[5]	86	9.96	0.70		113	8.95	0.70	
Exposure factor[10]				0.04	170			0.50
Vegetarian[3]	87	791.70	125.43		44	1220.07	230.07	
Partial vegetarian[4]	32	1413.24	205.46		25	804.17	295.65	
Nonvegetarian[5]	83	973.95	128.05		101	1130.93	154.63	

[1] Determined by using ANOVA. The means are estimated for a population with mean age and equal numbers of males and females

[2] Assayed by 2-step radioimmunoassay procedure (DiaSorin, Stillwater, MN).

[3] Ate meat or fish <1 time/mo.

[4] Ate meat and fish <1 time/wk, or ate meat <1 time/mo and fish ≥1 time/mo.

[5] Ate meat and fish totaling ≥1 time/wk.

[6] Adventist Health Study-2 food-frequency questionnaire collected within 1–3 mo of blood sample. Calorie adjusted by residual method (7).

[7] Adventist Health Study-2 food-frequency questionnaire collected within 1–3 mo of blood sample.

[8] Sum of the population mean dietary, energy-adjusted residual, and supplemental intakes.

[9] According to Wachtel's burn chart (9). Modified because only one side of body faces sun at any one time.

[10] Product of time in the sun and percentage of body exposed to sunshine.

DISCUSSION

As in other studies (10–15), we found statistically significant lower dietary vitamin D intake among vegetarians than among nonvegetarians but only in our white subjects. But unlike those same studies, we found no association between s25(OH)D concentrations and vegetarian status in either our black or white cohorts. This would indicate that factors other than diet have a greater effect on s25(OH)D than vegetarian status. For all our dietary groups, the mean dietary vitamin D intake was low, 119.45–165.32 IU in whites and 114.66–150.56 IU in blacks. These values are ≤41% than the Adequate Intake (AI) of 400 IU recommended for the age group represented in this study (age 51–70 y) (16). Among whites, dietary vitamin D intake increased from vegetarian to partial vegetarian to nonvegetarian, but the absolute difference of ≈46 IU was not large. Supplemental intake of 400 IU vitamin D/d raises s25(OH)D by only 7–12 nmol/L, depending on the starting point (17).

It is difficult to meet daily AIs for vitamin D from food, because few foods provide vitamin D naturally, and only a limited number of foods are fortified (2). Foods with high concentrations of naturally occurring vitamin D are not eaten frequently by many, because they are expensive. For example, wild cooked salmon contains one of the highest concentrations of vitamin D, providing 360 IU vitamin D/ serving (100 g or 3.5 ounces), but it is expensive. Cooked tuna, a less expensive and more commonly eaten fish, provides only 200 IU/100-g serving.

Naturally occurring vitamin D in foods appropriate for some vegetarians occur in trivial amounts, such as 20 IU from an egg yolk. Fortified foods contribute higher, although still inadequate, amounts. For example, 1 cup (237 mL) fortified milk, milk

TABLE 4
Percentages of each vegetarian group, by ethnicity, in the sufficient, insufficient, or deficient category[1]

Serum 25-hydroxyvitamin D categories	Whites: Vegetarian[2] ($n = 98$)	Whites: Partial vegetarian[3] ($n = 35$)	Whites: Nonvegetarian[4] ($n = 96$)	Blacks: Vegetarian[2] ($n = 52$)	Blacks: Partial vegetarian[3] ($n = 35$)	Blacks: Nonvegetarian[4] ($n = 96$)
Sufficient (≥75 nmol/L)	51.02	45.71	56.25	15.38	16.13	17.24
Insufficient (50–74.9 nmol/L)	36.73	37.14	26.04	21.15	22.58	27.59
Deficient (<50 nmol/L)	12.24	17.14	17.71	63.46	61.29	55.17

[1] $P = 0.4$ and $P = 0.9$ for whites and blacks, respectively (chi-square test for independence).
[2] Ate meat or fish <1 time/mo.
[3] Ate meat and fish <1 time/wk, or ate meat <1 time/mo and fish ≥1 time/mo.
[4] Ate meat and fish totaling ≥1 time/wk.

substitute, or fortified juice yields <100 IU, or less than one-fourth the daily AI for the age group represented in this study. Furthermore, fortification of foods is spotty. Although the United States permits fortification of cereal flours and related products, calcium-fortified fruit juices and drinks, including some milk replacements such as soy and nut ''milk'' and margarine (2), not all foods in these categories are fortified. According to 2006–2007 Food Label and Package Survey by the US Food and Drug Administration, ≈91% of cheeses, juices, and spreads, ≈75% of yogurts, slightly less than half of all milk substitutes, and ≈25% of ready-to-eat breakfast cereals are not fortified with vitamin D, although most fluid milks are (18). With so little vitamin D available from food, it is not unexpected that dietary intake of vitamin D is low.

For vegans wanting to obtain their dietary sources of vitamin D from plants only, mushrooms may become a valuable source. Mushrooms with vitamin D_2 content boosted to 400 IU by exposure to sunlight shortly after harvest were introduced to the market this year (19, 20). They are identified as vitamin D–enriched on their labels.

The variable causing the greatest difference in s25(OH)D concentrations was not diet but ethnicity. High percentages of both white and black subjects in our study did not meet sufficient s25(OH)D status, regardless of their dietary preferences, but the percentage with deficiencies was much higher among blacks (75.4%) than among whites (47.5%). This disparity occurred, even though most factors contributing to s25(OH)D concentrations were similar in both ethnic groups. These factors included dietary and supplemental vitamin D intake, time spent in the sun, and amount of skin exposed to sunshine. Age was significantly different between the 2 ethnic groups, but the size of that difference was small (4.9 y). Among whites, epidermal stores of vitamin D precursor contained in the skin declines 2–4-fold from age 20 to 80 y (21). Any effect because of age would decrease the difference between the ethnic groups. Mean body mass index for blacks was higher than for whites, 30.3 compared with 26.9, and this may have contributed somewhat to blacks having lower s25(OH)D concentrations than whites, because s25(OH)D is removed from circulation by sequestration in adipose tissue (22).

The largest difference between the 2 ethnic groups is the melanin content in skin which is much higher in blacks than in whites. Although blacks were exposed to the same amount of sunlight, they were not capable of producing the same amount of cutaneous vitamin D as were whites. The same quantity of ultraviolet B (UVB) irradiation (290–315 nm) has been found to produce as little as 10% the increase in s25(OH)D in those with dark brown skin as those with light skin type (23). As much as 90–100% of vitamin D requirement for light-skinned people is said to come from exposure to sunshine (23). Although it is difficult to obtain vitamin D from dietary sources, cutaneous production of relatively high amounts of vitamin D can occur in a relatively short time in lighter skinned persons when their skin is exposed to sufficiently strong sunshine. Exposure of a person in a bathing suit to 1 minimal erythemal dose (enough sun to turn the skin slightly red), is equivalent to an oral dose of vitamin D of 10,000–20,000 IU (23). For a person with light skin, this can take ≤15 min (24).

Limitations of the study

The limitations of the study concern the accuracy of measuring the variables that contribute to s25(OH)D concentrations and the strength of their effect in changing those concentrations. The values used for vitamin D content of foods in the US Department of Agriculture Standard Reference and related products (2) are not entirely accurate and are currently undergoing review by the Nutrient Data Laboratory (25).

We made no adjustments for possible difference in effects on s25(OH)D concentrations of D_2 (from plants) and D_3 (from animals). The data collected did not differentiate between them, and their relative efficiency is still under debate. Early research reported that D_2 was ≈40% less efficient than D_3 (26, 27). A more recent study reports that they have similar effects (28). Estimates of 25(OH)D and other vitamin D metabolites present in meat have not yet been assessed or included as dietary sources of vitamin D by the NDS. Many animal products contain 25(OH)D, and this metabolite is absorbed better and faster than vitamin D and has metabolic activities of its own in regulating cell growth and calcium metabolism. Depending on the biochemical reaction, it can have biological activity ≤5 times that of native vitamin D (29). 25(OH)D occurs in meat naturally but also as a result of cattle in the United States being fed foods highly fortified with vitamin D during the 8 d before slaughter to tenderize the meat (30).

Because vitamin D can be synthesized by the action of UVB on 7 dehydroxycholesterol in the skin (23), the effect of UVB exposure should be included as an adjustment when relating s25(OH)D concentrations to nutritional sources. A complex mixture of skin color, season of the year, geographical location, amount of time spent in the sunshine, as well as how much skin is exposed, must all be considered. This report included personal sun behavior activity but not sun exposure because of season of blood sample or geographic location of subjects. All these factors are difficult to determine accurately (31). Furthermore, vitamin D is sequestered in adipose tissue, and the rate of reentry into the circulation is not yet understood and is believed to contribute to the broad range of dose-response relations reported by various studies (32).

Conclusions

s5(OH)D concentrations are not associated with vegetarian status because vitamin D from dietary sources, both naturally occurring and fortified, is limited. Other factors, such as vitamin D supplementation, degree of skin pigmentation, and amount and intensity of sun exposure, have greater effect on s25(OH)D than does diet. (Other articles in this supplement to the Journal include references 33–59.)

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