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25-Hydroxyvitamin D Status of Healthy, Low-Income, Minority Children in Atlanta, Georgia

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Abstract

OBJECTIVES—The goals were to determine the prevalence of vitamin D deficiency among minority children in a southern US city, to examine differences in serum 25-hydroxyvitamin D levels between non-Hispanic black and Hispanic children, and to determine dietary sources of vitamin D.

METHODS—Low-income, minority children (N = 290; mean age: 2.5 ± 1.2 years) were recruited during well-child clinic visits. Serum 25-hydroxyvitamin D and calcium levels were measured and dietary information was assessed.

RESULTS—The mean 25-hydroxyvitamin D_3 level was 26.2 ± 7.6 ng/mL, whereas 25-hydroxyvitamin D_2 was not detected. Overall, 22.3% of children had deficient serum 25-hydroxyvitamin D_3 levels (≤20 ng/mL), 73.6% had less-than-optimal serum 25-hydroxyvitamin D levels (≤30 ng/mL), and 1.4% had low serum calcium levels (≤9 mg/dL). A significantly larger proportion of non-Hispanic black children, compared with Hispanic children, had vitamin D deficiency (26% vs 18%; P<.05). Age and season of recruitment were significantly associated with vitamin D deficiency and low serum calcium levels. Older children (≥3 years) were less likely to have vitamin D deficiency (odds ratio [OR]: 0.89 [95% confidence interval [CI]: 0.81–0.96]; P < .001). Study enrollment during spring and summer reduced the likelihood of vitamin D deficiency by ~20% (spring, OR: 0.85 [95% CI: 0.73– 0.98]; P = .03; summer, OR: 0.82 [95% CI: 0.73– 0.92]; P < .01). Fortified milk provided most dietary vitamin D (62%), with Hispanic children reporting greater intake.

CONCLUSIONS—Suboptimal vitamin D status was common among apparently healthy, low-income, minority children. Age and season were significant predictors of vitamin D deficiency.

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Keywords

vitamin D; 25-hydroxvitamin D; low-income; minority; preschool; children

Absorption of available calcium from the gastrointestinal tract is aided by vitamin D, a prohormone that is available in the diet and is produced by the skin. Vitamin D deficiency is associated with the occurrence of rickets (poor mineralization of developing cartilage and bone) in children and osteomalacia in adults. Various studies have identified potential associations between vitamin D deficiency and a variety of diseases, including diabetes mellitus, metabolic syndrome, cancer, cardiovascular disease, multiple sclerosis, and neuromuscular malfunction. [1–7] This has intensified interest in improving vitamin D status in populations at risk for deficiency.

A resurgence of vitamin D-dependent rickets in the United States and other western countries has been reported.[8] In young children, this can be prevented through adequate intake of vitamin D and sunlight exposure.[9,10] However, the previously recommended intake of 200 IU per day did not protect children adequately and prevent deficiency; therefore, in late 2008 the American Academy of Pediatrics revised recommendations for infants, children, and adolescents to 400 IU per day.[8,11]

The majority (>80%) of the vitamin D requirement comes from exposure to sunlight.[12] Dietary intake alone is unlikely to provide the daily recommended quantity of vitamin D to prevent deficiency states and associated problems. Sources of dietary vitamin D include foods fortified with vitamin D, such as milk, infant formulas, and breakfast cereals.13 The body has the capacity to synthesize vitamin D_3 when the skin is exposed to sunlight or ultraviolet B radiation. Any obstruction to ultraviolet B radiation penetration into the skin dramatically affects the cutaneous production of vitamin D; impediments may include skin pigmentation, sunscreens, clothing, and increases in latitude.[12]

Few studies have examined vitamin D status in young children in the southern latitudes of the United States.[14,15] The prevalence of vitamin D deficiency is high among breastfed infants and those with dark skin.[8] However, the prevalence among toddlers and preschool-aged children with dark skin who live in the sunny southern United States is not known. The main objectives of the study were to determine the prevalence of vitamin D deficiency in an at-risk population of minority children in a major city in the southern United States and to examine whether 25-hydroxyvitamin D levels varied between non-Hispanic black and Hispanic children. Dietary intake was evaluated, to identify food sources of vitamin D. The primary outcomes were the presence of vitamin D deficiency, defined on the basis of serum concentrations of 25-hydroxyvitamin D of ≤20 ng/mL, and dietary sources of vitamin D.

METHODS

Study Population

This was a cross-sectional study conducted in 2 clinics in metropolitan Atlanta, Georgia (pediatric clinics at Children's Healthcare of Atlanta at Hughes Spalding, Grady Memorial Hospital, and North Dekalb Grady Satellite Clinic). The study was approved by the research oversight committee of Grady Memorial Hospital and the institutional review boards of Emory University and Children's Healthcare of Atlanta.

These clinics serve predominantly low-income families who are eligible for or enrolled in the Supplemental Nutrition Program for Women, Infants, and Children. [16] A convenience sampling procedure was used for the recruitment of preschool-aged children (1–5 years of

age) between March 2006 and July 2007, at the 2 clinics, every weekday between 8 AM and 1 PM.

Included in the study were apparently healthy children 1 to 5 years of age who were attending the clinic for well-child visits. Children with a history of sickle cell anemia, acute diarrheal or respiratory illnesses, or overt malnutrition were excluded. Informed consent was obtained from the primary caregiver of each child, in either English or Spanish. Baseline data including date of birth, gender, race, and ethnicity were collected. Growth was assessed by measuring weight and height directly. Children <2 years of age had supine lengths measured with a horizontal stadiometer (Aryton Infantometer, model M-200 [Seca, Hamburg, Germany]). Children ≥2 years of age had standing heights measured to the nearest 0.1 cm with a vertical stadiometer (digital Heightronic 235 [Seca]). The heights/lengths were measured twice, and mean values were recorded. Weight was measured to the nearest 0.1 kg with a pediatric or beam balance scale (Seca). The weights also were measured in duplicate, and mean values were recorded. Height and weight percentiles were calculated with Epi Info 3.3.2 (Centers for Disease Control and Prevention, Atlanta, GA). Height and weight percentiles were used to assess nutritional status in comparison with age-matched children in the US population.

Laboratory Analyses

Blood was obtained from the children through conventional venipuncture. Samples were transported on ice to our laboratories, where they were centrifuged and stored at −80°C until analysis. Serum 25-hydroxyvitamin D analyses were performed at the laboratories of the Division of Laboratory Sciences, National Center for Environmental Health, Centers for Disease Control and Prevention, by using liquid chromatography-tandem mass spectroscopy. [17] Serum calcium analyses were performed at the chemistry laboratory of Emory University Hospital, by using an end-point assay in a multichannel analyzer (Roche Diagnostics, Indianapolis, IN). Parathyroid hormone levels were not measured. Vitamin D deficiency was defined as serum 25-hydroxyvitamin D concentrations of ≤20 ng/mL. Serum 25-hydroxyvitamin D levels of >30 ng/mL were considered optimal. Low serum calcium levels were defined as serum calcium levels of ≤9 mg/dL.

Food Records

Primary caregivers of the children were instructed by a trained study coordinator, in either English or Spanish, on how to complete a 3-day food record diary.[18] The document, a stamped addressed envelope, standard measuring devices (spoons and cups), and pictures of portion sizes were given to the caregiver. After completion of the 3-day record, the caregiver mailed the record to the research team. Upon receipt, this food record was assessed and entered into Food Processor SQL nutrition analysis software (ESHA Research, Salem, OR) at the Bionutrition Core of the Emory University Hospital site of the Atlanta Clinical and Translational Science Institute (formerly a General Clinical Research Center), for assessment of energy, protein, calcium, and vitamin D intakes.

Statistical Methods

The prevalence rates of vitamin D deficiency and low serum calcium levels were determined, and the differences between Hispanic and non-Hispanic black children were assessed by using the χ^2 test and Fisher's exact test. The χ^2 test and Fisher's exact test were used to identify categorical variables that were associated with both serum 25-hydroxyvitamin D levels and low serum calcium levels among children of the 2 racial/ethnic groups. Independent *t* tests were used to compare the serum concentrations of 25-hydroxyvitamin D and calcium between the 2 groups. Simple linear regression was used to identify continuous variables associated with serum 25-hydroxyvitamin D and calcium

levels and simple logistic regression to identify continuous variables associated with 25-hydroxyvitamin D deficiency and low serum calcium levels.

By using all predictors of interest, whether or not the simple association was significant, PROC GENMOD was used to develop multivariate logistic regression models for serum 25-hydroxyvitamin D deficiency and low serum calcium levels. Confounding variables were assessed by removing or adding variables and observing the effects on the statistical significance of the remaining variables in the model. All statistical analyses were conducted with SAS 9.2 (SAS Institute, Cary, NC).

RESULTS

Demographic characteristics of the 290 children enrolled are shown in Table 1. The age (mean ± SD) of the children in the study was 2.5 ± 1.2 years, with Hispanic children (age: 2.7±1.2 years) being older than non-Hispanic black children (age: 2.3 ± 1.1; $P < .05$). No significant differences were observed in the anthropometric indicators measured (ie, height-for-age and weight-for-age *z* scores) (Table 1). There was an equal gender distribution (50% boys and 50% girls), although there was a significantly larger proportion of boys in the non-Hispanic black group, compared with the Hispanic group.

Overall, 22.3% of the children ($n = 59$) had vitamin D deficiency (serum 25-hydroxyvitamin D levels of ≤20 ng/mL), 73.6% ($n = 195$) had vitamin D insufficiency (serum 25-hydroxyvitamin D levels of≤30 ng/mL), and 1.4% ($n = 4$) had low serum calcium levels (≤9mg/ dL). Although a significantly larger proportion of black children had vitamin D deficiency, mean serum levels were similar in the 2 groups (Table 1). There was no significant difference between the proportions of black and Hispanic children with vitamin D insufficiency. Mean serum calcium levels were similar for the 2 groups of children. There was no difference in the serum 25-hydroxyvitamin D levels among younger children (1–3 years of age) who reported ever breastfeeding in infancy (n=29), compared with those who did not breastfeed.

Completed food records were returned for 63.1% of the enrolled children ($n = 183$). The main dietary sources of vitamin D intake among this sample of children are shown in Fig 1. Fortified milk was the main source of vitamin D (62%) in the diet, followed by cereals (17%). Hispanic children had significantly greater intake of milk, compared with black children (68% vs 52%; P<.001) (Fig 2). Intake of vitamin D-fortified fruit juices accounted for <5% of the dietary intake of vitamin D in either group. None of the children used multivitamin supplements at the time of the study.

Correlations between serum levels of 25-hydroxyvitamin D and dietary intake of vitamin D or serum levels of calcium and dietary intake were not significant (Table 2). However, there were inverse relationships between intake of fat and serum levels of 25-hydroxyvitamin D ($R = −0.13$; $P < .01$) and calcium (R=−0.1; P=.03). Multivariate logistic regression models to estimate predictors of low serum calcium levels and vitamin D deficiency while controlling for other predictors are presented in Table 3. Age was associated with vitamin D deficiency. Older children were 11% less likely to have vitamin D deficiency (odds ratio [OR]: 0.89 [95% confidence interval [CI]: 0.81– 0.96]; $P < .01$). As expected, the season of recruitment (spring or summer) significantly predicted vitamin D deficiency. Children who enrolled in spring or summer were ~20% less likely to have vitamin D deficiency (spring, OR: 0.85 [95% CI: 0.73– 0.98]; $P = .03$; summer, OR: 0.82 [95% CI: 0.73– 0.92]; $P < .01$), whereas those recruited in winter were at higher risk of vitamin D deficiency, although the finding was not statistically significantly (OR: 1.06 [95% CI: 0.92–1.24]; P>.05). The mean ±SD serum 25-hydroxyvitamin D levels measured during the winter, spring, summer, and

autumn seasons were 24.8±8.5, 25.4 ± 7.9, 27.3 ± 5.7, and 27.9 ± 8.4 ng/mL, respectively. Race/ethnicity was not associated as a significant factor with vitamin D deficiency or low serum calcium levels.

DISCUSSION

The main objective of this study was to determine the prevalence of vitamin D deficiency among black and Hispanic, preschool-aged children from low-income families living in the southern United States. A relatively high prevalence (22%) of vitamin D deficiency was identified among these apparently healthy, minority, preschool-aged children from low-income families in a convenience sample from 2 clinics in Atlanta, Georgia. An even larger proportion (73.6%) had serum 25-hydroxyvitamin D levels below the threshold (<30 ng/mL) that is becoming increasingly accepted as optimal for bone health and protection against malignancies, infections, and other diseases.[12,19,20] Higher latitudes are known to reduce serum 25-hydroxyvitamin D levels adversely, and people who live at lower latitudes usually have a low prevalence of suboptimal serum 25-hydroxyvitamin D levels. However, the vitamin D deficiency prevalence in our study was higher than that found among healthy infants and toddlers in Boston, Massachusetts (42° N), which negates the assumption that children in the southern United States may be better off in terms of serum vitamin D status.[8] In the Boston study by Gordon et al,[8] skin pigmentation was not identified as a factor for deficiency. In our study cohort, however, non-Hispanic black children had an increased prevalence of vitamin D deficiency, compared with their Hispanic counterparts. The prevalence of vitamin D insufficiency was lower among non-Hispanic, nonblack children 1 to 6 years of age in the 2001–2004 National Health and Nutrition Examination Survey (43% for girls and 48% for boys),[21] compared with values reported for our cohort of Hispanic and black children. None of the children in our cohort had clinical signs of rickets on physical examination. The skin has an enormous capacity to synthesize vitamin D when exposed to sunlight or ultraviolet B radiation, and any attenuation of ultraviolet radiation penetrating the skin, such as caused by skin pigmentation or sunscreen, reduces dramatically the cutaneous synthesis of vitamin D. Vitamin D deficiency has been reported for individuals with dark skin, but the effects of diet and age have not been assessed systematically in this group.[22–25] Exposure to sunlight, measured on the basis of the time spent outdoors, the wearing of ultraviolet radiation-blocking clothing, and the use of sunscreen were not assessed in this study.

A strength of this study was the analysis of dietary vitamin D intake with the use of food diaries. Main sources of dietary vitamin D were milk and breakfast cereals. Hispanic children reported greater intakes of these foods, compared with black children. These food sources are fortified with vitamin D, which makes them good sources for this age group (preschool-aged children); few foods (oily fish such as mackerel, salmon, and sardines, cod liver oil, liver, and egg yolk) naturally contain adequate vitamin D, and these foods are consumed infrequently by children.[26] However, serum 25-hydroxyvitamin D levels may be limited by the bioavailability of dietary vitamin D.[26–28] This factor was not evaluated but might have affected the prevalence of vitamin D deficiency in this study. Dietary vitamin D intake did not seem to influence vitamin D status in this study, as predicted initially.

Age was an independent predictor of vitamin D deficiency, with older children having significantly reduced risk of vitamin D deficiency. This is in contrast to previous studies that determined vitamin D status in children and noted that older children had increased risk of vitamin D deficiency.[14,15] However, the children in the previous studies were older than those in this study. The observation in our study may be attributable to increased outdoor activities of the older children, compared with the younger children, as well as the use of sunscreens and protective clothing by the younger children. These might have a greater

impact on reducing the skin's ability to synthesize vitamin D than the age-related decline in cutaneous synthesis of vitamin D. Skin pigmentation, indicated by highly pigmented skin (black) and medium/lightly pigmented skin (Hispanic), was not a significant predictor of vitamin D status. These findings are consistent with the results from an earlier study of healthy infants and young children, among whom pigmentation, sunscreen use, and time spent outdoors did not predict vitamin D status.[8] Data on behaviors such as time spent outdoors, use of ultraviolet light-protective clothing, and use of sunscreens would be of interest but were not determined in this study. The season of recruitment had a very strong association with vitamin D status. Study participants recruited in the spring and summer were less likely to have vitamin D deficiency, compared with those recruited in the winter, despite year-round sunlight and generally moderate temperatures in Atlanta, Georgia. Similar seasonal observations were recorded among prepubertal girls in the southeastern United States.15 Although there is no consensus regarding the appropriateness of routine vitamin D screening for healthy children after the winter season, daily vitamin D supplementation at the newly recommended dose of 400 IU per day or higher during the winter would be of even greater importance for preschool-aged children with dark skin.

Physical stature and weight did not have significant effects on vitamin D deficiency or status in multivariate models in the current study. In another study in which toddlers were recruited, a significant association was reported between BMI and serum vitamin D levels, indicating that increased BMI is a risk factor for vitamin D deficiency. [8] These findings were not replicated in our study of preschool-aged children. The bioavailability of vitamin D, a fat-soluble vitamin, is decreased in obese individuals, which may result in the increased vitamin D deficiencies observed in such individuals.[28] This mechanism also could account for the inverse relationship between fat intake and vitamin D status. The inverse relationship between fat intake and serum calcium levels might be related to the binding of calcium by fatty acids in the small bowel, preventing absorption.[29]

Our results are limited by the cross-sectional design of the study, the small geographic area used for subject recruitment, and the lack of a cohort of socioeconomically matched white children, which limits the generalizability of our findings. However, the racial mixture of the cohort and the defined geographic location in urban Atlanta may be considered hypothesis-generating strengths of the study. For example, these children are likely to be at highest risk of developing nutrient deficiencies because of social and economic factors.

CONCLUSIONS

Our data confirm and extend data documenting that minority, low-income children in the southeastern US have a high prevalence of both 25-hydroxyvitamin D deficiency and insufficiency. A significantly larger proportion of black children presented with vitamin D deficiency, compared with Hispanic children. There was no difference in the mean serum 25-hydroxyvitamin D and calcium concentrations according to race/ethnicity. The age of the child and the season of recruitment were significant predictors of vitamin D deficiency but not calcium deficiency in the multivariate models. Older children (≥3 years of age) were less likely to have vitamin D deficiency. Enrollment into the study during spring and summer reduced the likelihood of vitamin D deficiency. However, additional studies are needed to determine whether a daily dose of 400 IU would provide adequate supplementation to prevent vitamin D deficiency. These findings suggest that additional vitamin D supplementation, through diet, sunlight exposure, and/or vitamin D supplementation strategies, may be warranted for children with dark skin during winter and spring seasons in the United States. The data also raise questions regarding whether children at risk for 25-hydroxyvitamin D deficiency should undergo periodic measurement of 25-hydroxyvitamin D levels during the winter season, to guide supplementation.

WHAT'S KNOWN ON THIS SUBJECT

There is a resurgence of vitamin D deficiency among children in the United States, especially among black children who live at northern latitudes.

WHAT THIS STUDY ADDS

This study adds that the prevalence of vitamin D deficiency is high among low-income, minority, preschool-aged children living in the southeastern United States. Intake of vitamin D is below that recommended, and seasonal variation in vitamin D levels is present.

Abbreviations

OR	odds ratio
CI	confidence interval

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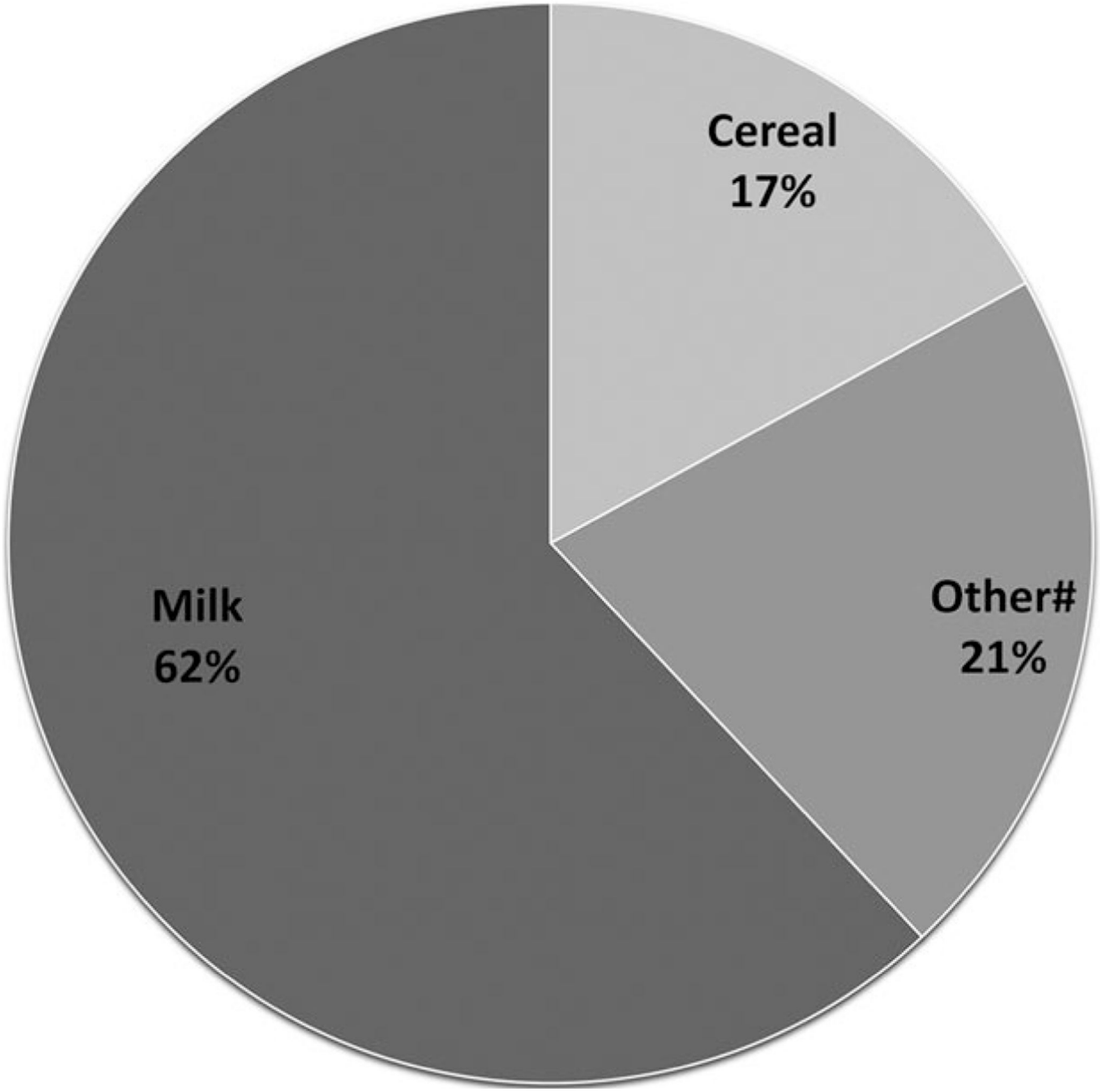

Figure 1.
Sources of dietary vitamin D estimated from 3–day food records (*N*=183). # Other includes the following food items: bread, cookies, eggs, fish (salmon, tuna, and mackerel), and fortified orange juice.

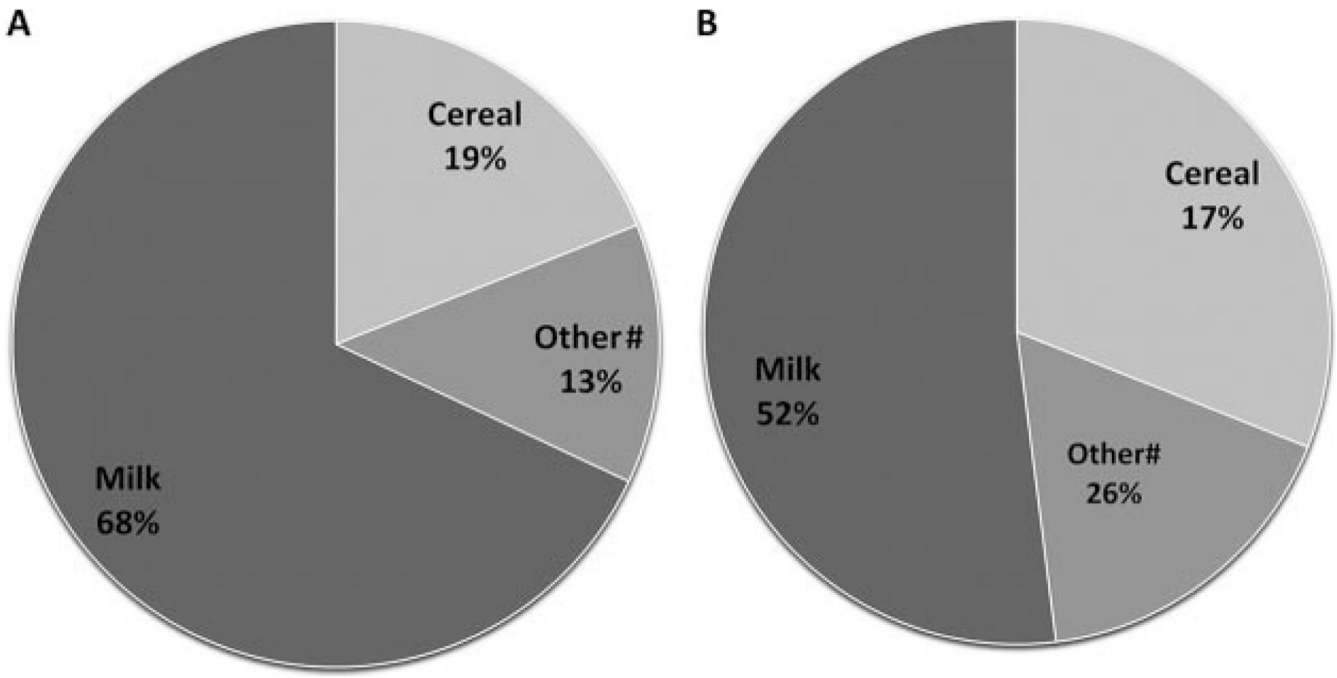

Figure 2.
Sources of dietary vitamin D calculated from the food records for Hispanic (nonblack) participants (N = 100) (A) and non-Hispanic black participants (N = 83) (B). # Other includes the following food items: bread, cookies, eggs, fish (salmon, tuna, and mackerel), and fortified orange juice.

TABLE 1

Characteristics of Participants

Characteristics	Hispanic (*N* = 141)	Non-Hispanic Black (*N* = 149)
Age, *n* (%)[a]		
1–2 y	52 (36.9)	65 (43.6)
2–3 y	26 (18.4)	49 (32.8)
3–4 y	37 (26.3)	16 (10.7)
4–5 y	26 (18.4)	19 (13.2)
Anthropometric measurements, mean ± SD[b]		
Height-for-age *z* score	−0.27±0.7	−0.16±1.1
Weight-for-age *z* score	0.14±1.3	−0.12±1.3
Gender, *n* (%)[c]		
Male	60 (42.6)	85 (57.1)
Female	81 (57.4)	64 (42.9)
Serum 25-hydroxyvitamin D_3 level (*N* = 264), *n* (%)[d]		
Deficient (≤20 ng/mL)	23 (18.1)	36 (26.3)
Nondeficient (>20 ng/mL)	104 (81.9)	101 (73.7)
Optimal (>30 ng/mL)	30 (23.6)	40 (29.2)
Less than optimal (≤30 ng/mL)	97 (76.4)	97 (70.8)
Serum calcium levels (*N* = 288), *n* (%)[e]		
Hypocalcemia (≤9 mg/dL)	2 (1.4)	2 (1.4)
Normal (>9 mg/dL)	138 (98.6)	146 (98.6)
Serum concentration, mean ± SD		
25-Hydroxyvitamin D, ng/mL	25.86±5.9	26.50±8.9
Calcium, mg/dL	9.85±0.4	9.77±0.6

To convert 25-hydroxyvitamin D levels to nanomoles per liter, multiply nanogram per milliter values by 2.496; to convert calcium levels to millimoles per liter, multiply milligram per deciliter values by 0.25.

[a] There was a significant difference in age distributions between the Hispanic and non-Hispanic black groups (χ^2 test, $P < .01$).

[b] There was no significant difference in height-for-age and weight-for-age *z* scores between the Hispanic and non-Hispanic black groups (independent *t* test, $P > .05$).

[c] There was a significantly larger proportion of boys in the non-Hispanic black group than in the Hispanic group (χ^2 test, $P < .05$) but a significantly larger proportion of girls in the Hispanic group than in the non-Hispanic black group (χ^2 test, $P < .05$).

[d] There was a statistically significant difference in the proportions of children with low serum 25-hydroxyvitamin D levels according to race/ethnicity (Fisher's exact test, $P = .03$) but no significant difference in the proportions of children with less-than-optimal serum 25-hydroxyvitamin D levels according to race/ethnicity (χ^2 test, $P > .05$).

[e] There was no difference in serum calcium concentrations ($P = .14$).

TABLE 2

Correlations Between Dietary and Serum Nutrient (25-hydroxy Vitamin D and Calcium) Levels

	Spearman's Correlation Coefficient	*P*
Serum 25-hydroxyvitamin D level (26.5 ± 7.5 ng/mL)		
Dietary vitamin D intake (174.6 ± 118.9 IU)	0.03	.53
Dietary calcium intake (727.4 ± 345.6 mg)	0.03	.56
Dietary fat intake (45.6 ± 25.1 g)	−0.10	.03
Serum calcium level (9.8 ± 0.5 mg/dL)		
Dietary vitamin D intake (174.6 ± 118.9 IU)	−0.03	.53
Dietary calcium intake (727.4 ± 345.6 mg)	−0.01	.74
Dietary fat intake (45.6 ± 25.1 g)	−0.13	<.01

TABLE 3

Multivariate Predictors of 25-Hydroxyvitamin D Deficiency and Low Serum Calcium Levels

Predictor	Low Serum Calcium Level (*N* = 290)		25-Hydroxyvitamin D Deficiency (*N* = 290)	
	OR (95% CI)[a]	*P*	OR (95% CI)[b]	*P*
Serum calcium level			0.96 (0.84–1.09)	.53
Serum 25-hydroxyvitamin D_3 level	1.00 (0.99–1.01)	.66		
Dietary calcium intake	1.00 (0.99–1.01)	.73	1.00 (0.99–1.01)	.08
Dietary vitamin D intake	1.01 (0.99–1.02)	.06	1.00 (0.97–1.03)	.98
Dietary fat intake	1.00 (0.99–1.01)	.45	0.98 (0.99–1.01)	.06
Season[c]				
Winter	0.97 (0.93–1.02)	.26	1.06 (0.92–1.24)	.42
Spring	0.96 (0.93–0.99)	.02	0.85 (0.73–0.98)	.04
Summer	0.97 (0.93–1.01)	.14	0.82 (0.73–0.92)	<.01
Autumn	Reference		Reference	
Age	0.99 (0.95–1.03)	.55	0.89 (0.81–0.96)	<.01
Gender				
Male	1.02 (0.95–1.01)	.09	1.11 (0.92–1.33)	.55
Female	Reference		Reference	
Race/ethnicity				
Non-Hispanic	1.01 (0.92–1.11)	.89	0.98 (0.78–1.25)	.52
Hispanic	Reference		Reference	
Height-for-age *z* score	1.04 (0.99–1.09)	.11	1.03 (0.92–1.16)	.61
Weight-for-age *z* score	0.98 (0.94–1.02)	.39	1.03 (0.93–1.13)	.60

[a] Odds of low serum calcium levels, defined as serum calcium levels of≤9 mg/dL (to convert to millimoles per liter, multiply by 0.25), compared with the reference category (for continuous predictors, increase in odds per unit predictor), from multivariate logistic regression analysis with PROC GENMOD, adjusted for all other predictors listed.

[b] Odds of vitamin D deficiency, defined as 25-hydroxyvitamin D levels of ≤20 ng/mL (to convert to nanomoles per liter, multiply by 2.496), compared with the reference category (for continuous predictors, increase in odds per unit predictor), from multivariate logistic regression analysis with PROC GENMOD, adjusted for all other predictors listed.

[c] Seasons were as follows: winter, December 21 to March 19; spring, March 20 to June 20; summer, June 21 to September 21; autumn, September 22 to December 20 (reference).