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Ethnic differences in food sources of vitamin D in adolescent American girls: The National Heart, Lung, and Blood Institute Growth and Health Study (NGHS)

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Abstract

The National Heart, Lung, and Blood Institute Growth and Health Study (NGHS) was a 10-year longitudinal study of the development of obesity and CVD risk factors (including dietary, psychosocial, environmental and others) in 2,379 African-American and white females who were 9 or 10 years old at study entry. Current studies have documented a high prevalence of vitamin D insufficiency among healthy children, adolescents and young adults in the United States, especially among low-income, black and Hispanic children (defined as serum 25-hydroxyvitamin D concentrations of ≤ 20 ng/mL). Although the main source of vitamin D is direct exposure of the skin to ultraviolet rays from sunlight, certain foods contribute vitamin D including fortified milk, meat, eggs, oils and fortified cereals. Vulnerable subgroups that are especially at risk of inadequate intakes of vitamin D, include teenage girls and women. Research providing the

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Conflict of interest

The funding organizations had no role in the design and conduct of the original study, nor collection, analysis or interpretation of these data.

Sandra Affenito, Sandra Affenito has received consultant fees from the Bell Institute of Health and Nutrition, General Mills, Inc.
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prevalent food sources of vitamin D, especially in the diets of both white and African American female adolescents is limited. The purpose of this study is to document food sources of vitamin D reported by this biracial young cohort and compare potential ethnic or other differences that could enhance tailored dietary interventions that are particularly relevant to this vulnerable population subgroup.

Keywords

dietary vitamin D; adolescents; ethnic differences; dietary intake in girls; children

1. Introduction

Vitamin D is essential for maintaining calcium homeostasis and skeletal integrity [1]. Growing evidence further documents a role for vitamin D in reducing risk of chronic diseases including some cancers [2–5], type 1 [6, 7] and type 2 diabetes mellitus [8], and multiple sclerosis [9, 10] Vitamin D may also be protective against cardiovascular disease [CVD] [1, 11–13] myocardial dysfunction [14], and hypertension in middle-aged and older women [15]. In children, vitamin D is especially important because of its vital role in bone mineralization [16, 17], insulin sensitivity in obese children and adolescents [18], and cardiac health [19]. Maintaining sufficient intake of vitamin D during teenage years is recommended to improve long-term health outcomes [19–22], but a high prevalence of vitamin D insufficiency has been reported among healthy children, adolescents and young adults in the United States [17, 19, 23–26], especially among certain subgroups.

Among low-income, black and Hispanic preschool children in Atlanta, prevalence of vitamin D deficiency (defined as serum 25-hydroxyvitamin D concentrations of ≤ 20 ng/mL) was 22% [27]. In a Boston clinic, 24.1% of adolescents [24] and 36% of young adults were found to be deficient in serum levels of 25-hydroxyvitamin D vitamin D [26]. According to National Health and Nutrition Examination Data (NHANES) 2001–2004 data, 9% of the pediatric population (7.6 million U.S. children and adolescents) was 25-hydroxyvitamin D deficient (< 15 ng/mL) and 61% (50.8 million U.S. children and adolescents) were insufficient (15–29 ng/mL) [19]. Updated 2003–2006 NHANES data report that 47 % and 53%, respectively, of adolescent girls and boys older than 9 years meet the Adequate Intake (AI) levels (5 mcg/d) [28]. The highest deficiency of vitamin D occurs among African-American girls, particularly in the winter [24, 29–31].

The main source of vitamin D is direct exposure of the skin to ultraviolet rays in sunlight [32]. Food sources include vitamin D-fortified milk, meat (especially fatty fish), eggs, oils and fortified cereals [33–36] and these play an especially important role for dark-pigmented individuals, whose skin has a lower rate of vitamin D formation per unit of exposure time than light-pigmented individuals [32, 37]. Lowest intakes of vitamin D (unadjusted for energy) occur among teenage girls and women [34]. Research documenting prevalent food sources of vitamin D in white and African American girls can help identify potential areas of needed education and intervention.

2. Methods and Materials

2.1. Participants and Recruitment

The National Heart, Lung, and Blood Institute Growth and Health Study (NGHS) was a 10-year longitudinal study of the development of obesity and CVD risk factors (including dietary, psychosocial, environmental and others) in 2,379 African-American and white females who were 9 or 10 years old at study entry [38]. Participants were recruited at three sites (University of California at Berkeley, University of Cincinnati/Cincinnati Children's Hospital Medical Center, and Westat, Inc./Group Health Association in Rockville, Maryland) from public and parochial schools or (in Maryland/DC only) from a membership listing of families enrolled in a large health maintenance organization and local Girl Scout troops. Eligible participants identified themselves (using census categories for race/ ethnicity) as "black" or "white," non-Hispanic, with racially concordant parents or guardians. All girls assented and their parents (or guardian) consented to their participation. In each race group, wide ranges of income (less than $10,000 to $75,000 or more) and educational levels (less than high school diploma to graduate degree) were represented (data not shown).

Due to variable annual participation rates, sample sizes varied from visit to visit. Retention rates (relative to the sample size of 2,379 at baseline) were very high at visits 2–4 [96%, 94%, 91%], declined to a low of 82% at visit 7, and increased to 89% at visit 10.

2.2. Measurements and Procedure

The NGHS procedures and measures have been reported elsewhere [38]. Briefly, data were collected annually at participating sites or, if the girl was unable to travel to the site, at her home. The protocol was approved by the Institutional Review Boards of all participating sites. Only instruments relevant to the present report are described and data from six annual visits (years 3, 4, 5, 7, 8 and 10) are reported here.

2.3. Food Diaries

Participants completed detailed food records at visits 1–5, 7, 8 and 10. Dietitians trained and certified by the University of Minnesota Nutrition Coordinating Center (NCC), and retrained in later years by staff at the Dietary Data Entry Center in Cincinnati, used age-appropriate materials to instruct girls to record all food and drink for 3 consecutive days (2 weekdays and 1 weekend day). Dietitians reviewed food records individually with the girls, using standard probes, labels and pictures to clarify incomplete responses and minimize default values. Food records were initially coded and analyzed for nutrients using Food Table Version 19 of the NCC nutrient database [38] and updated as the study progressed. Because rapid changes in vitamin D fortification have occurred more recently, these data may not have been completely represented in all cases and are specifically updated here. Diaries from visits 1 and 2 are excluded because foods were not measured in consistent quantities, but beginning in visit 3 and later, all food quantities were measured in grams.

2.4. Statistical Methods

Sources of vitamin D were analyzed as individual foods and as food categories (e.g., milk and milk products).

The proportion of group total vitamin D intake was calculated from each individual food by dividing the total vitamin D intake from reported foods for each girl and averaging this amount across girls. Supplemental vitamin D was excluded from this analysis. Sources of vitamin D from the major USDA food groups were assessed [39].

Using mixed models to adjust for repeated measures across time, vitamin D intake was examined in relationship to multiple participant characteristics to identify predictors of intake. Independent variables included demographic factors (race, parental education as an adjustment for socioeconomic status, two-parent household, and study site); eating patterns (total energy intake, breakfast eating, and family meals); BMI; and dieting (currently trying to lose weight and general frequency of dieting). Average daily vitamin D intake in

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micrograms was the dependent variable. All analyses were conducted using SAS version 9.1.3 [SAS Institute, Cary, NC].

3. Results

3.1. Food sources of vitamin D

Table 1 ranks the top 20 food sources of vitamin D as a percentage of total vitamin D intakes for all girls. This average does not refer to the vitamin D content of a standard serving size, but rather to the portions actually consumed by the girls as reported in their food diaries. Fortified milk (2% fat) contributed the greatest proportion of vitamin D to the diet of the "average girl" at all visits (Table 2). At visit 3, on average, girls obtained 24.1% of their food-based vitamin D intake from 2% milk but this declined over time to 15.6% at visit 10. Girls who drank 2% milk obtained an average of 83 IU (2.07) mcg of vitamin D per serving.

While many foods reported in the diaries contained some vitamin D, total vitamin D intake was highly concentrated in a very small number of foods. The top five foods alone contributed almost 50% of total vitamin D intake; the top ten foods, over 60%. Six varieties of fortified milk were in the top ten foods and contributed over 42% of all vitamin D.

As illustrated in Table 3, the meat and bean group (which includes fish sources rich in vitamin D) ranked second in contributing vitamin D across visits. The fats and oils category (including margarine, mayonnaise and salad dressing) was third, and its share of vitamin D intake increased steadily over time as milk drinking declined. Grains (mainly RTE vitamin-fortified cereals) were the fourth most important source across all visits.

3.2. Predictors of vitamin D intake

Parameter estimates and standard errors were calculated for predictors of vitamin D intake. As shown in Table 4. Energy intake [average calories per day] was significantly related to increased vitamin D intake such that for every 100 additional calories consumed, vitamin D intake increased by 7.2 IU (0.18 mcg per day) [0.072*100]. The single strongest predictor was race, with white girls consuming significantly more vitamin D than African-American girls. The effect of breakfast consumption was an increase of 18 IU (0.45 mcg) per day; this effect is independent of total calories consumed, which is a separate term in the model. Visit (a marker for age), and the interaction of race and visit were also significant. Average vitamin D consumption decreased over time, and the racial gap in vitamin D consumption narrowed (the difference was 39.2 IU [0.98mcg] per day at Visit 3, but 26.8 IU [0.67mcg] per day at Visit 10).

3.3. Ethnic differences in individual foods and food categories as sources of vitamin D

African-American girls consistently consumed more vitamin D from the meats and beans group (mainly fish and some meats) than did the white girls, consuming nearly twice of these foods at some visits. They also consistently obtained more vitamin D from fats and oils than white girls did, although both groups showed increases over time. There were significant race effects for all food categories except grains, which had a significant race-visit interaction. Among the top 10 individual food sources of vitamin D (as a percent of all vitamin D intake), racial differences were especially salient for types of fortified milk (Table 5). White girls increasingly selected lower-fat varieties of fortified milk as they aged, while African-American girls consistently chose higher-fat varieties throughout adolescence.

3.4.. Supplements as a source of vitamin D

Vitamin supplement use was not collected consistently at visits 3 and 4 but was assessed in visits 5, 7, 8, and 10. Relatively few girls, ranging from 10.3% at visit 5 to a low of 7.0% at visit 8, reported using supplements containing vitamin D. Girls who reported taking supplements obtained more than half of their vitamin D intake from this source. To explore this, vitamin D intake was recalculated as the sum of dietary and supplementary vitamin D. Supplements contributed between 57.5% (at visit 8) and 62.2% (at visit 10) of total vitamin D intake among those who reported using them. When averaged across *all* girls in the study, supplements contributed 4–6% of total vitamin D consumed by the entire sample, with relatively few girls reporting supplement use at any visit and white girls being 2.5 times more likely to obtain vitamin D from supplements than black girls at the final visit.

4. Discussion

This study reports food sources of vitamin D among a large sample of African-American and white girls (ages 9–18) during 1987–1997 and the characteristics of girls that predicted individual differences in total daily vitamin D intake. Overall, total vitamin D intake was highly concentrated in milk and dairy products and fortified foods. There were age- and race-related differences in food sources of vitamin D with lower Vitamin D consumption by African-American girls at all visits. Breakfast consumption predicted higher vitamin D intake among all groups.

Very few foods contain vitamin D in its natural form and those that are the richest natural source of vitamin D (fatty fish and its oil) [33] are not frequently consumed [40], thus fortified foods (milk, margarine, cereals) can assist with vitamin D intake [33, 35, 36]. In the NGHS, fortified milk and milk products were the most common food sources of vitamin D; milk provided over 42% of all vitamin D at all visits. These findings are in accord with national data [16, 34, 36, 41, 42] demonstrating the important contribution of fortified milk to vitamin D intake in adolescence.

Meats (primarily fatty fish, pork) and beans (meat alternatives) provided the distant second richest supply of vitamin D, across all NGHS visits. Consistent with past research [43, 44] naturally rich sources of vitamin D in the meat and beans group (particularly fatty fish) were consumed by a small percentage of girls in the NGHS.

RTE fortified cereal, combining all brands, contributed approximately 9% of the mean vitamin D intake in the NGHS, comparable with the 5%–10% documented by the 1999–2000 National Health and Nutrition Examination Survey (NHANES) [34]. Since milk and RTE cereal are often consumed together, these foods provide over half of the vitamin D intake from foods. Previous studies reported that for both African-American and white females [24, 37], consumption of fortified food sources of vitamin D [milk and cereal] was associated reduced the occurrence of vitamin D insufficiency.

Ethnicity, breakfast consumption, age (represented by visit), and energy intake were factors that predicted differences in total vitamin D intake in girls in the NGHS. The current and previous NGHS findings [45] add to the growing evidence that racial disparities exist in vitamin D intake [31, 34, 46]. In agreement with past studies [37, 41, 47] African American girls consumed less fortified milk compared with their white counterparts, perhaps partly attributed to lactose intolerance known to be common in this ethnic group [31, 43]. White girls more often consumed lower-fat milks whereas African-American girls more often obtained vitamin D from higher fat milks, higher fat meats and meat alternatives (sausage, ground beef, eggs), and margarine. Improving vitamin D intake from low saturated fat and cholesterol sources, especially lowfat/nonfat milk, dairy products and possibly other fortified foods such as margarine and soymilk, may be especially helpful [44] among African Americans who are at higher cardiovascular risk but often avoid these foods [48, 49].

All girls reduced milk and dairy intake with age, suggested as possibly being associated with decreased family influence on dietary habits [50, 51]. Milk is increasingly displaced with soft drinks, fruit juices, and/or fruit drinks as children age [52–54]. Increased frequency of breakfast skipping also occurs in adolescence [55–57], especially among African-American girls [55, 58].

Few girls in NGHS used supplements and their use decreased over time ranging from approximately 10% to 7% from mid- to late-adolescence, respectively. Approximately one-third of adolescent girls in the 1999–2000 National Health and Nutrition Examination Survey and one-quarter of the 2,761 adolescents surveyed in the 2001–2002 Child and Adolescent Trial for Cardiovascular Health Study [59] reported using multi-vitamin, multi-mineral supplements Whether supplements should be recommended to improve vitamin D insufficiency requires further investigation.

Study limitations include the absence of data regarding sunlight exposure and the self-reported dietary intake data subject to recall errors and underreporting [60]. Also NGHS did not report serum levels of 25-hydroxyvitamin D that could further help to differentiate bioavailability of these self-reported dietary sources.

Strengths, including the longitudinal nature of this study, a high follow-up rate and detailed dietary intake data enhance the value of this study. Diet assessment was performed by trained and certified dietitians using validated three-day food records, including a weekend day and two week days. The longitudinal study design reduces both between and within-subject variability and implicitly controlled the seasonal component of dietary intake [61], because recruitment into the study and dietary recall collection occurred throughout the year.

Findings from the National Heart, Lung and Blood Institute Growth and Health Study document that milk and dairy products provided the majority of vitamin D intake with sources differing by race. African-American girls [33, 62] reported a significantly lower intake of vitamin D from both food sources and supplements, compared with white girls. Given the important function of vitamin D in skeletal health and its emerging role in the prevention of chronic diseases [32, 63], food and nutrition professionals should renew efforts to educate adolescents, especially African Americans, to consume a healthful diet by choosing a wide variety of nutrient-dense foods and beverages, especially those that provide vitamin D.

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Abbreviations

NGHS	National Heart, Lung and Blood Institute Growth and Health Study
RTE	Ready to Eat

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Table 1

Top 20 food sources of vitamin D [mean percent of vitamin D intake] in the National Heart, Lung and Blood Institute Growth and Health Study.

		Vitamin D		VISIT					
NCC Food Name	**Total %**	**IU (mcg)/serving**	**Overall rank**	**3**	**4**	**5**	**7**	**8**	**10**
Milk, 2% fat	19.5	82.8 [2.07]	1	24.1	20.8	18.9	18.6	18.1	15.6
Milk, whole	9.4	81.2 [2.03]	2	9.6	9.8	9.9	9.1	9.0	9.0
Margarine, stick, brand unknown	7.6	37.7 [0.94]	3	7.4	7.1	6.8	7.3	7.3	9.3
Egg, whole	5.5	14.0 [0.35]	4	5.0	4.5	5.4	5.6	5.7	6.9
Milk, skim	5.4	100.0 [2.50]	5	4.0	5.0	4.7	5.8	5.9	7.2
Sausage, pork	3.2	30.0 [0.75]	6	3.4	3.2	4.3	3.1	3.1	2.3
Milk, 1%	3.1	105.2 [2.63]	7	1.0	3.0	3.7	3.9	4.0	3.3
Ground beef, regular	2.9	8.4 [0.21]	8	2.4	2.4	2.8	3.4	3.7	2.8
Chocolate milk, 2% fat	2.5	110.0 [2.75]	9	5.2	3.3	2.4	1.7	1.6	0.4
Milk, % fat unknown	2.4	10.0 [0.25]	10	2.4	2.4	2.5	2.2	2.4	2.5
Fish, total omega-3 <10% [e.g., flatfish]	1.5	63.2 [1.58]	11	1.7	1.5	1.7	1.0	1.2	1.5
Frankfurter, beef and pork	1.3	25.2 [0.63]	12	1.5	1.6	1.3	1.3	1.0	0.9
Tuna, canned, water packed	1.3	154.0 [3.85]	13	0.8	1.1	1.1	1.2	1.4	2.0
Cereals, dry, frosted flakes	1.2	105.2 [2.63]	14	1.3	1.3	1.2	1.5	1.0	1.2
Shrimp, cooked, w/o salt	1.0	50.8 [1.27]	15	0.8	1.0	0.8	1.2	1.0	1.2
Margarine, stick or tub, 80% fat	1.0	42.8 [1.07]	16	0.8	0.9	1.2	1.0	0.6	1.2
Tuna, canned, oil packed	0.8	132.0 [3.30]	17	1.2	1.0	0.7	0.7	0.8	0.5
Chocolate milk, 1% fat	0.8	102.4 [2.56]	18	1.6	1.2	1.0	0.3	0.3	0.2
Cereals, dry, corn flakes	0.4	78.4 [1.96]	19	0.9	0.8	0.6	0	0	0
Fish, total omega-3 <10% [e.g., mullet]	0.4	523.2 [13.08]	20	0.7	0.6	0.7	0.1	0.1	0.1

Note: “Serving” refers to the average portion of each food actually reported in the food diaries, rather than standard serving sizes

Table 2

Proportion of dietary vitamin D intake contributed by food categories (mean percent of vitamin D intake) in the National Heart, Lung and Blood Institute Growth and Health Study.

Food category	Visit 3	Visit 4	Visit 5	Visit 7	Visit 8	Visit 10
Milk	51.0	48.9	47.0	45.3	45.2	42.2
Meat and Beans	20.0	19.8	21.6	19.8	20.2	20.7
Fats &Oils	14.2	15.4	16.5	17.9	17.7	19.9
Grains	10.0	10.4	9.4	10.8	11.2	11.8
RTE cereals [subset of grains]	9.2	9.3	8.3	9.0	8.6	9.6
Sweets and desserts	3.6	3.9	3.8	5.5	5.0	4.8
Miscellaneous	1.2	1.6	1.6	0.6	0.6	0.6

Note: Numbers do not add to 100% within each column due to rounding and to the inclusion of RTE cereal [a subset of the grains category].

Table 3

Parameter estimates for predictors of total vitamin D intake in the National Heart, Lung and Blood Institute Growth and Health Study.

Effect	Parameter estimates [IU/day of Vitamin D]	Statistical Significance
Race (race=White is reference group)	56.30	p<.0001
Visit	−6.88	p<.0001
Race*Visit	−2.64	p=.014
Breakfast consumption	18.00	p<.0001
Energy (average calories per day)	0.072	p<.0001
Dieting frequency	−2.60	p=.274
Parental education	−4.44	p=.189
Site (site=3 is reference group)	−7.56 [site 1], −8.36 [site 2]	p=.069

Table 4

Percentage of total vitamin D intake from food categories, by race, among girls in the National Heart, Lung and Blood Institute Growth and Health Study.

Whites	Visit 3	Visit 4	Visit 5	Visit 7	Visit 8	Visit 10
Milk	58.9	57.2	56.7	53.2	52.6	49.4
Meat and Beans	14.1	13.6	14.1	13.3	14.3	14.4
Fats &Oils	13.2	14.1	15.1	17.0	15.7	18.0
Grains	9.8	10.4	9.5	10.5	11.8	12.5
RTE cereals (subset of grains)	9.0	9.4	8.3	8.8	9.0	10.2
Sweets and desserts	3.3	3.8	3.6	5.2	4.8	5.0
Miscellaneous	0.8	1.0	1.1	0.8	0.7	0.7
African-Americans						
Milk	43.5	41.1	37.8	37.5	38.7	35.5
Meat and Beans	25.7	25.6	28.6	26.2	25.6	26.6
Fats &Oils	15.0	16.6	17.8	18.7	19.4	21.7
Grains	10.3	10.5	9.4	11.1	10.8	11.1
RTE cereals (subset of grains)	9.5	9.4	8.5	9.0	8.3	9.1
Sweets and desserts	3.9	4.1	4.1	6.0	5.1	4.6
Miscellaneous	1.5	2.1	2.2	0.5	0.5	0.5

Note: Numbers do not add to 100% by race within each column due to rounding and to the inclusion of RTE cereal [a subset of the grains category].

Table 5

Percentage of total vitamin D intake from top 10 individual food sources, by race [mean and standard deviation] among girls in the National Growth and Health Study.

Food source	Group	Visit 3	Visit 4	Visit 5	Visit 7	Visit 8	Visit 10
Milk, whole	Whites	7.4[17.3]	6.4[16.8]	6.5[17.2]	4.9[15.9]	5.5[16.9]	5.5[16.0]
	African Americans	11.1[18.6]	13.0[19.9]	13.0[21.1]	12.8[22.3]	12.1[21.3]	12.2[21.0]
Milk, 2%	Whites	31.9 [27.5]	27.6 [27.5]	25.1 [28.6]	23.4 [28.9]	20.7 [27.2]	17.8 [25.1]
	African Americans	16.7 [21.5]	14.4 [21.5]	13.2 [20.6]	13.8 [21.1]	15.7 [23.3]	13.6 [21.4]
Milk, 1%	Whites	1.7 [8.9]	5.4 [16.0]	7.2 [18.9]	7.0 [19.3]	7.0 [19.1]	5.6 [17.1]
	African Americans	0.4 [3.8]	0.8 [6.1]	0.4 [4.2]	1.0 [7.6]	1.2 [8.0]	1.3 [7.8]
Milk, skim	Whites	6.4 [17.5]	8.1 [20.3]	8.1 [19.9]	10.3 [22.4]	10.6 [22.8]	13.1 [24.4]
	African Americans	1.8 [8.3]	2.2 [10.0]	1.5 [7.8]	1.5 [7.9]	1.6 [7.9]	1.8 [9.1]
Milk, % unknown	Whites	1.8 [3.3]	1.8 [3.6]	2.1 [4.8]	1.8 [4.4]	1.9 [5.8]	5.6 [17.1]
	African Americans	2.9 [5.4]	3.0 [6.1]	2.8 [5.1]	2.7 [5.5]	2.9 [6.4]	3.0 [6.5]
Chocolate milk, 2%	Whites	5.0 [12.0]	3.4 [10.1]	2.9 [10.3]	1.5 [7.8]	1.4 [7.2]	0.4 [4.4]
	African Americans	5.3 [13.1]	3.2 [11.1]	2.0 [9.0]	2.0 [9.5]	1.7 [9.3]	0.3 [3.2]
Ground beef	Whites	1.7 [3.9]	1.7 [4.6]	1.7 [5.0]	2.2 [5.6]	2.7 [7.7]	2.1 [6.8]
	African Americans	3.1 [7.4]	3.1 [5.9]	3.9 [7.4]	4.5 [8.6]	4.6 [9.4]	3.6 [8.1]
Pork sausage	Whites	2.1 [5.6]	1.8 [5.0]	2.4 [6.6]	1.6 [5.4]	1.8 [6.7]	1.4 [5.5]
	African Americans	4.6 [10.1]	4.5 [10.1]	6.0 [12.8]	4.6 [9.4]	4.3 [9.5]	3.2 [8.6]
Whole eggs	Whites	3.7 [5.9]	3.3 [6.4]	3.9 [7.0]	3.9 [7.6]	3.8 [7.3]	5.0 [9.6]
	African Americans	6.2 [9.0]	5.7 [8.7]	6.7 [10.8]	4.3 [9.5]	7.4 [11.4]	8.6 [12.0]
Margarine	Whites	6.2 [10.1]	5.4 [9.9]	5.7 [11.2]	6.7 [12.3]	6.8 [12.8]	8.1 [14.3]
	African Americans	8.6 [13.4]	8.7 [14.6]	7.7 [14.1]	7.6 [14.5]	7.7 [13.7]	10.5 [16.2]