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The Relationships between Sugar-Sweetened Beverage Intake and Cardiometabolic Markers in Young Children

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Abstract

Background—The consumption of sugar-sweetened beverages has been implicated as a major contributor to the development of obesity and cardiometabolic disease.

Objective—To evaluate the relationships between sugar-sweetened beverage intake and cardiometabolic markers in young children.

Design—A cross-sectional analysis of the National Health and Nutrition Examination Survey data collected by the National Center for Health Statistics.

Participants—A total of 4,880 individuals aged 3 to 11 years from nationally representative samples of US children participating in the National Health and Nutrition Examination Survey during 1999-2004 were studied.

Main outcome measures—Concentrations of total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, triglyceride, and C-reactive protein as well as waist circumference and body mass index percentile for age–sex.

Statistical analyses performed—Multivariate linear regression analyses were performed to determine independent associations between each outcome variable and the number of serving equivalents of sugar-sweetened beverages consumed after adjusting for age, sex, race, poverty status, physical activity, and energy intake.

Results—Increased sugar-sweetened beverage intake was independently associated with increased C-reactive protein concentrations (*P*=0.003), increased waist circumference (*P*=0.04),

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST
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and decreased high-density lipoprotein cholesterol concentrations (*P*=0.001). Subgroup analyses demonstrated differences in the association of sugar-sweetened beverage intake with metabolic markers and anthropometric measurements among age ranges, sex, and racial/ethnic groups.

Conclusions—In this cross-sectional analysis of children's dietary data, sugar-sweetened beverage intake was independently associated with alterations in lipid profiles, increased markers of inflammation, and increased waist circumference in children. Prospective studies are needed, but awareness of these trends is essential in combating the growing metabolic and cardiovascular disease burden in the pediatric population.

Keywords

Sugar-sweetened beverage; Epidemiology; Lipids; Nutrition

The increase in obesity prevalence during recent decades has emerged as one of the world's foremost public health problems. In the US pediatric population alone, approximately one third of children and adolescents are overweight (defined as being at or above the 85th percentile of body mass index [BMI] for age and sex)[1] and, thus, potentially at increased risk for future cardiometabolic disease.[2]

Importantly, increased consumption of sugar-sweetened beverages (SSBs) appears to be a major contributor to the obesity epidemic. The rise in SSB intake in the United States has paralleled the obesity trend, and from the late 1970s to 2001, Americans increased their average daily SSB intake by 135%.[3] In the pediatric population, the increase in SSB consumption has paralleled the rise in childhood obesity as well,[4] and the percentage of total daily energy intake from SSBs has more than doubled from 4.8% to 10.3%[3]; children and adolescents today consume ~175 kcal/day from SSBs.[5] Furthermore, SSBs—including sodas, fruit drinks, sport drinks, energy drinks, chocolate milk, and vitamin water—are the largest single source of added sugar in American diets.[6]

Unfortunately, the increase in SSB intake in the pediatric population has been associated with childhood obesity,[7-10] hypertension,[11] dyslipidemia,[12] BMI, and waist circumference,[13] as well as other insulin resistance-associated parameters.[14] The cardiometabolic effects of SSBs in children also appear to differ between the sexes and among racial groups.[15] Studies evaluating the effects of macronutrient intakes on high-BMI African-American children in particular have shown that increases in carbohydrate energy, especially in the form of sugar, may be detrimental to cardiometabolic health.[16,17] Moreover, a higher intake of SSBs in children is associated with poor overall dietary choices.[13]

Although studies examining the effects of SSBs in adolescents continue to emerge, little has been reported on the effects of SSB intake in younger children. This is a significant shortcoming given that the rate of increased SSB consumption in the pediatric population during the past 2 decades has been greatest in children aged 6 to 11 years,[18] placing the preadolescent pediatric population at potential risk for cardiovascular and metabolic disease as well. We therefore examined the relationship between SSB intake and cardiometabolic markers in children aged 3 to 11 years using data from the National Health and Nutrition Examination Survey (NHANES) collected from 1999-2004.

METHODS

Study Design and Population

The NHANES is conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention and since 1999 has been performed as a continuous annual series of cross-sectional surveys designed to monitor the health and nutritional status of the US civilian, noninstitutionalized population. Since 1999, the NHANES data have been released in 2-year increments; a nationally representative sample is selected annually using a multistage probability cluster sample design. The NHANES protocol was approved by the National Center for Health Statistics Institutional Review Board, and written informed assent was obtained for participants younger than age 18 years in addition to parent or guardian consent. This study was also approved by the Institutional Review Board at Vanderbilt University.

Subjects and Data Collection

The NHANES protocol consists of a home interview performed by a trained interviewer, followed by a visit to an examination center where participants undergo a physical examination, provide blood and urine samples, and complete questionnaires. The details of the participant examination and laboratory assessments are available on the NHANES website.[19] For our study, we evaluated blood total cholesterol, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, triglyceride, and C-reactive protein (CRP) concentrations, as well as waist circumference and BMI. Given our interest in determining the relationships between SSB intake and cardiometabolic markers in young children, we specifically chose to study the data available for children younger than age 12 years. However, after 2004, complete lipid panels were not performed in children younger than age 12 years. Thus, we only utilized data obtained from NHANES 1999-2000, 2001-2002, and 2003-2004 because these were the most recently available NHANES data sets that had complete lipid profiles available for our target population. Individuals were excluded from analysis if they were pregnant and/or used antihyperlipidemic medications, steroids, blood glucose regulators, insulin, other antidiabetes agents, growth hor mone, or sex hormones. Subjects were classified as non-Hispanic white, non-Hispanic black, Mexican American, and other race/ethnicity (including “Other/Multiracial” and “Other/ Hispanic”) based on information derived from the NHANES questionnaire. Given the low number of NHANES participants in the “Other/Multiracial” (n=228) and “Other/Hispanic” (n=225) categories, subjects from these race/ethnicity groups were excluded from the subgroup analyses; thus, only the non-Hispanic white, non-Hispanic black, and Mexican American participants were included in the race/ethnicity-based subgroup analyses.

Measurements

Outcome variables included total cholesterol levels, HDL cholesterol levels, LDL cholesterol levels, triglyceride levels, CRP levels, waist circumference, and BMI percentile for age–sex (per NCHS references).[20] LDL cholesterol and triglyceride results are limited to those who had completed at least an 8-hour fast. Mean waist circumference is presented as the least squares mean controlling for age and sex. In brief, total cholesterol levels were measured enzymatically in serum in a series of coupled reactions that hydrolyze cholesteryl esters. HDL cholesterol levels were measured using two methods, heparin-manganese precipitation and a direct HDL cholesterol immunoassay, depending on the subject age and specimen amount. The potential bias between the two procedures in 2003-2004 was acceptable (<4%); however, HDL cholesterol data from 1999-2000 and 2001-2002 were adjusted by the Centers for Disease Control and Prevention using the following formula: corrected HDL cholesterol=[(Solomon Park assigned HDL cholesterol value)×(participant HDL cholesterol)]/ (quality control HDL cholesterol value associated with participant sample).[19] Triglyceride levels were determined using a series of enzymatic reactions producing glycerol and then hydrogen peroxide. LDL cholesterol levels were calculated using the Friedewald calculation: (LDL cholesterol)=(total cholesterol)– (HDL-cholesterol)–(triglyceride/5).[21] CRP concentrations were quantified by latex-enhanced nephelometry. BMI was assessed with standardized protocols for each body composition measurement. Height was measured in an upright position with a stadiometer; weight was measured in a standing position on a self-zeroing scale; waist circumference was measured at the midpoint between the bottom of the rib cage and above the top of the iliac crest.

Definitions

SSB information was obtained through a 24-hour dietary recall interview. In NHANES 2003-2004, the 24-hour recall was assessed on two separate interviews; the first was an in-person interview comparable to the previous NHANES study periods primary interview mode, whereas the second was a telephone interview 3 to 10 days later. For consistency in the methodology of data collection, only the first day of the NHANES 2003-2004 24-hour recall was used in our analyses. SSBs were defined as energy-containing soft drinks, colas, sugar-sweetened fruit drinks, or other sugar-sweetened beverages; as in our previous studies, pure fruit juices and diet soft drinks were not included.[14,15] SSB intake in grams for each reported beverage was divided by 250 g (a serving equivalent; approximately 8 oz or 1 cup beverage) and summed for each child. In each NHANES data set analyzed, low SSB intake was defined as the lowest quintile (≤20th percentile) of the sum of the number of SSB serving equivalents a subject consumed per day; medium was defined as the second to fourth quintiles (>20th to <80th percentile); high was defined as the highest quintile (≥80th percentile). Because approximately 25% of our study population had no SSB intake, the lowest quintile was adjusted to include all non-SSB consumers. As such, the term “non-SSB consumers” is used throughout the text instead of “low-SSB consumers.” The units of SSB intake are defined as the number of SSB serving equivalents per day. Physical activity was determined by the number of times per week a child played or exercised enough to sweat and breathe hard; the daily energy intake was determined by the amount of total energy consumption (in kilocalories) per day; and poverty status was determined by the poverty income ratio; that is, the ratio of household income to the poverty threshold after accounting for inflation and family size.[19]

Statistical Analysis

Statistical analyses were performed with SUDAAN, version 10.0 (2008, Research Triangle Institute) using techniques appropriate for the complex NHANES survey design. All of the analyses used the NHANES-provided sampling weights that were calculated to take into account unequal probabilities of selection resulting from the sample design, nonresponse, and planned over-sampling of selected subgroups, so that the results are representative of the US community-dwelling population. Dietary variables were analyzed as continuous variables and in quin-tiles to minimize the chance that a small number of extreme observations would have undue influence on the results. Descriptive statistics summarize the data and are expressed as the mean±standard error. Multivariate linear regression analyses were performed using SSB consumption as a contin uous exposure to determine independent associations between each outcome variable and the number of serving equivalents of SSBs consumed after adjusting for age, sex, race, poverty status, physical activity, and energy intake. Subgroup analyses were performed based on age ranges (age 3 to 5 years, 6 to 8 years, and 9 to 11 years), sex (boy and girl), and race/ethnicity (non-Hispanic white, non-Hispanic black, and Mexican American). All *P* values are two-sided and statistical significance was established a priori at α=.05.

RESULTS

Sample Characteristics

The characteristics of the study participants are provided in Table 1. A total of 4,880 children aged 3 to 11 years were analyzed. The mean age of the participants was 6.9 years, 50.7% were boys, 49.3% were girls, 32.1% were between ages 3 and 5 years, 35% were between ages 6 and 8 years, and 32.9% were between ages 9 and 11 years. The racial/ethnic distribution of the participants was 59% non-Hispanic white, 14.8% non-Hispanic black, 13.1% Mexican American, and 13% other races (including other/hispanic and other/ multiracial subjects). All three SSB consumption groups (ie, non-SSB consumers, medium-SSB consumers, and high-SSB consumers) differed in the number of children aged 3 to 5 years and 9 to 11 years that comprised their samples ($P<0.05$), and the high-SSB intake group was composed of more boys than the other two groups ($P<0.01$).

Relationships between SSB Intake with Cardiometabolic Markers

The characteristics of the non-SSB consumers, medium-SSB consumers, and high-SSB consumers along with the results of the adjusted multivariate linear regression analyses evaluating the associations between SSB intake and lipid levels, CRP, and anthropometric measurements are shown in Table 2. The non-SSB consumers did not consume any SSB serving equivalents per day, the medium-SSB intake group consumed a mean of 1.48±0.70 SSB serving equivalents (~11.84 oz) per day (range=0.01 to 2.89 oz [~0.08 to 23.12 oz]), and the high-SSB intake group consumed a mean of 4.39±1.71 SSB serving equivalents (~35.12 oz) per day (range=2.90 to 16.92 oz [~23.22 to 135.33 oz]). Higher SSB intake in children was significantly associated with increased CRP concentrations and waist circumference, whereas higher SSB intake was inversely associated with HDL cholesterol levels. The association between BMI percentile and SSB intake approached statistical significance (P=0.07), whereas no significant associations were found between SSB intake

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and total cholesterol, LDL cholesterol, and triglyceride concentrations. In summary, each additional SSB serving equivalent consumed per day was associated with a 0.01 mg/dL (0.85 nmol/L) increase in CRP levels, a 0.27 cm increase in waist circumference, and a 0.57 mg/dL (0.015 mmol/L) decrease in HDL cholesterol levels after adjustment for age, sex, race, physical activity, energy intake, and poverty status.

Age-Specific Subgroup Analyses

Because we suspected the quantity of SSB intake may vary depending on the subject age, multivariate linear regression models assessing SSB intake and lipid levels, CRP, and anthropometric measurements were also stratified by age (see Table 3). In the 9- to 11-year-old subgroup, HDL cholesterol levels, CRP levels, and waist circumference maintained significant associations with SSB intake. In addition, the association between SSB intake and BMI percentile was significant in the 9-to 11-year-old subgroup. However, among the 3- to 5-year-old and 6- to 8-year-old age groups, no associations reached significance with the exception of a positive association between SSB intake and LDL cholesterol levels in the 3- to 5-year-old age group.

Sex-Specific Subgroup Analyses

The results were also stratified by sex as shown in Table 4. In both boys and girls, significant inverse associations between SSB intake and HDL cholesterol levels were seen, as were significant positive associations between SSB intake and CRP levels. In addition, SSB intake was positively associated with LDL cholesterol levels in girls but not boys. No significant associations were found between SSB intake and total cholesterol levels, triglyceride levels, waist circumference, or BMI percentile.

Racial/Ethnic Group-Specific Subgroup Analyses

When the data were stratified by race/ethnicity (Table 5), a significant inverse association was found between SSB intake and HDL cholesterol concentrations in both the non-Hispanic white population and the non-Hispanic black population. Moreover, in the non-Hispanic black population, significant positive associations were found between SSB intake and triglyceride concentrations and CRP levels.

DISCUSSION

In this large, nationally representative sample of US children, we found significant associations between SSB intake and lipid levels, markers of inflammation, and anthropometric measurements. Specifically, multivariate linear regression analyses demonstrated that SSB intake in children aged 3 to 11 years is independently associated with HDL cholesterol levels, CRP concentrations, and waist circumference.

Subgroup analyses by age suggest that the positive associations between SSB intake and HDL cholesterol levels, CRP concentrations, and waist circumference are driven largely by the 9- to 11-year-old age group, which is consistent with our finding that the 9- to 11-year-old age subgroup is the largest consumer of SSBs in these younger children. Subgroup analyses by sex showed that the association between SSB intake and CRP and HDL cholesterol levels remained positive in both boys and girls, but that a significant association also exists between SSB intake and LDL cholesterol levels in girls. Subgroup analyses by race/ethnicity demonstrated a significant inverse association between SSB intake and HDL cholesterol concentrations in both the non-Hispanic white population and the non-Hispanic black population, findings supported by other previous studies of pediatric populations.[15,17] Further more, in the non-Hispanic black population, significant positive associations were found between SSB intake and triglyceride and CRP concentrations. These findings complement our previous study demonstrating differing relationships between SSB intake with metabolic markers and anthropometric measurements among racial groups and between the sexes,[15] and reinforce the importance of race/ethnicity and sex in the investigation of diseases such as obesity and metabolic syndrome.

Importantly, our results indicate that the intake of SSBs in children aged 3 to 11 years is positively associated with known cardiovascular disease risk factors. First, alterations in lipoprotein profiles in children, including the presence of lower HDL cholesterol and higher LDL cholesterol levels, have been found to correlate with coronary artery and aortic atherosclerosis[22] and have been shown to place affected children at risk for the persistence of dyslipidemia into adulthood.[23] In our study, we found significant associations between SSB in-take and alterations in LDL cholesterol levels in female participants and very young children (aged 3 to 5 years) and HDL cholesterol levels in the entire study population, suggesting an altered state of lipoprotein metabolism. Although other traditional markers of dyslipidemia like alterations in triglyceride and total cholesterol concentrations were not significantly associated with SSB intake in this study, this is not necessarily surprising given that diet-induced dyslipidemias may take many years to develop and, thus, the young age of the study participants may preclude these findings. Second, inflammation is known to play a central role in the pathogenesis of atherosclerosis.[24] CRP is an acute phase reactant that has been shown to be a reliable marker of systemic inflammation and a predictor of future cardiovascular events,[25] and in our study was positively associated with SSB intake, suggesting a proinflammatory state. Third, we found that SSB intake was significantly associated with an increased waist circumference. A high waist circumference in childhood has been strongly associated with visceral adiposity[26] and has been found to place children at higher risk for dyslipidemia and insulin resistance.[27] In fact, in high-BMI African-American children, waist circumference is a stronger predictor for lipo-protein variables and blood pressure than other anthropo-metric indexes.[28] Furthermore, a high waist circumference in childhood is a strong predictor for subsequent development of metabolic syndrome in early adulthood.[29]

SSBs are thought to cause adverse cardiovascular and metabolic effects through several mechanisms. The high sugar content of SSBs and incomplete compensatory reduction in energy intake at future meals often leads to net positive energy balance and subsequent obesity over time.[30] Moreover, the rapidly absorbable sugars in SSBs lead to a high dietary glycemic load, which is associated with inflammation, insulin resistance, and increased cardiovascular risk.[31,32] Of great importance to pediatric health care providers, the results of this study suggest that the proposed dysmetabolic effects of SSBs may be manifesting themselves in even the youngest consumers.

In accordance with our previous study, subgroup analyses demonstrated differences in the association of SSB in-take with metabolic markers and anthropometric measurements among age ranges, sexes, and racial/ethnic groups.[15] Although a detailed investigation into the reasons for these differences is beyond the scope of this study, they are not necessarily surprising given the multifactorial nature of diet-associated metabolic conditions (including genetics and the physical environment) and the disparities observed in obesity across sex, age, socioeconomic status, and racial/ethnic groups.[33]

There are several reasons why the results of this study may not be as robust as similar previous studies in adolescents and adults. First, the sample sizes—particularly in the subgroup analyses—may not have been adequate to determine the slight metabolic changes that we would expect to find in young children. Second, the composition of SSBs consumed by the 3- to 11-year-old population is different than older age groups. Specifically, less than half of SSBs consumed by 2- to 11-year-olds are soda whereas approximately two thirds of SSBs consumed by 12- to 18-year-olds are soda.[18] Because a greater proportion of SSB consumption in children aged 3 to 11 years is fruit juice, there may be some nutritive value offsetting the potential metabolic and inflammatory risk posed by soda and other nonjuice SSBs. It is also likely that the re sults for children are affected by the chronicity of the metabolic derangements being measured and the lag time required before appreciable differences are statistically significant. However, despite these factors, the significant associations found in this study should raise concern that lipid alterations, systemic inflammation, and anthropometric changes are present in young children even without the compounding effects of time.

Our study also has several limitations. First, because of its cross-sectional nature, an accurate temporal sequence cannot be obtained and, thus, causality cannot be determined; the data merely determine associations. Second, as with all questionnaire studies, the NHANES dietary data are prone to recall bias. This fact is especially relevant in the 3- to 11-year-old population as dietary data were collected with the help of a proxy and not solely reported by the individual consumer.

However, there are important strengths to our study as well. First, we studied large nationally representative data sets that provide detailed variables allowing for the better control of confounding factors. Second, given the extensive training of the NHANES staff,[19] the precision of the data is high. Third, we can be confident that our findings represent the independent associations between SSB intake and not just energy intake with the cardiometabolic markers because we adjusted our analyses for total daily energy intake.

CONCLUSIONS

This is the first study to examine SSB intake in young children and its associations with cardiometabolic markers and we report that SSB intake is positively associated with decreased HDL cholesterol levels, increased CRP concentrations, and increased waist circumference in children aged 3 to 11 years. Although prospective studies are needed to confirm these results, our study adds to the mounting evidence now present across all age groups about the potential deleterious effects of SSB intake on cardiovascular and metabolic health.

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Table 1

Characteristics of US children aged 3 to 11 y by sugar-sweetened beverage (SSB) consumption

	SSB Consumption Level[a]			
Characteristic	**None (no SSBs)**	**Medium (11.8±5.6 oz)**	**High (35.1 ±13.7 oz)**	**Total**
Participants (n)	1,199	2,711	970	4,880
Age distribution (%)				
3-5 y	41.5	33.3	17.8	32.1
6-8 y	32.8	36.3	34.2	35.0
9-11 y	25.7	30.5	48.0	32.9
Sex (%)				
Boy	50.1	47.3	60.4	50.7
Girl	49.9	52.7	39.6	49.3
Race or ethnicity (%)				
Non-Hispanic white	58.5	58.1	62.2	59.0
Non-Hispanic black	15.4	15.0	13.4	14.8
Mexican American	11.4	13.8	13.5	13.1
Other race/ethnicity	14.6	13.2	10.8	13.0

[a]None: ≤20th percentile, medium: >20th to <80th percentile, high: ≥80th percentile.

Table 2

Characteristics of sugar-sweetened beverage (SSB) intake groups and the multivariate linear regression coefficients[a]

Characteristic	Sample size (n)	SSB Consumption Level[b]			Adjusted β coefficient[c]±standard error	*P* value
		None (no SSBs)	Medium (11.8±5.6 oz)	High (35.1 ±13.7 oz)		
		unadjusted mean± standard error				
Total cholesterol (mg/dL[d])	3,792	167.6±1.4	164.3±1.0	164.9±1.5	–.50±.43	0.25
Low-density lipoprotein cholesterol (mg/dL[d])	1,599	94.0±2.0	93.2±1.3	95.3±2.0	–.10±.51	0.85
High-density lipoprotein cholesterol (mg/dL)[d]	3,789	54.0±0.6	51.8±0.5	51.3±0.5	–.57±.13	<0.001
Triglyceride (mg/dL[e])	1,604	90.5±4.5	87.6±2.5	87.4±3.8	.77± 1.04	0.46
C-reactive protein (mg/dL[f])	3,918	0.12±0.01	0.14±0.01	0.14±0.01	.01±.003	0.003
Waist circumference (cm)	4,671	60.0±0.4	61.0±0.3	61.7±0.5	.27±.13	0.04
Body mass index percentile	4,743	57.9±1.3	61.6±1.0	65.6±1.3	.71±.38	0.07

[a]Multivariate linear regression analyses were performed using SSB consumption as a continuous exposure and all outcome measurements as continuous variables.

[b]None: ≤20th percentile, medium: >20th to <80th percentile, high: ≥80th percentile.

[c]Adjusted for amount of physical activity performed per week, age, sex, race, energy intake, and poverty status.

[d]To convert mg/dL cholesterol to mmol/L, multiply mg/dL by 0.26. To convert mmol/L cholesterol to mg/dL, multiply mmol/L by 38.6. Cholesterol of 193 mg/dL=5.0 mmol/L.

[e]To convert mg/dL triglyceride to to mmol/L multiply mg/dL by 0.0113. To convert mmol/L triglyceride to mg/dL, multiply mmol/L by 88.6. Triglyceride of 159 mg/dL = 1.80 mmol/L.

[f]To convert mg/dL C-reactive protein to nmol/L, multiply mg/dL by 95.24. To convert nmol/LC-reactive protein to mg/dL, multiply nmol/L by 0.0105. C-reactive protein of 0.15 mg/dL = 14.29 nmol/L.

Table 3

Characteristics of sugar-sweetened beverage (SSB) intake groups and the multivariate linear regression coefficients[a] stratified by age

Characteristic	Sample size (n)	SSB Consumption Level[b]			Adjusted β coefficient[c] ±standard error	*P* value
		None (no SSBs)	Medium (11.8±5.6 oz)	High (35.1 ±13.7 oz)		
		unadjusted mean± standard error				
Total cholesterol (mg/dL[d])						
3-5 y	1,153	162.9±1.8	161.3±1.1	161.3±2.6	.40±.57	0.49
6-8 y	1,284	168.8±2.2	163.9±1.3	164.0±2.9	–.53±.58	0.36
9-11 y	1,355	172.0±2.5	167.4±1.5	166.7±1.7	–.97±.79	0.22
Low-density lipoprotein cholesterol (mg/dL[d])						
3-5 y	467	89.8±2.6	90.9±1.7	95.8±3.5	1.64±.71	0.03
6-8 y	558	96.5±3.7	94.4±1.9	96.3±3.3	.06±.82	0.94
9-11 y	574	96.0±2.6	93.8±2.1	94.4±3.0	–.87±1.02	0.40
High-density lipoprotein cholesterol (mg/dL[d])						
3-5 y	1,151	51.6±0.9	50.9±0.5	49.6±1.3	–.15±.33	0.66
6-8 y	1,284	55.2±0.8	51.9±0.7	52.5±0.7	–.34±.27	0.22
9-11 y	1,354	55.8±1.0	52.3±0.7	50.9±0.8	–.95±.20	<0.001
Triglyceride (mg/dL[e])						
3-5 y	468	80.2±5.7	83.9±5.0	84.1±4.0	.21±2.21	0.93
6-8 y	560	93.3±9.3	86.5±4.6	84.8±7.7	.96±1.62	0.55
9-11 y	576	100.0±4.1	91.9±3.6	90.0±5.0	.98±1.47	0.51
C-reactive protein (mg/dL[f])						
3-5 y	1,227	0.15±0.03	0.12±0.02	0.12±0.02	–.003±.01	0.64
6-8 y	1,316	0.12±0.03	0.14±0.02	0.13±0.02	.01±.01	0.12
9-11 y	1,375	0.10±0.01	0.14±0.02	0.16±0.02	.01±.01	0.01
Waist circumference (cm)						
3-5 y	1,566	52.7±0.3	53.0±0.3	52.8±0.4	.06±.16	0.71
6-8 y	1,568	58.9±0.5	60.2±0.5	60.6±0.7	–.22±.19	0.23
9-11 y	1,537	67.4±0.9	69.6±0.6	70.4±0.8	.76±.23	0.001
Body mass index percentile						
3-5 y	1,606	58.3±1.8	59.0±1.7	59.7±2.0	–.46±.68	0.50
6-8 y	1,588	56.1±2.0	61.4±1.5	65.6±2.5	.19±.65	0.76
9-11 y	1,549	59.6±2.5	64.5±1.7	67.6±1.7	1.42±.46	0.002

[a]Multivariate linear regression analyses were performed using SSB consumption as a continuous exposure and all outcome measurements as continuous variables.

[b]None: ≤20th percentile, medium: >20th to <80th percentile, high: ≥80th percentile.

[c] Adjusted for sex, race, amount of physical activity performed per week, energy intake, and poverty status.

[d] To convert mg/dL cholesterol to mmol/L, multiply mg/dL by 0.26. To convert mmol/L cholesterol to mg/dL, multiply mmol/L by 38.6. Cholesterol of 193 mg/dL=5.0 mmol/L.

[e] To convert mg/dL triglyceride to to mmol/L multiply mg/dL by 0.0113. To convert mmol/L triglyceride to mg/dL, multiply mmol/L by 88.6. Triglyceride of 159 mg/dL=1.80 mmol/L.

[f] To convert mg/dL C-reactive protein to nmol/L, multiply mg/dL by 95.24. To convert nmol/L C-reactive protein to mg/dL, multiply nmol/L by 0.0105. C-reactive protein of 0.15 mg/dL=14.29 nmol/L.

Table 4

Characteristics of sugar-sweetened beverage (SSB) intake groups and the multivariate linear regression coefficients[a] stratified by sex

Characteristic	Sample size (n)	SSB Consumption Level[b]			Adjusted *β* coefficient[c]±standard error	*P* value
		None (no SSBs)	Medium (11.8±5.6 oz)	High (35.1±13.7 oz)		
		unadjusted mean± standard error				
Total cholesterol (mg/dL[d])						
Boys	1,914	167.9±2.0	162.8±1.1	163.1±1.6	–.73±.56	0.19
Girls	1,878	167.2±2.0	165.8±1.2	167.9±2.5	.04±.62	0.95
Low-density lipoprotein cholesterol (mg/dL[d])						
Boys	803	93.6±3.6	90.6±1.6	93.7±3.2	–1.05±.87	0.23
Girls	796	94.4±2.8	95.6±1.8	98.0±3.3	1.36±.56	0.01
High-density lipoprotein cholesterol (mg/dL[d])						
Boys	1,913	54.5±0.8	52.8±0.6	51.5±0.7	–.51±.17	0.002
Girls	1,876	53.6±0.7	50.8±0.4	50.9±0.8	–.62±.22	0.01
Triglyceride (mg/dL[e])						
Boys	807	87.7±6.0	86.3±3.7	81.6±4.6	.91±1.38	0.51
Girls	797	93.4±5.7	88.8±3.1	97.3±5.1	.77±1.61	0.63
C-reactive protein (mg/dL[f])						
Boys	1,986	0.12±0.02	0.12±0.01	0.15±0.01	.01±.004	0.02
Girls	1,932	0.12±0.02	0.16±0.02	0.12±0.02	.01±.004	0.03
Waist circumference (cm)						
Boys	2,324	59.9±0.5	61.0±0.4	61.6±0.6	.24±.18	0.17
Girls	2,347	60.1±0.4	61.0±0.4	61.8±0.5	.30±.21	0.16
Body mass index percentile						
Boys	2,350	58.6±1.8	61.6±1.1	65.6±1.7	.64±.45	0.16
Girls	2,393	57.2±1.6	61.5±1.3	65.6±1.8	.80±.51	0.12

[a]Multivariate linear regression analyses were performed using SSB consumption as a continuous exposure and all outcome measurements as continuous variables.

[b]None: ≤20th percentile, medium: >20th to <80th percentile, high: ≥80th percentile.

[c]Adjusted for age, race, amount of physical activity performed per week, energy intake, and poverty status.

[d]To convert mg/dL cholesterol to mmol/L, multiply mg/dL by 0.26. To convert mmol/L cholesterol to mg/dL, multiply mmol/L by 38.6. Cholesterolof 193 mg/dL=5.0 mmol/L.

[e]To convert mg/dL triglyceride to to mmol/L multiply mg/dL by 0.0113. To convert mmol/L triglyceride to mg/dL, multiply mmol/L by 88.6. Triglyceride of 159 mg/dL=1.80 mmol/L.

[f]To convert mg/dL C-reactive protein to nmol/L, multiply mg/dL by 95.24. To convert nmol/L C-reactive protein to mg/dL, multiply nmol/L by 0.0105. C-reactive protein of 0.15 mg/dL=14.29 nmol/L.

Table 5

Characteristics of sugar-sweetened beverage (SSB) intake groups and the multivariate linear regression coefficients[a] stratified by ethnicity

Characteristic	**Sample size (n)**	**SSB Consumption Level[b]**			**Adjusted β coefficient[c]±standard error**	***P* value**
		None (no SSBs)	**Medium (11.8±5.6 oz)**	**High (35.1±13.7 oz)**		
		unadjusted mean± standard error				
Total cholesterol (mg/dL[d])						
Non-Hispanic white	993	170.0±1.6	164.2±1.2	164.0±2.1	–.96±.64	0.13
Non-Hispanic black	1,218	167.1±2.2	168.6±1.3	168.7±2.7	.59±.64	0.36
Mexican American	1,248	160.4±1.8	161.8±0.9	163.9±1.9	.92±.55	0.09
Low-density lipoprotein cholesterol (mg/dL[d])						
Non-Hispanic white	411	96.2±2.9	93.2±2.0	95.9±3.0	–.37±.70	0.60
Non-Hispanic black	540	93.6±2.4	97.8±1.7	94.3±2.5	.43±.82	0.60
Mexican American	507	88.6±2.5	90.3±1.1	93.0±3.3	1.17±.78	0.14
High-density lipoprotein cholesterol (mg/dL[d])						
Non-Hispanic white	992	53.0±0.9	50.2±0.5	49.9±0.8	–.63±.19	0.001
Non-Hispanic black	1,218	57.4±1.0	56.8±0.6	56.0±0.9	–.64±.23	0.005
Mexican American	1,246	52.2±0.9	52.0±0.4	52.5±0.9	.08±.25	0.75
Triglyceride (mg/dL[e])						
Non-Hispanic white	411	95.8±6.2	91.0±3.7	87.5±5.4	1.10±1.44	0.45
Non-Hispanic black	541	68.5±2.4	69.5±1.7	82.7±7.2	3.13±1.42	0.03
Mexican American	511	89.2±6.7	96.7±4.4	93.5±5.4	–.61±1.48	0.68
C-reactive protein (mg/dL[f])						
Non-Hispanic white	1,023	0.11±0.02	0.13±0.02	0.13±0.01	.01±.004	0.09
Non-Hispanic black	1,263	0.10±0.02	0.14±0.01	0.15±0.02	.01±.01	0.03
Mexican American	1,286	0.17±0.03	0.18±0.01	0.15±0.01	.01±.01	0.34
Waist circumference (cm)						
Non-Hispanic white	1,276	60.0 (0.6	61.1±0.5	61.7±0.7	.24±.22	0.29
Non-Hispanic black	1,496	59.3±0.4	59.8±0.3	60.9±0.7	.36±.28	0.19
Mexican American	1,477	62.6±0.6	62.1±0.4	62.4±0.6	–.05±.16	0.74
Body mass index percentile						
Non-Hispanic white	1,288	56.4±1.9	60.0±1.5	64.8±2.1	.77±.62	0.21
Non-Hispanic black	1,516	58.9±1.7	61.3±1.4	67.2±2.2	.79±.82	0.33
Mexican American	1,511	64.2±2.1	64.7±1.2	67.9±2.0	.13±.67	0.85

[a]Multivariate linear regression analyses were performed using SSB consumption as a continuous exposure and all outcome measurements as continuous variables.

[b]None: ≤20th percentile, medium: >20th to <80th percentile, high: ≥80th percentile.

[c]Adjusted for age, race, amount of physical activity performed per week, energy intake, and poverty status.

[d]To convert mg/dL cholesterol to mmol/L, multiply mg/dL by 0.26. To convert mmol/L cholesterol to mg/dL, multiply mmol/L by 38.6. Cholesterol of 193 mg/dL=5.0 mmol/L.

[e]To convert mg/dL triglyceride to to mmol/L multiply mg/dL by 0.0113. To convert mmol/L triglyceride to mg/dL, multiply mmol/L by 88.6. Triglyceride of 159 mg/dL=1.80 mmol/L.

[f]To convert mg/dL C-reactive protein to nmol/L, multiply mg/dL by 95.24. To convert nmol/L C-reactive protein to mg/dL, multiply nmol/L by 0.0105. C-reactive protein of 0.15 mg/dL=14.29 nmol/L.