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Beverage intake of girls at age 5 y predicts adiposity and weight status in childhood and adolescence[1–3]

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ABSTRACT

Background: Increased consumption of sweetened beverage has been linked to higher energy intake and adiposity in childhood.

Objective: The objective was to assess whether beverage intake at age 5 y predicted energy intake, adiposity, and weight status across childhood and adolescence.

Design: Participants were part of a longitudinal study of non-Hispanic white girls and their parents (n = 170) who were assessed biennially from age 5 to 15 y. At each assessment, beverage intake (milk, fruit juice, and sweetened beverages) and energy intake were assessed by using three 24-h recalls. Percentage body fat and waist circumference were measured. Height and weight were measured and used to calculate body mass index. Multiple regression analyses were used to predict the girls' adiposity. In addition, at age 5 y, girls were categorized as consuming <1, ≥ 1 and <2, or ≥ 2 servings of sweetened beverages. A mixed modeling approach was used to assess longitudinal differences and patterns of change in sweetened beverage and energy intake, adiposity, and weight status by frequency of sweetened beverage intake.

Results: Sweetened beverage intake at age 5 y, but not milk or fruit juice intake, was positively associated with adiposity from age 5 to 15 y. Greater consumption of sweetened beverages at age 5 y (≥ 2 servings/d) was associated with a higher percentage body fat, waist circumference, and weight status from age 5 to 15 y.

Conclusion: These findings provide new longitudinal evidence that early intake of sweetened beverages predicts adiposity and weight status across childhood and adolescence. *Am J Clin Nutr* doi: 10.3945/ajcn.2009.27623.

INTRODUCTION

The prevalence of overweight and obesity in children has increased at an alarming rate during the past 3 decades (1), and various environmental and social factors relating to diet have been identified as contributors to the childhood obesity epidemic (2). One factor receiving attention is the consumption of sweetened beverages. A recent systematic review revealed that, in most studies, higher sweetened beverage intake was linked to increased weight status and obesity among children and adolescents (3). However, most research was cross-sectional, and beverage consumption as well as weight status were measured at only one point in time (3).

Much of the research has focused exclusively on the effects of sweetened beverages, and the potential contribution of other beverage categories to children's adiposity has not been investigated. With respect to links between the intake of other beverages and childhood obesity, 100% fruit juice has also been associated with increased energy intake and weight status among preschool children in some studies (4, 5) but not in others (6, 7). Negative associations between milk intake and weight status in children have been noted in some studies (8, 9), but others have failed to confirm this relation (10–12). It is possible that the inconsistencies in this literature are in part due to the failure to assess the relative effect of milk, fruit juice, and sweetened beverage intake within the same study. In studies investigating the effect of more than one beverage, intake of milk and sweetened beverages is negatively correlated (13, 14), which raises the question of whether the relations noted between beverage and weight status are due to what is consumed or what is not consumed.

Limited research suggests that early food and beverage preferences and consumption patterns begin to develop in early childhood and can persist over time to influence preferences and patterns of intake later in life (15–18). Retrospective studies (19–21) indicate that, although milk intake declines during childhood and adolescence, dietary habits that include frequent milk intake during childhood tend to track over time and to set the course for milk intake during adulthood. In another study, soda intake tracked from adolescence into adulthood (22). However, few studies have focused on patterns of beverage intake within individuals over time, and there is little evidence regarding the long-term effect of early beverage intake patterns on adiposity in childhood and adolescence.

The overall objective of this study was to assess whether beverage intake at age 5 predicted adiposity from age 5 to 15 y. Given the evidence that sweetened beverage intake is associated

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with higher weight status and adiposity (6), we hypothesized that sweetened beverage intake at age 5 y, but not milk or fruit juice intake, would be a significant and positive predictor of adiposity in childhood and adolescence. Furthermore, we categorized girls by the number of daily sweetened beverage servings consumed at age 5 y (<1, ≥1 and <2, or ≥2 servings/d) and hypothesized that a higher intake of sweetened beverage at age 5 y would predict higher 24-h energy intake, adiposity, and weight status from age 5 to 15 y.

SUBJECTS AND METHODS

Subjects

Participants were part of a longitudinal study of the health and development of young girls living in central Pennsylvania. Participants included one hundred ninety-seven 5-y-old girls and their parents; participants and families were reassessed every 2 y (at ages 7, 9, 11, 13, and 15 y). The final assessment included 167 families. Attrition was primarily due to family relocation outside of the study area. Only girls with complete dietary intake and body weight data at 4 of 6 times of measurement were included in this study, which resulted in a final sample of 166 girls.

Families were recruited for participation in the study by using flyers and newspaper advertisements. In addition, families with age-eligible female children within a 5-county radius received mailings and follow-up phone calls. Eligibility criteria for the girls' participation at the time of recruitment included living with both biological parents, the absence of severe food allergies or chronic medical problems affecting food intake, and the absence of dietary restrictions involving animal products; families were not recruited on the basis of weight status or concerns about weight.

Families were predominantly non-Hispanic and white, and the average income for the sample ranged from $50,000 to $75,000. Parents were relatively well educated: fathers had a mean (±SD) educational level of 14.9 ± 2.7 y, and mothers had an educational level of 14.8 ± 2.3 y. Parents were on average slightly overweight at the first time of measurement with a mean (±SD) body mass index (BMI; in kg/m^2) of 28.0 ± 4.35 for fathers and 26.4 ± 6.05 for mothers. The Pennsylvania State University Institutional Review Board approved all study procedures, and parents provided consent for their family's participation before the study began.

Weight status

Height and weight measurements were taken in the laboratory and were used to calculate BMI. Age- and sex-specific BMI percentiles were also calculated and used to determine the prevalence of overweight in girls in this sample. With the use of the Centers for Disease Control and Prevention growth charts, girls were classified as overweight if their BMI percentile was ≥85th (23).

Adiposity

To estimate percentage body fat for triceps and subscapular skinfold thickness, measurements were collected when participants were 5, 7, 9, and 11 y of age, and dual-energy X-ray absorptiometry (DXA) scans were administered at 9, 11, 13, and 15 y of age. To most accurately estimate the girls' body fatness at 5 and 7 y of age, regression equations were created to describe the relation between skinfold and DXA measurements at 9 and 11 y of age (when collection of these 2 measures overlapped). On the basis of previous research by Slaughter et al (24), the equation created regressed DXA data on the sum and squared sum of triceps and subscapular skinfold-thickness measurements. The equation derived from this regression model was applied to skinfold-thickness data taken at 5 and 7 y of age to calculate estimates of the percentage body fat at these assessment points. To estimate central adiposity, trained nurses measured the subjects' waist circumference at 7, 9, 11, 13, and 15 y of age.

Beverage and energy intake

Three 24-h recall interviews were conducted at each occasion by trained staff of the Dietary Assessment Center at the Pennsylvania State University by using the computer-assisted Nutrition Data System for Research (NDS-R) software (Database Version 4.01_30; Nutrition Coordinating Center, University of Minnesota, Minneapolis, MN). The NDS-R software itself provides a structured, guided controlled platform on which questions and probes are standard and the process of conducting the 24-h recall is standardized. The NDS-R time-related database updates analytic data annually while maintaining nutrient profiles true to the bastion used for data collection. At ages 5, 7, 9, 11, 13, and 15 y, the participants provided three 24-h recalls within a 2- to 3-wk period, including 2 randomly selected weekdays and 1 weekend day. Recalls were conducted from June through October. At ages 5, 7, and 9 y, mothers in the presence of their daughters were the primary reporters of the girls' intake. At ages 11, 13, and 15 y, the girls were the primary reporters with mothers participating in the interview as needed. Participants were mailed a poster depicting 2-dimensional representations of food portions (2D Food Portion Visual; Nutrition Counseling Enterprises, Framingham, MA) as a visual aid for estimating the amounts of food eaten. Nutrient data were averaged across 3 d to obtain an estimate of 24-h energy.

Beverage data were averaged across 3 d to obtain an estimate of the number of servings reported consumed by using the 2005 Dietary Guidelines for Americans (25) and the US Department of Agriculture Food Guide Pyramid Guidelines (26). Beverage data were grouped into 3 intake categories: *1*) milk, *2*) fruit juice, and *3*) sweetened beverage. Milk included whole and reduced fat (plain or flavored) milk and was quantified as that consumed as a beverage. Fruit juice was defined as containing 100% fruit juice. At age 5 y, artificially sweetened beverages were a small fraction of the girls' beverage consumption, so sugar and artificially sweetened beverages were summed into a composite variable referred to as "sweetened beverages." Sweetened beverages included the following: *1*) any sugar-sweetened or artificially sweetened fruit-flavored drinks, sports (natural or artificial) drinks, and drinks that contained <100% fruit juice; *2*) sodas that included carbonated sugar-sweetened or artificially sweetened, caffeinated or decaffeinated colas; and *3*) sugar-sweetened or artificially sweetened, caffeinated or decaffeinated tea or coffee. The girls' intake of water was not assessed. Consumption in each category was expressed in servings (1 serving = 8 ounces).

Statistical analyses

Data were analyzed by using the SAS software package (version 9.1; SAS Institute, Cary NC) (27). Descriptive information was generated for all variables of interest, and each outcome variable was assessed for normality. In all analyses, P values <0.05 were considered statistically significant. Change was defined as the linear decrease or increase in the variable of interest from age 5 to 15 y.

To examine the participants' change in adiposity and weight status, a mixed modeling approach (PROC MIXED; SAS Institute) was used. Mixed modeling is a useful tool for analyzing the linear relation over time, and a major advantage of the PROC MIXED procedure is its ability to retain cases with one or more missing data points (28). Spearman rank-order correlations were used to assess stability for milk, fruit juice, and sweetened beverages between measurement occasions from age 5 to 15 y. Stability is defined as the consistency of participants' beverage intake between 2 measurement occasions, which is represented by the correlation coefficient between values taken at 2 times across individuals (29). A series of simple regression analyses were conducted to determine whether the girls' intake of milk, fruit juice, and sweetened beverage at age 5 y was an independent predictor of their adiposity measured as percentage body fat at each time point from age 5 to 15 y. The contribution of each predictor variable was determined by examining the standardized variable estimate. Multiple regression analysis was used to determine whether sweetened beverage intake at age 5 y predicted the percentage body fat over time, after controlling for potential covariates. Covariates examined in the model included sweetened beverage intake measured at the same point in time as adiposity, 24-h energy intake at age 5 y, parental education, family income, and maternal BMI at study entry.

At age 5 y, girls were classified as drinking <1, ≥1 and <2, or ≥2 servings/d of sweetened beverages. Differences in the percentage body fat, waist circumference, and BMI-for-age percentiles at each time of measurement among beverage groups were assessed by using repeated measures with a mixed modeling approach (PROC MIXED). Repeated-measures-type analyses (PROC GENMOD; SAS Institute), which are appropriate when dealing with binary data, were used to assess the following: *1*) whether girls who consumed ≥2 servings of sweetened beverage at age 5 y were more likely to be overweight (≥85th BMI-for-age percentile) compared with girls with lower intakes and *2*) whether the proportion of participants who were overweight increased from age 5 to 15 y. PROC MIXED was used to examine the longitudinal changes in sweetened beverage and 24-h energy intake, percentage body fat, waist circumference, and BMI-for-age percentiles, assessed from age 5 to 15 y for participants drinking <1 serving/d, ≥1 to <2 servings/d, and ≥2 servings/d sweetened beverages. Post hoc pairwise comparisons of sweetened beverage group membership were made by using the least squares means and by applying a Tukey adjustment for comparisons. Given that sweetened beverage groups were defined at age 5 y, we examined change for sweetened beverage intake only among groups from age 7 to 15 y, excluding those who were 5 y of age. The main effect of beverage group and age and the interaction between beverage group and age were variables of interest.

RESULTS

Adiposity and weight status

Descriptive information on the participants' percentage body fat, waist circumference, and weight status is presented in **Table 1**. Weight status, measured as BMI-for-age percentile, showed high stability between adjacent ages from age 5 to 15 y, with stability estimates ranging from $r = 0.85$ ($P < 0.0001$) to $r = 0.92$ ($P < 0.0001$) and moderate stability overall between ages 5 and 15 y ($r = 0.60$, $P < 0.0001$). The proportion of girls classified as overweight increased significantly from age 5 to 15 y. Findings indicate that the prevalence of overweight in our sample across the study period is similar to that shown by national data for the prevalence of overweight (≥85th percentile) in children and adolescents (1). In addition, as expected and as a result of normal growth, the participants' percentage body fat increased significantly from age 5 to 15 y.

Association between beverages and stability of beverage intake over time

Relations between girls' milk, fruit juice, and sweetened beverage intake at age 5 y were assessed. The association of sweetened beverages with milk ($r = -0.20$, $P < 0.01$) and fruit juice ($r = -0.19$, $P < 0.05$) intake was negative, whereas milk and fruit juice were not associated ($r = -0.10$, NS). The participants' beverage intake stability between measurement occasions from age 5 to 15 y is shown in **Table 2**. For milk and sweetened beverage intake, stability was moderate, but stability

TABLE 1

Mean percentage body fat, waist circumference, BMI-for-age percentile, and proportion of girls classified as overweight from age 5 to 15 y[1]

	Age 5 y	Age 7 y	Age 9 y	Age 11 y	Age 13 y	Age 15 y	Change (P value)
Body fat (%)	20.6 ± 4.3[2]	21.8 ± 5.6	26.8 ± 7.5	27.3 ± 7.1	26.9 ± 6.8	27.9 ± 6.0	<0.01
Waist circumference (cm)	—[3]	66.9 ± 8.5	73.4 ± 10.7	73.4 ± 10.7	78.7 ± 10.7	78.8 ± 10.1	<0.01
BMI-for-age percentile[4]	59.3 ± 26.6	58.2 ± 27.7	64.0 ± 26.9	63.5 ± 27.5	62.4 ± 26.1	61.3 ± 24.9	<0.05
Percentage of sample overweight[5]	18	19	29	29	25	20.5	<0.05

[1] $n = 170$ for each age group. Mixed modeling analyses were used to generate the data in this table.

[2] Mean ± SD (all such values).

[3] Data not available.

[4] Mean BMI percentiles correspond directly to the sample mean BMI by using age- and sex-specific Centers for Disease Control and Prevention growth charts (23).

[5] Overweight is defined as ≥85th BMI-for-age percentile (23).

TABLE 2
Stability of beverage intake: Spearman correlations between measurement occasions of beverage intake in girls aged 5–15 y[1]

Beverages	Age 5–7 y	Age 7–9 y	Age 9–11 y	Age 11–13 y	Age 13–15 y	Age 5–15 y
Milk	0.62[2]	0.57[2]	0.45[2]	0.44[2]	0.47[2]	0.36[2]
Fruit juice	0.45[2]	0.24[3]	0.23[3]	0.25[3]	0.21[3]	0.14
Sweetened beverage	0.50[2]	0.56[2]	0.52[2]	0.42[2]	0.36[2]	0.23[3]

[1] n = 170. Column headings represent correlations between 2 ages (eg, age 5 y correlated with age 7 y).
[2] $P < 0.0001$.
[3] $P < 0.01$.

declined from aged 5 to 15 y. In contrast, fruit juice intake showed lower stability over the study period.

Beverage intake at age 5 y as a predictor of adiposity from age 5 to 15 y

Results of the simple regressions conducted to assess milk, fruit juice, and sweetened beverage intake at age 5 y as independent predictors of participants' adiposity at each age from 5 to 15 y are shown in **Table 3**. These findings indicate that only sweetened beverage intake at age 5 y was a significant predictor of adiposity at each age from 5 to 15 y. Sweetened beverage intake at age 5 y significantly explained 9%, 7%, 9%, 5%, 3%, and 3% of the variation in the prediction of participants' percentage body fat at each time point assessed at ages 5, 7, 9, 11, 13, and 15 y, respectively.

The association between sweetened beverage intake at age 5 y and adiposity from age 5 to 15 y was also assessed after controlling for potential covariates (Table 3). After sweetened beverage intake at the same age at which adiposity was measured was controlled for, higher sweetened beverage intake at age 5 y continued to be a significant predictor of percentage body fat at each time point assessed between ages 5 and 15 y. Similarly, when 24-h energy intake at age 5 y was controlled for, sweetened beverage intake at age 5 y remained significantly and positively associated with participants' adiposity at each time point assessed between ages 5 and 15 y. Adjustment for 24-h energy intake at the same time point at which sweetened beverage intake was measured did not alter the results (data not shown). Furthermore, we assessed whether sweetened beverage intake at age 5 y was associated with higher adiposity after accounting for parental education at study entry. Results showed that higher sweetened beverage intake at age 5 y remained a predictor of higher percentage body fat at ages 5, 7, 9, and 11 y after taking parental education into account; however, at 13 and 15 y of age, the association was no longer significant. When maternal BMI at study entry was added as a covariate, sweetened beverage intake at age 5 y continued to predict participants' adiposity at each time point assessed between age 5 and 11 y. However, at 13 and 15 y of age, the association was no longer significant. Finally, early sweetened beverage intake continued to predict higher adiposity from age 5 to 15 y after family income at study entry was taken into account.

Participants who consumed <1, ≥1 and <2, or ≥2 servings of a sweetened beverage at age 5 y

Given that sweetened beverage intake at age 5 y, but not milk or fruit juice intake, was associated with adiposity, the second aim of this study focused on whether the higher intake of sweetened beverage at age 5 y was associated with greater 24-h energy intake and measures of adiposity from 5 to 15 y of age. To this end, girls were categorized by their daily frequency of sweetened beverage intake at age 5 y. Sweetened beverage intake was

TABLE 3
Standardized regression coefficients for beverage intake at age 5 y in predicting percentage body fat in girls aged 5–15 y[1]

Beverage consumption at age 5 y	Age 5 y (n = 160)	Age 7 y (n = 169)	Age 9 y (n = 158)	Age 11 y (n = 164)	Age 13 y (n = 150)	Age 15 y (n = 160)
Milk, unadjusted	−0.06	−0.02	−0.06	0.01	0.04	−0.08
Fruit juice, unadjusted	0.09	0.02	0.02	0.03	0.00	−0.02
Sweetened beverage, unadjusted	0.31[2]	0.27[2]	0.32[2]	0.23[3]	0.20[4]	0.18[4]
Sweetened beverage, adjusted for sweetened beverage intake at the age adiposity was measured		0.29[3]	0.30[3]	0.20[4]	0.21[4]	0.17[4]
Sweetened beverage, adjusted for energy intake at age 5 y	0.29[3]	0.26[3]	0.29[3]	0.20[4]	0.20[4]	0.18[4]
Sweetened beverage, adjusted for maternal BMI at study entry[5]	0.27[3]	0.22[3]	0.25[3]	0.15[4]	0.12	0.09
Sweetened beverage, adjusted for parental education at study entry[5]	0.30[3]	0.23[3]	0.24[3]	0.16[4]	0.12	0.08
Sweetened beverage, adjusted for family income at study entry	0.32[2]	0.28[3]	0.30[3]	0.23[3]	0.21[4]	0.18[4]

[1] Standardized variable estimates made by using independent linear regression analysis.
[2] $P < 0.0001$.
[3] $P < 0.01$.
[4] $P < 0.05$.
[5] Significant predictor of percentage body fat only at ages 13 and 15 y ($P < 0.05$).

averaged across 3 d. Fifty-five percent (n = 93), 30% (n = 51), and 15% (n = 26) of girls were categorized as consuming <1, ≥1 and <2, or ≥2 servings/d of sweetened beverages at age 5 y, with mean (±SD) intakes of 0.5 ± 0.3, 1.4 ± 0.3, and 2.7 ± 0.7 servings/d, respectively.

Participants who consumed <1, ≥1 and <2, or ≥2 servings of a sweetened beverage at age 5 y: family demographics and parental weight status

Parents of girls in the beverage group drinking ≥2 daily servings of sweetened beverage reported lower income at study entry compared with parents of girls drinking <1 serving of sweetened beverage at 5 y ($P < 0.05$). In addition, parents of girls in the beverage groups drinking ≥1 and <2 or ≥2 servings of sweetened beverages at age 5 y reported significantly lower education levels compared with parents of girls drinking <1 serving of a sweetened beverage at age 5 y ($P < 0.001$). No significant differences were seen among beverage groups for daughters' birth weight and maternal breastfeeding. At study entry, the BMI for mothers of girls in the beverage group drinking ≥2 daily servings of a sweetened beverage was significantly higher than for mothers of girls drinking <1 serving of a sweetened beverage at age 5 y ($P < 0.05$). Fathers of girls drinking ≥2 servings of a sweetened beverage had a BMI significantly higher at study entry than fathers of girls consuming <1 or ≥1 and <2 servings of a sweetened beverage at age 5 y ($P < 0.05$).

Participants who consumed <1, ≥1 and <2, or ≥2 servings of a sweetened beverage at age 5 y: differences in sweetened beverage intake from age 5 to 15 y

Patterns of change in mean sweetened beverage intake from age 5 to 15 y by frequency of sweetened beverage intake at age 5 y were examined (**Figure 1**). Given that differences in sweetened beverage intake at age 5 y between groups were based on the categorization criteria for sweetened beverage consumption at age 5 y, we examined changes in sweetened beverage intake between groups from ages 7 to 15 y, with the exclusion of data from age 5 y. Although the beverage groups converge over time, with the age 5 y data excluded from the analyses, the interaction of beverage group by age was not significant, but there was a main effect for beverage group membership ($P < 0.001$). Post hoc Tukey means comparison tests revealed that girls drinking ≥2 servings of a sweetened beverage at age 5 y had significantly higher intakes from age 7 to 15 y than girls drinking <1 serving of a sweetened beverage. However, no differences were noted over time between girls drinking ≥2 servings or ≥1 and <2 servings of a sweetened beverage at age 5 y. The main effect for age was not significant for participants' sweetened beverage intake from age 7 to 15 y, which showed that overall sweetened beverage intake remained relatively stable over time.

Participants who consumed <1, ≥1 and <2, or ≥2 servings of a sweetened beverage at age 5 y: differences in energy intake from age 5 to 15 y

Patterns of change in 24-h energy intake by frequency of sweetened beverage intake at age 5 y were examined (**Figure 2**). Neither the main effect for beverage group or age nor the interaction between beverage group and age was significant for participants' 24-h energy intake.

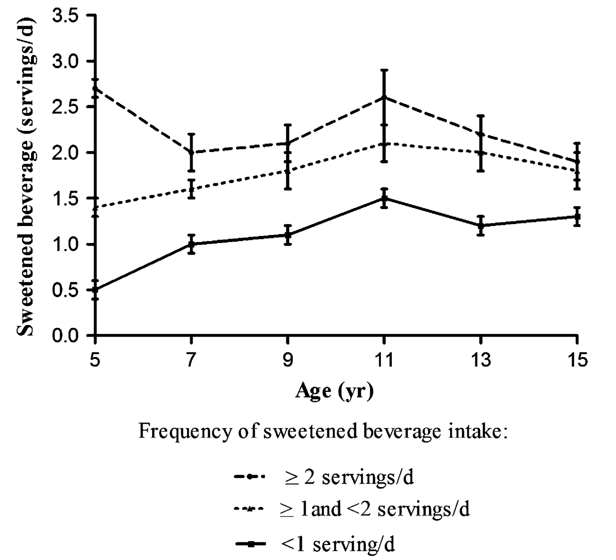

FIGURE 1. Group mean (±SE) change in sweetened beverage intake from age 7 to 15 y in girls who consumed <1, ≥1 and <2, or ≥2 servings of sweetened beverage at age 5 y (1 serving of sweetened beverage = 8 ounces). Differences in sweetened beverage intake at age 5 y between beverage groups reflect categorization criteria; thus, the change in sweetened beverage intake was tested from age 7 to 15 y. The main effect for beverage group ($P < 0.0001$) was significant by using mixed modeling analyses of variance. Post hoc Tukey means comparison test revealed that participants who drank ≥2 servings/d of a sweetened beverage at age 5 y had significantly higher intakes from age 7 to 15 y than did those who drank <1 serving of a sweetened beverage. No differences were noted over time between participants who drank ≥2 servings or ≥1 and <2 servings/d of a sweetened beverage at age 5 y.

Participants who consumed <1, ≥1 and <2, or ≥2 servings of a sweetened beverage at age 5 y: differences in adiposity and weight status from age 5 to 15 y

Patterns of change in mean percentage body fat, waist circumference, BMI-for-age percentiles, and percentage of girls classified as overweight for girls consuming <1, ≥1 and <2, or ≥2 servings of a sweetened beverage at age 5 y are shown in **Table 4**. The interaction of beverage group and age was significant only for percentage body fat ($P < 0.01$). Although all groups showed increases in percentage body fat from age 5 to 15 y, smaller increases were noted for participants consuming ≥2 servings of sweetened beverage at age 5 y because of their significantly higher percentage body fat at age 5 y. The initial differences between beverage groups in percentage body fat persist to age 15 y, which indicates that girls drinking ≥2 servings of a sweetened beverage at age 5 y had higher scores for percentage body fat from age 5 to 15 y compared with girls with lower sweetened beverage intakes. A significant main effect for beverage group was noted for waist circumference ($P < 0.05$) and BMI percentile ($P < 0.05$); the post hoc Tukey means comparison test revealed that girls drinking ≥2 servings of sweetened beverage at age 5 y had higher BMI-for-age percentiles from age 5 to 15 y and higher scores for waist circumference from aged 7 to 15 y compared with girls with lower sweetened beverage intakes. Similarly, a main effect for

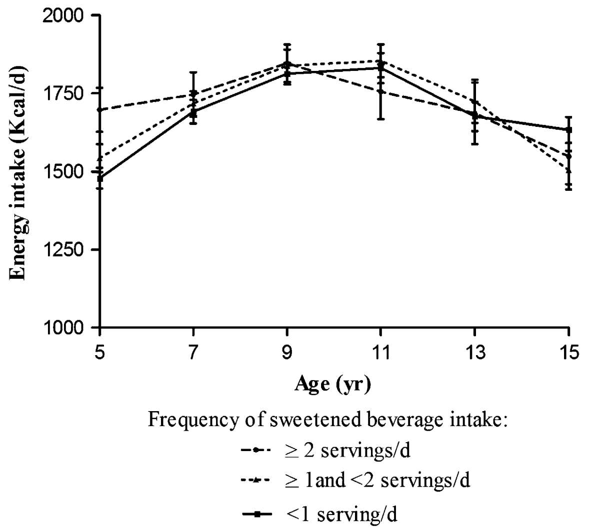

FIGURE 2. Group mean (±SE) change in 24-h energy intake from age 5 to 15 y in girls who consumed <1, ≥1 and <2, or ≥2 servings/d of a sweetened beverage at 5 y. The frequency of sweetened beverage intake defined at age 5 y was <1 (n = 93), ≥1 and <2 (n = 51), and ≥2 (n = 26) servings/d. Neither the main effect nor the interaction was significant by using mixed modeling analyses of variance.

beverage group was detected for the percentage of participants classified as overweight ($P < 0.01$); girls consuming ≥2 servings of sweetened beverage at age 5 y were more likely to be overweight from age 5 to 15 y compared with girls with lower intakes (Table 4). A main effect for age was detected for waist circumference ($P < 0.01$), which indicates a general increase in adiposity over time among the 3 beverage groups. These results remained unaltered after controlling for covariates at study entry (ie, family income, parental education, and maternal BMI) (data not shown).

DISCUSSION

Although neither milk nor fruit juice intake was related to girls' adiposity or weight status, servings of sweetened beverages consumed at age 5 y predicted participants' adiposity and overweight from age 5 to 15 y. Girls who consumed more servings of sweetened beverage at age 5 y had significantly higher adiposity during childhood and adolescence. In addition, differences in sweetened beverage intake that were already present at age 5 y persisted across childhood and adolescence and predicted differences in adiposity and weight status in childhood and adolescence.

In support of our first hypothesis, early sweetened beverage intake, but not milk or fruit juice intake, predicted higher adiposity during childhood and adolescence, even after adjustment for sweetened beverage intake at the same time that adiposity was measured. Results from this longitudinal study provide more definitive evidence than do those from previous cross-sectional studies (30–33) on the relation between sweetened beverage intake and measures of adiposity and extend previous findings from other longitudinal studies (34–39) in children and adolescents; the strength of this study is the number of measurement occasions over a 10-y period. Our failure to note associations between the consumption of fruit juice or milk and adiposity is consistent with previous studies that have indicated that fruit juice and milk intakes are not related to adiposity (6–8, 10, 12, 40). Furthermore, our findings corroborate the well-documented negative relation between milk and sweetened beverages in the diets of children and adolescents (13, 14).

TABLE 4
Percentage body fat, waist circumference, BMI-for-age percentile, and percentage of girls aged 5–15 y classified as being overweight for those who consumed <1, ≥1 and <2, or ≥2 servings/d of a sweetened beverage at age 5 y[1]

Variable	Frequency of intake[2]	Age 5 y	Age 7 y	Age 9 y	Age 11 y	Age 13 y	Age 15 y	*P* value Group	Age	Group × age
	servings/d									
Body fat (%)	<1	20.2 ± 3.6[3]	21.4 ± 5.2	25.4 ± 6.4	26.9 ± 6.9	26.4 ± 6.6	27.4 ± 5.5			
	≥1 and <2	19.8 ± 3.6	20.6 ± 4.5	26.8 ± 8.0	26.9 ± 7.6	26.6 ± 7.1	28.1 ± 6.6	<0.01	<0.01	<0.01
	≥2	23.9 ± 6.4	25.7 ± 7.4	31.4 ± 8.1	30.9 ± 5.5	29.1 ± 6.7	29.4 ± 6.0			
Waist circumference (cm)	<1	—[4]	58.8 ± 5.8	65.5 ± 7.7	71.5 ± 9.7	77.0 ± 9.8	77.8 ± 9.3			
	≥1 and <2	—[4]	58.3 ± 5.3	66.4 ± 8.3	74.1 ± 11.6	79.0 ± 11.1	79.1 ± 10.6	<0.05	<0.01	NS
	≥2	—[4]	63.2 ± 7.9	72.5 ± 9.9	78.7 ± 10.6	83.7 ± 11.8	81.6 ± 11.9			
BMI-for-age percentile	<1	57.6 ± 25.5	56.2 ± 27.3	60.8 ± 27.3	60.1 ± 27.0	60.1 ± 26.2	60.3 ± 25.5			
	≥1 and <2	56.6 ± 26.6	56.3 ± 26.7	63.0 ± 26.8	63.6 ± 29.4	62.4 ± 25.3	60.4 ± 23.9	<0.05	NS	NS
	≥2	70.5 ± 28.9	69.4 ± 29.4	77.1 ± 22.4	75.4 ± 22.5	70.6 ± 26.9	66.6 ± 25.2			
Overweight (%)[5]	<1	16.1	15.1	24.2	21.7	22.2	18.5			
	≥1 and <2	11.8	11.8	29.4	29.4	19.6	18.4	<0.01	NS	NS
	≥2	38.5	46.2	46.2	53.9	46.2	32.0			

[1] Mixed modeling analyses of variance were used to generate the data in this table.
[2] Frequency of sweetened beverage intake defined at 5 y: <1 (n = 93), ≥1 and <2 (n = 51), ≥2 (n = 26).
[3] Means ± SD (all such values).
[4] Data not available.
[5] Overweight is defined as ≥85th BMI-for-age percentile (23).

In support of our second hypothesis, higher intakes of sweetened beverage at an early age were associated with higher adiposity and weight status. Girls who consumed ≥2 sweetened beverage servings/d at age 5 y had greater adiposity and weight status and were more likely to be overweight than were girls classified with lower intakes over the study period. These results agree with other studies that indicate positive associations between sweetened beverage intake and BMI (34, 35, 37, 41, 42), but we extend these findings with measures of waist circumference and percentage body fat by DXA.

Several studies have provided evidence that the association between sweetened beverage intake and adiposity is mediated by the additional energy provided by higher intake of sweetened beverage consumption, which leads to positive energy balance and increased adiposity (3). However, we showed that the association between sweetened beverage and adiposity remained significant after initial energy intake at age 5 y was controlled for. Furthermore, despite significant differences in adiposity and weight status between sweetened beverage groups, no differences in 24-h energy intake across the groups were noted. It is possible that 24-h energy differences between sweetened beverage groups may have not been detected because of greater tendencies toward underreporting bias among heavier girls and because underreporting also increases at later ages (43–45). However, we showed that girls drinking ≥2 servings of sweetened beverage at age 5 y had a significantly higher percentage of energy from sweetened beverages over the study period (data not shown). The high fructose content of many sweetened beverages may explain links to obesity that are based on differences in the rates of digestion and absorption between fructose and glucose (46).

The association between sweetened beverage intake and adiposity in girls persisted but was attenuated as participants aged by the inclusion of parental characteristics in the model. Girls who were already consuming more servings of sweetened beverage by age 5 y were living in families with lower levels of parental education, lower income, and higher parental BMIs at study entry. Characteristics of parents and family environments are recognized as having a substantial influence on childhood weight status (47–49). Beverage availability and parental beverage intake provide a strong environmental influence for children's beverage intake (50). Cost may be a factor in familial beverage choices (51). The cost of fruit juice and milk is higher than the cost of sweetened beverages, which represents a clear barrier for families to choose healthy alternatives (51). Thus, it is possible that parents of girls drinking ≥2 servings of sweetened beverage at age 5 y chose to purchase a less expensive, less healthy beverage for their family.

A limitation of this study is the inability to generalize results beyond non-Hispanic white girls. Furthermore, the relatively small sample size may have limited power to detect effects—for example, the failure to note differences in 24-h energy intake across sweetened beverage groups. Also, these data were self-reported; thus, there is the potential for reporting bias. In fact, previous investigators have contended that foods that are high in added sugars, such as sodas, are selectively underreported (43, 52). Given the observational nature of this study, we cannot infer that the observed associations are causal; however, our data implicate early sweetened beverage intake in the development and persistence of obesity. The pattern of effects noted for the covariates used in this study suggests that sweetened beverage intake may be a marker of other lifestyle differences that affect adiposity.

The prospective design of this study provided several strengths. We used a longitudinal data set, which allowed us to predict measures of adiposity and weight status during childhood and adolescence. Childhood and adolescence is a developmental period during which major social, environmental, and biological changes occur that may have a persistent effect throughout life. This prospective, longitudinal design offers advantages over previous cross-sectional and longitudinal research by assessing beverage intake and measures of adiposity repeatedly over 10 y. In addition, this study examined several different beverages and their effect on measures of adiposity. Finally, the availability of measures in this data set gave us the opportunity to include additional measures of the family environment that are associated with girls' beverage intake and measures of adiposity.

The fact that higher sweetened beverage intake at age 5 y was associated with greater adiposity during the subsequent 10-y period suggests that early guidance, including specific recommendations about limiting the amounts of sweetened beverages in the diets of children and adolescents, are needed (53). Although the American Academy of Pediatrics has issued fruit juice consumption recommendations (54), no specific recommendations have been made regarding sweetened beverage intake. Guidance to limit the early introduction and intake of sweetened beverages and to reduce their availability should include recommendations to substitute these beverages with healthy alternatives, such as reduced-fat milk and water, while also limiting fruit juice, which is consistent with the recommendations of the American Academy of Pediatrics (54).

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