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Adolescent beverage habits and changes in weight over time: findings from Project EAT[1–3]

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ABSTRACT

Background: Obesity in adolescence has been increasing in the past several decades. Beverage habits among adolescents include increased consumption of sugar-sweetened beverages and decreased consumption of milk.

Objective: This study aimed to examine the association between beverage consumption and 5-y body weight change in 2294 adolescents.

Design: Project EAT ("Eating Among Teens") is a 5-y longitudinal study of eating patterns among adolescents. Surveys were completed in 1998–1999 (time 1) and in 2003–2004 (time 2). Multivariable linear regression was used to examine the association between beverage consumption at time 2 and change in body mass index from time 1 to time 2, with adjustments for age, socioeconomic status, race, cohort, physical activity, sedentary behavior, coffee, tea, time 1 body mass index, and beverage variables.

Results: In prospective analyses, consumption of beverages was not associated with weight gain, except for consumption of low-calorie soft drinks (positive association, $P = 0.002$) and white milk (inverse association, $P = 0.03$), but these associations did not appear to be a monotonic linear dose-response relation. The positive association with low-calorie soft drinks was no longer present after adjustment for dieting and parental weight-related concerns, which suggests that the use of low-calorie soft drinks is a marker for more general dietary behaviors and weight concerns.

Conclusions: We showed no association between sugar-sweetened beverage consumption, juice consumption, and adolescent weight gain over a 5-y period. A direct association between diet beverages and weight gain appeared to be explained by dieting practices. Adolescents who consumed little or no white milk gained significantly more weight than their peers who consumed white milk. Future research that examines beverage habits and weight among adolescents should address portion sizes, adolescent maturation, and dieting behaviors. *Am J Clin Nutr* doi: 10.3945/ajcn.2009.27573.

INTRODUCTION

Childhood and adolescent obesity has been increasing in the United States (1, 2). According to the National Health and Nutrition Examination Survey (NHANES), from 2003 to 2006, 31.9% of children and adolescents were overweight or obese (3). Adolescent obesity has been attributed to a variety of factors that are related to diet and physical activity (4). One dietary factor, which has recently been gaining attention, is beverage consumption.

Beverages are currently contributing more calories and a larger percentage of daily energy intake than at any other time in history (5). According to NHANES 2002, the average American consumes 21% of their daily energy intake from beverages (up from 11.8% in 1965) (5). Data from the US Department of Agriculture Continuing Surveys of Food Intakes by Individuals from 1977 to 1994 indicate that soft drink consumption among adolescents increased by 74% among males and by 65% among females while at the same time milk consumption decreased from 82% to 57% among males and from 72% to 52% among females (6). Studies suggest that sugar-sweetened beverages may lead to increased energy intake because the calories consumed in liquid form may be less satiating than calories consumed in solid form (7, 8) and that milk is more satiating than sugar-sweetened soft drinks due to its protein content (9).

A recent publication by Haines et al (10), which used data from Project EAT ("Eating Among Teens"), assessed a variety of factors influencing adolescent weight status, which included milk, sugar-sweetened beverages, and diet soda consumption. The purpose of the present study was to expand on the analyses of Haines et al (10) to more fully examine associations between beverage intake and change in body mass index (BMI; in kg/m^2) over 5 y by including all beverages in a model to take into account correlations among beverages that may be a source of confounding. For descriptive purposes and to identify potential confounders, we also examined the correlations among the various beverages as well as the associations between beverage habits and sociodemographic characteristics, physical activity, and dietary variables. Furthermore, we adjusted the associations for dieting and parental weight-related concerns. We hypothesized that sugar-sweetened beverages would be positively associated with weight gain over the 5-y period and that milk intake would be inversely associated with weight gain.

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SUBJECTS AND METHODS

Study population and design

Project EAT is an ongoing prospective cohort study examining eating and weight-related issues in adolescents (11–15). A diverse population of 4746 adolescents from various socioeconomic and ethnic backgrounds in 31 public middle and high schools in the Minneapolis/St Paul metropolitan area of Minnesota participated in Project EAT-I during the 1998–1999 school year.

Project EAT-II is a follow-up study aimed at resurveying all of the original participants of Project EAT-I by mail 5 y later (2003–2004) to assess changes in eating patterns and weight status as they moved from adolescence to early adulthood. Of the original study population, 1049 subjects were lost to follow-up for various reasons including missing contact information. Although the remaining sample is somewhat biased demographically from the original sample, we have statistically weighted all of our regression variables in the current analyses so that results are generalizable to the original full cohort (11–15). The data were weighted to adjust for differential response rates by using the response propensity method, with the inverse of the estimated probability that an individual would respond at time 2 used as the weight. Response propensities (ie, the probability of responding to the survey) were estimated by using a logistic regression of response to the EAT-II (time 2 survey participation, yes/no) on a large number of predictor variables available from the EAT-I survey (time 1 survey). The selected response propensity model included the main effects for baseline, sex, native born, race-ethnicity, socioeconomic status, overweight status, parental marital status, individual's concern about health, and most common grade in school. The weighting method results in estimates representative of the demographic makeup of the original sample.

From the remaining participants, 2516 completed the mailed surveys. We excluded those who did not complete food-frequency questionnaires at time 1 or time 2, had implausible energy intakes, and did not report BMI at time 1 or time 2. Data were collected in compliance with the University of Minnesota's Institutional Review Board and Human Subjects Committee. The final sample size was 2294 participants (1032 males and 1262 females). The mean age of the study participants at time 1 was 14.9 y. The racial-ethnic backgrounds included the following: 62.9% white, 17.9% Asian American, 9.7% African American, 3.9% Hispanic, 2.7% American Indian, and 2.9% mixed/other.

Measures

Beverage intake, as well as energy intake, nutrients, and food groups, was assessed with the 149-item youth and adolescent food-frequency questionnaire (YAQ). The YAQ has been tested for validity and reliability and has been shown to be within acceptable ranges for dietary assessment tools for this age group (16, 17). Beverages assessed in the YAQ are soft drinks, punch (Hawaiian punch, lemonade, Koolaid, or other noncarbonated fruit drink), low-calorie soft drinks, milk, chocolate milk, instant breakfast, apple juice, orange juice, sweetened iced tea, beer, liquor (eg, vodka or rum), wine or wine coolers, tea, and coffee. Responses ranged from "never/less than once per month" to ≥4 glasses, cups, cans, or drinks per day depending on the type of beverage. Other variables assessed by the YAQ that may be confounders (or mediators in the case of energy intake) of the association between beverage intake and BMI change included total energy (kcal/d), fiber (g/1000 kcal), percentage of total diet from saturated fat (%kcal), and calcium (mg/d), as well as intake of grains, fruit, vegetables, meats, and snacks (servings per day).

BMI was derived by using the standard metric formula: weight in kilograms divided by the square of height in meters. At time 1, in addition to collecting self-reports of height and weight, trained research staff also measured height and weight in a private screened area by using standardized equipment and procedures. Self-reported and measured BMI values were shown to be highly correlated ($r \geq 0.85$) (18). At time 2, participants filled out mailed surveys, so only self-reported heights and weights were collected. Self-reported BMI at times 1 and 2 were used in our analyses to assess change in BMI. Adolescents were classified on the basis of the Must et al (19, 20) classification for overweight status (BMI ≥85th percentile for sex and age on the basis of NHANES).

Sociodemographic characteristics were based on self-report at time 1 and included age, sex, ethnicity/race, and socioeconomic status (SES). SES was primarily based on parent education level, which was defined by the highest level of educational attainment of either parent. However, an algorithm was developed that was used for students who did not know their parent's education level and to avoid classifying students as high SES if they were on public assistance, eligible for free/reduced school meals, or had 2 unemployed parents (21). SES levels reported in Project EAT-I by adolescents and a subsample of 861 parents of participating adolescents who were interviewed by telephone were compared and correlations were shown to be acceptable ($r = 0.68$) (12). In addition, a binary cohort variable was created that classified the adolescents into older (≥15 y of age) and younger (<15 y of age) cohorts at baseline.

Dieting and parental weight-related concerns were assessed with the Project EAT survey. Dieting was assessed with the question, "How often have you gone on a diet during the last year? By 'diet' we mean changing the way you eat so you can lose weight." Responses ranged from "never" to "I'm always dieting" on a 5-point scale. Parental weight-related concerns were assessed with the question "My mother/father encourages me to diet to control my weight." Responses ranged from "not at all" to "very much" on a 4-point Likert scale.

Other behaviors with the potential to influence beverage consumption and its association with weight status were also examined. Smoking was assessed with the single question, "How often have you used cigarettes during the past year (12 mo)?" Responses ranged from "never" to "daily" (22). Physical activity was measured by using questions adapted from the Leisure Time Exercise Questionnaire (23, 24). Adolescents were asked: "In a usual week, how many hours do you spend doing the following activities?" Activity was categorized as "strenuous (heart beats rapidly)" and "moderate (not exhausting)." Examples of specific activities were given after each question. Responses ranged from 0 to ≥6 h/wk. Sedentary activity was examined by using questions modified from Planet Health (25): "In your free time on an average weekday (Monday–Friday), how many hours do you spend watching TV and videos?" and "In your free time on an average weekend day (Saturday or Sunday), how many hours

do you spend watching TV and videos?" Responses ranged from 0 to ≥5 h/d.

Statistical analysis

SAS version 9.1 (SAS Institute, Cary, NC) was used for all analyses. Beverages examined as independent variables included soft drinks, punch, low-calorie drinks, milk, chocolate milk, orange juice, and apple juice. Other beverages were considered as covariates: instant breakfast, beer, liquor, wine or wine coolers, tea, coffee, and sweetened iced tea. Sweetened iced tea was originally included as a main exposure variable, but because of a limited range of reported intake for this beverage we were unable to estimate the association with weight gain with sufficient precision (data not shown). Beverage frequency within each beverage was described in 3 categories—"rarely/never," "0.5–6 times per week," and "≥7 per week"—to make clear comparisons among beverages consumed. For descriptive purposes, unadjusted associations between nonbeverage covariates and beverage categories for each beverage were examined by using chi-square tests or simple linear regression models at time 1. Spearman correlations were used to assess the relation between beverages at time 1 and time 2. Multivariable linear regression was used to examine the association between time 2 beverages (independent variables) and change in BMI, with time 1 BMI and beverages as covariates.

In model 1, we used multivariable linear regression to assess the association between each beverage individually and change in BMI and adjusted for potential confounders including age, sex, race, SES, baseline BMI, and baseline beverage consumption of the beverage being analyzed. In model 2, we assessed the relation between beverage intake and change in BMI while taking into account all beverages consumed and other lifestyle and dietary factors, described above, that may affect the relation. We combined all beverages at time 2 into one model and adjusted for all beverages at time 1 as well as for additional factors that may have been confounders of beverage intake and BMI change, which included the beverage variables (milk, soft drinks, punch, low-calorie drinks, chocolate milk, apple juice, and orange juice), change in BMI, baseline BMI, cohort, strenuous exercise, time 2 weekday television watching, coffee, and tea. Covariates with high P values (>0.20), which were most of the dietary factors described above, were not included in the model. To examine several a priori hypotheses regarding effect modification of the beverage and BMI change associations, we added the following interaction terms to model 2: intake of each beverage and BMI percentile status (≥85th percentile compared with <85th percentile), sex, age (≥15 y compared with <15 y), and ethnicity (white compared with nonwhite). None of these terms were statistically significant ($P > 0.10$ for all), and thus we did not stratify any of the models.

Finally, to examine a more parsimonious model (model 3) that included our primary beverages of interest—milk and soft drinks—we removed the beverage variables with P values >0.20 (chocolate milk, apple juice, orange juice, and punch). Furthermore, we adjusted model 3 for dieting and parental weight-related concerns, which were identified as possible confounders of beverage consumption and change in BMI, because we were interested in examining the association with low-calorie beverages.

RESULTS

Baseline correlates

Baseline correlates for descriptive purposes, including sociodemographic characteristics, physical activity, and measures of dietary intake, of sugar-sweetened beverages and milk/juice intake are shown in **Table 1** and **Table 2**, respectively. At baseline, the majority of participants consumed ≥7 servings of white milk per week (n = 1289). Most of the study participants consumed sugar-sweetened beverages (punch and soft drinks) 0.5–6 times/wk (n = 1456 and n = 1325, respectively). The

TABLE 1
Baseline correlates of sugar-sweetened beverage and low-calorie soft drink intake in Project EAT ("Eating Among Teens")[1]

	Soft drinks (servings/wk)			Punch (servings/wk)			Low-calorie soft drinks (servings/wk)		
	0	0.5–6	≥7	0	0.5–6	≥7	0	0.5–6	≥7
n	241	1325	612	313	1456	401	1409	636	135
Sex [n (%)]									
Female	158 (65.6)	758 (57.2)	274 (44.8)[2]	191 (61.0)	786 (54.0)	206 (51.4)	707 (50.2)	388 (61.0)	95 (70.4)[2]
Male	83 (34.4)	567 (42.8)	338 (55.2)[2]	122 (39.0)	670 (46.0)	195 (48.6)	702 (49.8)	248 (39.0)	40 (29.6)[2]
Age (y)	14.9 ± 0.1[3]	14.8 ± 0.0	15.1 ± 0.1[2]	15.0 ± 0.1	14.9 ± 0.0	14.9 ± 0.1	14.9 ± 0.0	14.8 ± 0.1	14.9 ± 0.1
Ethnicity-race [n (%)]									
White	144 (59.7)	535 (40.4)	159 (25.9)[2]	186 (59.3)	954 (65.5)	244 (60.8)[2]	881 (62.5)	411 (64.6)	99 (73.1)
Nonwhite	97 (40.3)	790 (59.6)	453 (74.1)[2]	127 (40.7)	502 (34.5)	157 (39.2)[2]	528 (37.5)	225 (35.4)	36 (26.9)
SES (highest) [n (%)]	45 (18.8)	249 (18.8)	87 (14.2)[2]	67 (21.3)	246 (16.9)	66 (16.5)	248 (17.6)	108 (17.0)	26 (19.4)
Strenuous exercise (h/wk)	4.1 ± 0.1	3.9 ± 0.0	3.9 ± 0.1	3.5 ± 0.1	3.9 ± 0.0	4.2 ± 0.1[2]	3.9 ± 0.0	3.9 ± 0.1	3.5 ± 0.1[2]
Dietary intakes									
Energy (kcal/d)	1885 ± 62	1947 ± 26	2414 ± 38[2]	1653 ± 53	2018 ± 24	2574 ± 46[2]	2093 ± 26	2020 ± 39	2101 ± 85
Saturated fat (%kcal)	10.0 ± 0.2	10.3 ± 0.1	10.5 ± 0.1[2]	10.1 ± 0.1	10.5 ± 0.1	9.9 ± 0.1[2]	10.4 ± 0.1	10.1 ± 0.1	10.3 ± 0.2[2]
Fiber (g/1000 kcal)	9.2 ± 0.2	8.2 ± 0.1	6.5 ± 0.1[2]	8.6 ± 0.1	7.8 ± 0.1	7.1 ± 0.1[3]	7.6 ± 0.1	8.0 ± 0.1	8.1 ± 0.2[2]
Calcium (mg/d)	590 ± 15	578 ± 6	522 ± 9[2]	602 ± 13	563 ± 6	535 ± 11[2]	562 ± 6	570 ± 9	559 ± 20

[1] SES, socioeconomic status.
[2] $P < 0.05$ for chi-square and F values.
[3] Mean ± SE (all such values).

TABLE 2
Baseline correlates of milk and juice intake in Project EAT ("Eating Among Teens")[1]

	White milk (servings/wk)			Chocolate milk (servings/wk)			Apple juice (servings/wk)			Orange juice (servings/wk)		
	0	0.5–6	≥7	0	0.5–6	≥7	0	0.5–6	≥7	0	0.5–6	≥7
n	160	710	1289	1014	974	168	276	1307	497	216	1279	587
Sex [*n* (%)]												
Female	97 (60.6)	452 (63.7)	626 (48.6)[2]	638 (62.9)	463 (47.5)	71 (42.3)[2]	123 (44.6)	714 (54.6)	297 (59.8)[2]	128 (59.3)	688 (53.8)	319 ± 54.3[2]
Male	63 (39.4)	258 (36.3)	663 (51.4)[2]	376 (37.1)	511 (52.5)	97 (57.7)[2]	153 (55.4)	593 (45.4)	200 (40.2)[2]	88 (40.7)	591 (46.2)	268 (45.7)[2]
Age (y)	15.1 ± 0.1[3]	14.9 ± 0.1	14.9 ± 0.0	15.0 ± 0.1	14.8 ± 0.1	14.9 ± 0.1	15.0 ± 0.1	14.9 ± 0.0	14.8 ± 0.1	14.9 ± 0.1	14.9 ± 0.0	14.9 ± 0.1[2]
Ethnicity-race [*n* (%)]												
White	68 (42.5)	347 (48.9)	967 (75.0)[2]	599 (59.1)	675 (69.3)	104 (62.2)[2]	186 (67.5)	873 (66.8)	280 (56.3)[2]	143 (66.4)	838 (65.5)	359 (61.2)
Nonwhite	92 (57.5)	363 (51.1)	322 (25.0)[2]	415 (40.9)	299 (30.7)	64 (37.8)[2]	90 (32.5)	434 (33.2)	217 (43.7)[2]	73 (33.6)	441 (34.5)	228 (38.8)
SES (highest) [*n* (%)]	13 (7.9)	88 (12.4)	275 (21.3)[2]	192 (18.9)	168 (17.2)	17 (10.4)[2]	48 (17.5)	223 (17.1)	95 (19.1)	32 (15.0)	212 (16.6)	123 (20.9)[2]
Strenuous exercise (h/wk)	3.5 ± 0.1	3.6 ± 0.1	4.1 ± 0.0[2]	3.8 ± 0.0	4.0 ± 0.0	4.1 ± 0.1[2]	3.7 ± 0.1	3.9 ± 0.0	4.1 ± 0.1[2]	3.7 ± 0.1	3.8 ± 0.0	4.2 ± 0.1[2]
Dietary intakes												
Energy (kcal/d)	1577 ± 77	1839 ± 35	2256 ± 26[2]	1836 ± 29	2187 ± 30	2802 ± 71[2]	1652 ± 55	1984 ± 25	2661 ± 40[2]	1721 ± 62	1920 ± 25	2633 ± 37[2]
Saturated fat (%kcal)	9.5 ± 0.2	10.3 ± 0.1	10.4 ± 0.1[2]	10.1 ± 0.1	10.6 ± 0.1	10.5 ± 0.2[2]	10.6 ± 0.1	10.4 ± 0.1	9.5 ± 0.1[2]	10.8 ± 0.2	10.4 ± 0.1	9.5 ± 0.1[2]
Fiber (g/1000 kcal)	8.2 ± 0.2	8.0 ± 0.1	7.6 ± 0.1[2]	8.1 ± 0.1	7.6 ± 0.1	7.3 ± 0.2[2]	7.5 ± 0.1	7.9 ± 0.1	8.4 ± 0.1[2]	7.2 ± 0.2	7.8 ± 0.1	8.6 ± 0.1[2]
Calcium (mg/d)	329 ± 15	414 ± 7	674 ± 5[2]	527 ± 7	580 ± 7	709 ± 17[2]	568 ± 13	564 ± 6	523 ± 9[2]	569 ± 15	563 ± 6	531 ± 9[2]

[1] SES, socioeconomic status.
[2] $P < 0.05$ for chi-square and F values.
[3] Mean ± SE (all such values).

majority of participants responded that they "never/rarely consumed" low-calorie soft drinks (n = 1409) or chocolate milk (n = 1014).

Spearman correlation coefficients

When correlations between beverage categories at time 2 were assessed (data not shown in tables), the highest correlation was shown between apple juice and orange juice (r = 0.38, $P <$ 0.001). Punch was correlated with apple juice (r = 0.27, $P <$ 0.001), sweetened soft drinks (r = 0.25, $P < 0.001$), and orange juice (r = 0.15, $P < 0.001$). Sweetened soft drinks were inversely correlated with low-calorie soft drinks ($r = -0.16$, $P <$ 0.001), and white milk was positively correlated with chocolate milk (r = 0.26, $P < 0.001$). White milk and soft drinks were not correlated (r = 0.04, P = 0.07). Similar correlations were shown between beverage categories at time 1 (data not shown).

Prospective analyses of beverages at time 2 and change in BMI

Model 1

In model 1 (**Table 3**), beverages were assessed individually and adjusted for time 1 BMI, time 1 beverage and sociodemographic characteristics. The only statistically significant association in model 1 between beverage consumption and 5-y change in BMI was in the low-calorie soft drink category ($P < 0.01$). The association was positive, but it did not appear to be a monotonic linear dose-response relation.

Model 2

In model 2 (Table 3), all beverages were included in the model at once and adjusted for model 1 covariates in addition to all time 1 beverages and additional confounding lifestyle factors. A similar pattern to model 1 was shown in the low-calorie soft drinks category of model 2 ($P < 0.01$). The mean change in BMI (mean ± SE) was largest in the adolescents who consumed 0.5–6 servings/wk (2.30 ± 0.15), followed by those who consumed >7 servings/wk (2.02 ± 0.28) and those who consumed low-calorie soft drinks "never/rarely" (1.68 ± 0.09). The only statistically significant difference between serving categories was between "never/rarely" and 0.5–6 servings/wk ($P < 0.01$). The difference between 0.5–6 and ≥7 servings/wk was not significant (P = 0.36). Similarly, the difference between "never/rarely" and ≥7 servings/wk was not significant (P = 0.26).

Further adjustment in model 2 also resulted in a significant inverse association between white milk and weight gain (P = 0.05), but, similar to low-calorie soft drinks, it did not appear to be a monotonic linear dose-response relation. Adolescents who consumed white milk "rarely/never" had the largest change in BMI (2.33 ± 0.25), followed by adolescents who consumed white milk ≥7 servings/wk (1.94 ± 0.11) and 0.5–6 times/wk (1.64 ± 0.12). The only statistically significant difference between serving categories was between "never/rarely" and 0.5–6 servings/wk ($P < 0.05$), which remained statistically significant after Bonferroni correction for multiple comparisons. The difference between 0.5–6 and ≥7 servings/wk was marginally significant (P = 0.07), and the difference between "never/rarely" and ≥7 servings/wk was not significant (P = 0.16). With respect to the other beverage variables, we did not observe any other

TABLE 3
Change in BMI (in kg/m^2) over 5 y by number of servings per week of time 2 beverage categories (n = 2294)[1]

	Change in BMI							
	Model 1 (servings/wk)[2]				Model 2 (servings/wk)[3]			
	0	0.5–6	≥7	P value[4]	0	0.5–6	≥7	P value[4]
Soft drinks	1.66 ± 0.17	1.92 ± 0.10	1.77 ± 0.14	0.36	1.74 ± 0.18	1.92 ± 0.10	1.80 ± 0.15	0.60
Punch	1.93 ± 0.17	1.85 ± 0.09	1.74 ± 0.18	0.76	2.02 ± 0.18	1.80 ± 0.09	1.93 ± 0.20	0.50
Low-calorie soft drinks	1.66 ± 0.09	2.27 ± 0.15[5]	2.05 ± 0.27	0.001	1.68 ± 0.09	2.30 ± 0.15[5]	2.02 ± 0.28	0.002
White milk	2.25 ± 0.24	1.70 ± 0.11	1.88 ± 0.11	0.08	2.33 ± 0.25	1.64 ± 0.12[6]	1.94 ± 0.11	0.05
Chocolate milk	1.87 ± 0.09	1.77 ± 0.12	2.09 ± 0.42	0.68	1.89 ± 0.10	1.77 ± 0.12	2.43 ± 0.44	0.31
Orange juice	1.83 ± 0.19	1.90 ± 0.09	1.54 ± 0.18	0.20	1.67 ± 0.19	1.94 ± 0.09	1.70 ± 0.19	0.28
Apple juice	1.89 ± 0.16	1.89 ± 0.09	1.56 ± 0.20	0.30	1.84 ± 0.17	1.91 ± 0.09	1.60 ± 0.21	0.42

[1] All values are adjusted means ± SEMs.
[2] Model 1: beverages were assessed individually and adjusted for age, sex, race-ethnicity, socioeconomic status, baseline BMI, and baseline of same beverage.
[3] Model 2: beverages were assessed together in the model and adjusted for all baseline beverages, baseline BMI, age, cohort, sex, race-ethnicity, and socioeconomic status; baseline and time 2 strenuous physical activity; and time 2 weekday television watching and coffee and tea consumption.
[4] Obtained by overall F test for each beverage.
[5,6] Significantly different from 0 serving/wk: [5]$P < 0.01$, [6]$P < 0.05$.

significant associations in model 2 between the beverage variables and change in BMI.

Model 3

In model 3 (**Table 4**), when only white milk, soft drinks, and low-calorie soft drinks were analyzed without the other beverage variables as a more parsimonious model, a statistically significant inverse association was shown between white milk intake and change in BMI (P = 0.03), and a significant positive association was shown between low-calorie soft drinks and change in BMI ($P < 0.01$). However, there did not appear to be monotonic linear dose-response relations between the beverage variable and change in BMI. Further adjustment for dieting and parental weight-related concerns, however, appeared to explain the positive association between low-calorie soft drinks and change in BMI because after adjustment the association was no longer significant (P = 0.13).

DISCUSSION

We examined prospective associations between beverage consumption and weight gain in a large diverse sample of adolescents in Minnesota. Contrary to our hypothesis, sugar-sweetened beverages were not shown to be positively associated with weight gain. However, white milk was shown to be inversely associated with weight gain, although not monotonically. Interestingly, we observed a significant positive association between low-calorie soft drink intake and weight gain. However, this association was no longer present after adjustment for dieting and parental weight-related concerns.

In contrast to the present study, 6 prospective studies have shown a positive association between sugar-sweetened beverages and weight gain (7, 8, 26–29) However, only 2 of the studies were at least 3 y in length with a study population >250 adolescents (27, 28). Consistent with the present study, the study by Libuda et al (29) also showed that, in boys, fruit juice and soft drink consumption were not associated with change in BMI. The present study also expands on the results of the publication by Haines et al (10) from the Project EAT data set, which showed that overweight status as a dichotomy was associated with sugar-sweetened beverage consumption. However, in the present study, which adjusted for all beverages consumed, the association was no longer present.

We also are aware of 2 randomized trials (30, 31) and one meta-analysis (32–34) related to beverage consumption and adolescent weight. In both trials, sugar-sweetened beverage consumption decreased in the intervention groups while consumption increased or stayed the same in the control groups. Nonetheless, change in BMI was not significantly different between the intervention and control groups except in the upper baseline BMI tertile (>25.6) of the Ebbling et al study (31) in which a significant intervention effect was observed. The recent meta-analysis by Forshee et al (32) observed that the overall association between sugar-sweetened beverage consumption and weight gain in children and adolescents was near zero. Given the high energy content of sugar-sweetened beverages, the lack of consistent findings showing a positive association with weight gain over time is somewhat counterintuitive. Certainly, difficulties in assessing the portion sizes of beverages, particularly soft drinks, needs to be considered in interpreting these findings.

With respect to milk consumption in adolescents, in contrast to the present study that observed a nonmonotonic, inverse association between milk consumption and weight gain, 2 prospective studies have observed a positive association (27, 35) and one has observed no association (28). In the studies that observed a positive association, estimates became considerably smaller after adjusting for total energy intake, which indicates that calories may explain the association between beverages and change in BMI. Furthermore, unlike the present study, both studies did not differentiate between white milk and chocolate milk. Three randomized controlled trials conducted with dairy product supplementation in adolescents detected no significant differences in body weight or body composition changes (36–38). However, these trials had a number of limitations, which included short study duration, age selection, and possible confounding due to puberty status.

TABLE 4
Change in BMI (in kg/m^2) over 5 y by number of servings per week of time 2 soft drinks, low-calorie soft drinks, and white milk, with further adjustment for dieting, in model 3[1]

	Change in BMI			
	0 serving/wk	0.5–6 serving/wk	≥7 servings/wk	*P* value[2]
Soft drinks	1.81 ± 0.17	1.93 ± 0.10	1.81 ± 0.15	0.73
Adjusted for dieting variables[3]	1.79 ± 0.18	1.95 ± 0.10	1.83 ± 0.16	0.66
Low-calorie soft drinks	1.69 ± 0.09	2.33 ± 0.15[4]	2.01 ± 0.28	0.002
Adjusted for dieting variables[3]	1.80 ± 0.09	2.15 ± 0.15	1.81 ± 0.29	0.13
White milk	2.34 ± 0.24	1.68 ± 0.11[5]	1.93 ± 0.11	0.03
Adjusted for dieting variables[3]	2.27 ± 0.25	1.69 ± 0.12[5]	1.98 ± 0.11	0.04

[1] All values are adjusted means ± SEs. Soft drinks, low-calorie soft drinks, and white milk were assessed together in the model and adjusted for age, cohort, sex, race-ethnicity, socioeconomic status, and baseline BMI; baseline white milk, soft drink, and low-calorie drink consumption; baseline and time 2 strenuous physical activity; and time 2 weekday television watching and coffee and tea consumption.

[2] Obtained by overall *F* test for each beverage.

[3] Also adjusted for baseline and time 2 dieting and parental weight-related concerns.

[4,5] Significantly different from 0 serving/wk: [4]$P < 0.01$, [5]$P < 0.05$.

In the present study, consumption of low-calorie soft drinks was positively associated with weight gain. These findings are consistent with 2 prospective studies of metabolic syndrome in adults (39, 40) and with one study of change in BMI in adolescents (27). The positive association between low-calorie soft drinks and change in BMI in the present study was explained by dieting and parental weight-related concerns, which the above studies did not adjust for in their analyses. Our findings suggest that low-calorie soft drink consumption was associated with dieting behaviors, which, in turn, was associated with weight gain. Dieting has been shown to be associated with weight gain in several previous studies with adolescents (41–44).

The present study has a number of strengths that are worth noting. First, the prospective study design of Project EAT allowed for the evaluation of longitudinal associations between beverage consumption and change in BMI over a critical period of growth and development. Second, the assessment of a variety of beverages allowed for the examination of overall beverage habits and not just sugar-sweetened beverage or milk associations. Finally, the assessment of dieting and weight-related concerns allowed for the evaluation of their effects on the association between low-calorie soft drinks and change in BMI.

A major study limitation was the necessity of collecting data by self-report of exposure and outcome variables. Beverage consumption was assessed by using the YAQ, a self-report food-frequency questionnaire, which may have underestimated intakes. However, the YAQ has been evaluated and is considered to be a valid form of dietary assessment for adolescents (16). Although the YAQ did suggest portion sizes—"milk (glass or with cereal)"—it did not specify the number of ounces in a glass, can, bottle, or cup. The lack of accurate assessment of portion sizes is particularly problematic for soft drinks, which come in different sizes of cups, cans, and bottles. Because of this limitation, our analyses may have been further biased toward the null. The YAQ was not able to evaluate all beverages consumed by adolescents, including soymilk, energy drinks, or sports drinks, which may have an effect on overall beverage habits. There may also be residual confounding due to a limited number of food groups that may pertain to dietary habits related to soft drink intake (eg, fast-food habits). Furthermore, BMI was assessed according to self-reported height and weight. Although this may lead to self-report biases and errors, correlations at baseline between measured and self-reported BMIs were high (18). Finally, this study was not able to assess sexual maturation stages or puberty status of the adolescents. Sexual maturation has been associated with obesity in both boys and girls and should be assessed, if possible, when evaluating adolescent obesity (45–47).

Beverage consumption may have a significant effect on public health as intake of sugar-sweetened beverages increases and milk consumption decreases throughout adolescence and into adulthood (6). Interventions with adolescents should promote the consumption of low-fat white milk and other low-calorie, nutrient-dense beverages and decrease the availability of sugar-sweetened beverages in school and home settings. Longitudinal studies and randomized controlled trials, especially with soft drinks, that more accurately address portion sizes, maturation, and dieting, are needed to evaluate the possible causal link between beverage consumption and adolescent obesity and provide a basis for future community-based intervention strategies.

The authors' responsibilities were as follows—MSV contributed to the design of the study and the statistical analyses and was the primary writer of the manuscript; MAP contributed to the design and to the writing of the manuscript and was the primary analyst; DN-S contributed to the design, analysis, and writing; and SKR contributed to the design and writing. None of the authors had any conflicts of interest.

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