Beverage Intake in Early Childhood and Change in Body Fat from Preschool to Adolescence

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Abstract

Background: Childhood obesity is closely associated with adult obesity, hypertension, and cardiovascular disease. This study's aim was to determine the effects of beverage intake patterns on body composition from early childhood into adolescence in the Framingham Children's Study.

Methods: Multiple sets of 3-day records were used to assess diet over 12 years, beginning in 1987, in 103 non-Hispanic white boys and girls. BMI, waist circumference, and four skinfolds (triceps, subscapular, suprailiac, and abdominal) were measured yearly. Percent body fat was assessed by dual-energy X-ray absorptiometry at end of follow-up. Analysis of covariance and longitudinal mixed modeling were used to control for potential confounding by age, baseline body fat, percent of energy from fat, television/video viewing time, other beverage intakes not included in exposure group, mother's education, and BMI.

Results: Children with the lowest milk intakes in early childhood had 7.4% more body fat in later adolescence than those with higher intakes (30.0% body fat in tertile 1 vs. 22.6% in tertile 3; $p=0.0095$). Fruit and vegetable juice was similarly protective—those in the highest tertile of fruit and vegetable juice intake during childhood had an 8.0-cm smaller waist circumference at 15–17 years of age, compared with those in the lowest tertile ($p=0.0328$). There was no relation between sugar-sweetened beverages (SSBs) and percent body fat ($p=0.9296$) or other outcomes.

Conclusions: These results suggest that adequate intakes of milk and fruit and vegetable juice may reduce the risk of excess body fat in later childhood and adolescence. Further, modest intakes of SSBs in early childhood may not adversely affect body fat change.

Introduction

Childhood obesity is closely linked with adult obesity and related conditions, including hypertension, cardiovascular disease, and type 2 diabetes.^{1,2} The prevalence of overweight and obesity among children has increased dramatically over the past several decades.^{3–5} Data from the 2007–2008 National Health and Nutrition Examination Survey found that 16.9% of children and adolescents had a BMI at or above the 95th percentile on the BMI-for-age growth charts and 31.7% were at or above the 85th percentile of BMI for age.⁶ Identification of modifiable risk factors in early childhood is critical for the prevention of obesity and related comorbidities.

Questions persist about the role of beverage consumption in the development of overweight and obesity during childhood. Recent reviews of observational studies of dairy consumption in children conclude that there is no con-

vincing evidence that dairy has an adverse effect on weight or obesity risk.^{7,8} One review and meta-analysis found little to no association between sugar-sweetened beverage (SSB) consumption and body fat in children and adolescents,⁹ whereas others reached the opposite conclusion.^{10,11} Findings from studies of 100% fruit juice and body fat have yielded inconsistent results, leading a recent review to conclude that the evidence remains unclear.¹²

The aim of this study was to estimate the effect of beverage intake patterns on body fat and composition from early childhood (ages 3–5 years) into adolescence (15–17 years of age) in the prospective Framingham Children's Study (FCS).

Methods

The current analyses were approved by the Boston University Institutional Review Board (Boston, MA) and

used data from the FCS. This longitudinal study was designed to examine development of diet and physical activity habits among third- and fourth-generation descendants of the members of the original Framingham cohort. In 1987, 106 non-Hispanic white two-parent families with a 3- to 5-year-old child were enrolled and followed annually for 12 years. Only 1 child per family was followed. Dietary intake was assessed for each child by collecting up to four sets of 3-day diet records annually. A total of 103 children provided at least some dietary data, and, of these, 98 had both dietary information at 3–9 years of age and follow-up anthropometry measures at ages 15–17 years. Before age 10, the study parents completed all diet records for the child with input from the child and other caregivers. After age 10, the roles of the children and parents were reversed. A study nutritionist instructed each family in the completion of the diet records, including how to use common household measures to estimate portion sizes.

The Nutrition Data System (NDS) of the University of Minnesota¹³ was used to calculate mean nutrient intakes. Average daily intakes of foods and beverages were estimated by combining data output from the NDS from the children's food records with the Food Guide Pyramid¹⁴ servings database available through the technical files of the USDA's Continuing Survey of Food Intakes by Individuals (CSFII).¹⁵ When information on composite foods was insufficient to make an exact match between NDS and CSFII food codes, nutrient content data along with recipe and ingredient information were compared to determine the appropriate servings for each food component. In this way, beverage information was extracted from the diet records in the FCS. Intake data on plain milk, flavored milk, sweetened and unsweetened fruit juices, part-fruit juice beverages, sugar-sweetened nonjuice beverages, including carbonated beverages, tea, and coffee, artificially sweetened nonjuice beverages, including carbonated beverages, tea, and coffee, vegetable juices, soy beverages, rice beverages, and other mixed beverages were assessed. Data were not collected systematically on water intake.

Weight in light clothing and without shoes (to the nearest 0.25 pound) and height without shoes (to the nearest 0.25 inch) were measured annually using a standard counterbalance scale with a measuring bar. BMI was calculated as weight in kilograms divided by height in meters squared. Waist circumference was measured yearly (to the nearest millimeter) with a cloth tape; four skinfolds (SF; *i.e.*, triceps, subscapular, suprailiac, and abdominal) were measured in duplicate to the nearest millimeter using Lange calipers, following a standard protocol. If a between-measure discrepancy of more than 2 mm was observed at any one site, two additional measures were taken. Percent body fat (by region and in total) was measured on a single occasion at the end of follow-up with a Lunar dual-energy X-ray absorptiometry (DXA) scan; percent body fat was calculated as total fat mass divided by total body weight.

Data on the following possible confounders were examined: mother's age, education level, and BMI; and the

child's sex, baseline anthropometric measures of body fat, age at time of anthropometry, physical activity (PA), mean television (TV) and video time, percent of energy from dietary fat, total energy intake, other beverage intakes not included in the exposure group, and Tanner stage. PA was assessed using the Caltrac accelerometer during each examination cycle on multiple days. Usual number of hours of TV and video time on weekdays and weekend days were evaluated by questionnaire. Only those variables found to be independent predictors or confounders were retained in the final multi-variable models (*i.e.*, age, baseline body fat, percent of calories from fat, mean TV and video time, other beverages consumed, and maternal education and BMI).

Statistical Analysis

Each child's mean daily beverage intake was estimated from all days of diet records in each age group. Individual types of beverages were classified into four categories: (1) milk; (2) fruit and vegetable juices; (3) SSBs; and (4) unsweetened (or artificially sweetened) beverages.

Total milk intake comprised both plain and flavored varieties plus small amounts of soymilk and rice beverages. Fruit and vegetable juice included unsweetened fruit juice and small intakes of sweetened fruit and vegetable juices. SSBs combined sweetened carbonated beverages, sweetened noncarbonated beverages, sweetened tea or coffee, and part-juice beverages. Part-juice beverages were primarily juice drinks, often having only 10% fruit juice. Unsweetened/diet beverages included diet/artificially sweetened carbonated and noncarbonated beverages, as well as unsweetened and artificially sweetened tea or coffee.

Intake of each beverage type was measured as ounces (oz) per day. Descriptive data presented include the median and range of beverage intakes per day during four age periods: 3–5, 6–9, 10–12, and 13–17 years. Intake per day in each beverage category was also classified according to sex-specific tertiles of intake. Because the patterns of intake were similar in the two youngest age groups, these two age categories were collapsed for most analyses.

Analysis of covariance models were used to estimate the effects of each beverage type on mean BMI, sum of four SFs, waist circumference, and percent body fat at the end of follow-up (at 15–17 years of age), adjusting for previously described confounders. To maximize power from the repeated measures of both diet and body fat and to adjust for both fixed and changing covariates, longitudinal mixed models were used. These models estimated adjusted mean body fat levels in 2-year intervals (*i.e.*, ages 3–4, 5–6, 7–8, 9–10, 11–12, 13–14, and 15+ years); there were a total of 614 repeated measures among 103 children.

Results

Table 1 illustrates the types of beverages consumed (fluid milk, fruit and vegetable juice, SSBs, and unsweetened/diet beverages) in each of four age periods during

Table 1. Beverage Intake in Four Age Periods during Childhood

	Ages 3–5 (n=98)	Ages 6–9 (n=96)	Ages 10–12 (n=94)	Ages 13–17 (n=92)
Beverages	Median (5th–95th percentile)			
Intake (oz/day)				
Total beverage	21.8 (10.5, 34.8)	22.2 (12.0, 34.8)	25.9 (8.1, 41.2)	33.4 (8.1, 58.0)
Total fluid milk	8.8 (2.2, 15.5)	8.9 (2.6, 21.1)	6.6 (0.0, 18.7)	6.5 (0.0, 21.3)
Plain milk	6.9 (1.0, 14.7)	6.8 (0.7, 18.1)	4.7 (0.0, 15.6)	3.9 (0.0, 16.9)
Flavored milk	0.9 (0.0, 4.9)	1.5 (0.0, 5.7)	1.2 (0.0, 6.9)	1.4 (0.0, 10.2)
Fruit/vegetable juice	5.6 (0.7, 15.0)	4.1 (0.0, 12.2)	3.1 (0.0, 10.7)	3.4 (0.0, 16.9)
Sugar-sweetened beverages	4.5 (0.0, 14.1)	6.4 (1.3, 14.5)	10.0 (2.7, 25.1)	18.0 (4.0, 41.4)
Unsweetened/diet beverages	0.0 (0.0, 3.3)	0.3 (0.0, 5.3)	0.0 (0.0, 7.2)	0.0 (0.0, 8.1)
Percent (%) of daily calories				
Total beverage	19.6 (9.5, 31.3)	17.1 (10.5, 25.5)	16.6 (7.1, 26.4)	19.2 (8.2, 33.8)
Total fluid milk	8.8 (2.8, 17.0)	7.9 (2.0, 18.1)	5.4 (0.0, 17.4)	5.5 (0.0, 17.1)
Plain milk	6.8 (1.5, 15.0)	5.5 (0.5, 15.1)	3.4 (0.0, 10.6)	2.4 (0.0, 9.8)
Flavored milk	1.3 (0.0, 7.4)	1.8 (0.0, 6.4)	1.4 (0.0, 7.4)	1.4 (0.0, 9.2)
Fruit/vegetable juice	5.4 (0.6, 15.7)	3.1 (0.0, 11.1)	2.1 (0.0, 7.6)	2.3 (0.0, 9.0)
Sugar-sweetened beverages	4.0 (0.0, 10.9)	4.5 (1.1, 10.0)	7.2 (1.7, 15.8)	9.0 (2.4, 19.6)
Unsweetened/diet beverages	0.0 (0.0, 0.1)	0.0 (0.0, 0.1)	0.0 (0.0, 0.2)	0.0 (0.0, 0.4)
Percent (%) of total beverage intake				
Total fluid milk	42.3 (11.2, 68.9)	42.3 (12.8, 79.2)	27.0 (0.0, 73.9)	22.8 (0.0, 59.8)
Plain milk	34.1 (7.8, 57.3)	32.7 (4.4, 67.4)	16.7 (0.0, 62.0)	13.5 (0.0, 58.0)
Flavored milk	4.3 (0.0, 26.7)	7.6 (0.0, 31.5)	4.6 (0.0, 25.7)	4.4 (0.0, 26.7)
Fruit/vegetable juice	29.1 (3.9, 66.4)	16.5 (0.0, 51.8)	11.9 (0.0, 43.7)	12.3 (0.0, 42.3)
Sugar-sweetened beverages	23.5 (0.0, 55.8)	29.6 (6.2, 57.6)	46.7 (15.3, 82.6)	56.1 (15.2, 90.7)
Unsweetened/diet beverages	0.1 (0.0, 15.8)	1.2 (0.0, 19.1)	0.0 (0.0, 32.2)	0.0 (0.0, 34.4)
oz, ounces.				

childhood. Whereas total beverage intake increased from ages 3–17 years, there were noticeable differences in the changes in intake of different beverages. Both plain and flavored milk intakes (oz/day) and percent of total beverages derived from milk began to decrease at 10–12 years of age. Before age 10, milk constituted approximately 42% of all beverages consumed; this was reduced by half by 13–17 years of age. SSB consumption increased at 10–12 years of age and again in the oldest age group (13–17 years). By the teen years, SSB consumption had doubled to more than half of all beverages consumed. Fruit juice consumption was highest during the preschool years, but even then children consumed less than 6 oz/day, on average. Finally, unsweetened/diet beverages were consumed in very small amounts in this study population.

In Table 2, baseline characteristics of the children according to intake of each beverage are shown. There are few baseline differences in the child's mean BMI or ac-

tivity level associated with beverage intake. The sum of four SFs was highest for those in the highest tertile of unsweetened/diet beverage consumption. Total energy intake was significantly higher for those with the highest intakes of either milk intake or SSBs ($p=0.0326$ and 0.0008 , respectively). Kilocalories (kcal) from added sugars were significantly higher for those with the highest intakes of SSBs ($p<0.0001$). Percent of kcal from fat were lowest for preschool children in the highest tertile of fruit and vegetable juice consumption, whereas protein intake was significantly higher among those with higher milk intakes ($p<0.0001$ for both).

Figure 1 illustrates the effects of usual beverage intake at ages 3–9 years on four measures of body fat at 15–17 years of age. After adjusting for confounding by age, baseline body fat, percent of energy from fat, mean TV and video hours per day, other beverages consumed, and maternal education and BMI, these results show that higher intakes

Table 2. Baseline Characteristics According to Sex-Specific Tertiles of Four Beverage Types

	Fluid milk intake			Fruit/vegetable juice		
	Tertile 1 (n=32)	Tertile 2 (n=34)	Tertile 3 (n=32)	Tertile 1 (n=32)	Tertile 2 (n=34)	Tertile 3 (n=32)
	(Mean±SD)					
Children (3–9 years of age)						
BMI (kg/m ²)	16.1±1.2	16.2±1.2	16.3±1.1	16.2±1.4	16.2±1.1	16.2±1.0
Sum of four skinfolds (mm)	26.0±6.7	27.5±6.3	27.9±8.3	26.6±7.8	29.0±7.2	25.7±6.0
Activity (Caltrac counts/hr)	10.8±1.4	10.6±1.7	10.6±1.9	10.8±1.6	10.5±1.6	10.7±1.9
TV and video (hrs/day)	2.1±0.9	2.3±0.7	2.1±0.9	2.4±0.9	2.2±0.8	1.9±0.7
Energy intake (kcal/day)	1642±221	1746±240	1783±242	1664±247	1778±222	1728±244
Kcal from added sugars (%)	16.6±4.3	18.2±3.9	14.7±2.7	17.2±4.4	16.4±4.0	15.9±3.5
Kcal from fat (%)	33.5±4.4	33.0±3.6	34.9±3.3	36.4±3.2	34.4±3.0	30.7±3.0
Kcal from protein (%)	13.3±1.8	13.2±1.6	14.5±1.2	13.6±1.8	14.0±1.5	13.4±1.7
Total dairy (svgs/day)	1.4±0.5	2.0±0.5	2.6±0.5	2.0±0.8	2.2±0.7	1.9±0.6
Total fruit and vegetables (svgs/day)	3.9±1.5	3.4±1.1	3.3±0.9	2.7±0.9	3.5±0.9	4.5±1.0
Milk intake (oz/day)	5.0±2.2	8.9±1.6	13.9±3.2	9.0±4.9	10.6±4.4	8.1±3.5
Fruit/vegetable juice (oz/day)	5.9±4.6	5.6±3.9	5.5±3.1	1.9±1.0	4.9±1.2	10.2±2.8
Sugar-sweetened beverages (oz/day)	6.7±4.0	7.5±3.5	5.2±3.3	6.8±3.7	7.0±4.2	5.7±3.0
Unsweetened/diet beverages (oz/day)	1.0±1.4	0.8±1.3	1.0±1.3	0.8±1.1	0.8±1.1	1.1±1.7
Mothers						
Education ≥ college (column %) ^a	35.3	31.4	35.3	20.6	34.3	50.0
BMI (kg/m ²)	24.9±4.5	24.3±4.3	24.3±4.6	24.9±4.3	24.8±5.1	23.8±3.8
	Sugar-sweetened beverages			Unsweetened/diet beverages		
	Tertile 1 (n=32)	Tertile 2 (n=34)	Tertile 3 (n=32)	Tertile 1 (n=43)	Tertile 2 (n=22)	Tertile 3 (n=33)
	(Mean±SD)					
Children (3–9 years of age)						
BMI (kg/m ²)	16.2±1.2	16.2±1.2	16.2±1.1	15.9±1.1	16.3±1.1	16.5±1.3
Sum of four skinfolds (mm)	28.1±7.1	27.0±8.0	26.3±6.3	26.9±6.5	25.2±5.0	29.2±8.9
Activity (Caltrac counts/hr)	10.4±1.7	10.7±1.6	10.8±1.7	10.7±2.0	10.7±1.5	10.6±1.6
TV and video (hrs/day)	2.1±0.9	2.2±0.8	2.3±0.8	2.2±0.9	2.2±0.9	2.2±0.8
Energy intake (kcal/day)	1700±266	1684±216	1789±229	1735±303	1706±168	1729±230
Kcal from added sugars (%)	13.8±3.3	16.3±3.3	19.4±3.2	16.3±4.6	17.6±3.7	15.6±3.3
Kcal from fat (%)	34.3±4.5	33.3±3.3	33.8±3.7	34.0±4.2	32.9±3.4	34.5±3.8
Kcal from protein (%)	14.4±1.7	13.6±1.7	13.0±1.3	13.7±2.1	13.3±1.5	14.0±1.2
Total dairy (svgs/day)	2.2±0.8	1.9±0.6	2.0±0.6	2.0±0.8	2.0±0.5	2.1±0.8
Total fruit and vegetables (svgs/day)	3.6±1.3	3.4±1.1	3.6±1.2	3.5±1.2	3.6±1.2	3.5±1.2
Milk intake (oz/day)	10.7±5.5	8.4±3.4	8.7±3.8	9.8±4.8	8.7±3.7	9.2±4.6
Fruit/vegetable juice (oz/day)	6.4±4.3	5.5±3.7	5.0±3.7	5.1±3.7	6.1±4.1	5.8±3.9
Sugar-sweetened beverages (oz/day)	2.8±1.2	5.8±0.9	10.7±2.6	6.8±4.3	6.6±3.5	5.9±3.2
Unsweetened/diet beverages (oz/day)	0.9±1.3	1.0±1.4	0.8±1.3	0.0±0.0	0.4±0.2	2.3±1.5

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Table 2. Baseline Characteristics According to Sex-Specific Tertiles of Four Beverage Types *continued*

	Sugar-sweetened beverages			Unsweetened/diet beverages		
	Tertile 1 (n=32)	Tertile 2 (n=34)	Tertile 3 (n=32)	Tertile 1 (n=43)	Tertile 2 (n=22)	Tertile 3 (n=33)
	(Mean±SD)					
Mothers						
Education, ≥ college (column %) ^a	38.2	31.4	35.3	33.3	42.4	29.4
BMI (kg/m ²)	24.0±3.5	25.3±5.2	24.2±4.4	24.2±3.8	24.4±4.6	24.9±4.9

^aEducation reflects highest education for child's mother.

kg/m², kilograms divided by height in meters squared; mm, millimeters; TV, television; hrs, hours; kcals, kilocalories; svgs, servings; oz, ounces; SD, standard deviation.

of both milk and fruit and vegetable juices tended to be associated with lower levels of body fat at ages 15–17 years. Children with the lowest milk intakes in early childhood had mean percent body fat in mid-adolescence of 30.0%, whereas those in the highest tertile of milk intake had only 22.6% body fat. Those in the highest tertile of fruit and vegetable juice intake during childhood had a mean waist circumference that was 8.0 cm smaller at 15–17 years of age than those in the lowest tertile of intake. Both milk ($p=0.0465$) and fruit and vegetable juice ($p=0.0383$) were also associated with a lower sum of four

SFs. There were no consistent trends in body fat associated with intakes of SSBs or unsweetened/diet beverages.

The longitudinal effects of each of the four beverage types on the sum of four SFs from the preschool years to mid-adolescence are shown in Figure 2. Those in the highest tertile of fluid milk intake had a statistically significantly lower sum of SFs throughout childhood and into adolescence, compared with those in either of the lower tertiles. The group with the highest fruit and vegetable juice intakes was also associated with a consistently lower sum of four SFs. There was no statistically significant

Body fat measures adjusted for age at anthropometry, baseline anthropometry, percentage of energy from fat, mean tv and video time, other beverage intakes not included in exposure group, mother's education, and mother's BMI

Figure 1. Effects of beverage intake at ages 3–9 years on measures of body fat at end of follow-up (ages 15–17 years). DXA, dual-energy X-ray absorptiometry.

Sum of skinfold measures at each age are adjusted for age, mean tv and video time, percent of total energy from fat, other beverages not included in exposure variable, mother's education, & mother's BMI

Figure 2. Beverage intake categories and change in sum of skinfolds throughout childhood.

longitudinal effect of SSB intake on sum of SFs, whereas those with the highest intakes of unsweetened/diet beverages had a larger sum of SF measures starting at about 7–8 years of age.

Discussion

There are several important results from these analyses. Starting at about 10 years of age, milk drinking declined whereas the intake of SSBs rose. Consumption of fruit and vegetable juices declined even earlier. Further, the results of these analyses suggest that the higher intakes of fluid milk and fruit and vegetable juices in early childhood may have beneficial effects on changes in body fat during childhood and adolescence. There was no association between SSB intake and body fat change during childhood in this study, whereas there was a weak tendency for unsweetened/diet beverage consumption to be positively associated with body fat gain.

These findings are consistent with those for adolescents in Project EAT, where those who consumed little or no milk gained significantly more weight over a 5-year period than their peers who were milk drinkers.¹⁶ Data from

earlier analyses in the FCS also showed that total dairy intake was inversely associated with body fat gain¹⁷; children in the lowest tertile of dairy intake gained an additional 3 mm of subcutaneous fat per year, compared with those in the highest tertile of total dairy.

Earlier studies of fruit juice consumption on weight gain have yielded variable results. A systematic review of 100% fruit juice found no consistent association between moderate levels of intake and risk of overweight in children and adolescents.¹² Some studies suggest that high intakes of fruit juice in younger children who are already overweight should perhaps be avoided,¹⁸ because large amounts of fruit juice (or other energy-dense beverages) in early childhood may lead to excessive weight gain. For example, Dennison and colleagues found, in cross-sectional analyses, that preschool children consuming more than 12 oz of fruit juice per day had a higher BMI.¹⁹ By contrast, in a repeated-measures longitudinal study, Skinner and Carruth found that juice intake between 24 and 72 months of age was not associated with height, weight, BMI, or ponderal index.²⁰ The amount of fruit and vegetable juice (the vast majority of which was fruit juice) consumed by these

Framingham children was generally modest (mean intakes of 1.9, 4.9, and 10.2 oz/day from tertile 1 to 3).

Our results differ from some other studies in that no consistent effects of SSB intake on subsequent body fat measures were identified. In a 19-month longitudinal study of 11 to 12 year olds, Ludwig and colleagues found that each additional serving of SSBs (one serving=one can/glass of soda, generally 12 oz) was associated with a 0.24-kg/m² increase in BMI.²¹ Similarly, a longitudinal study of girls followed from the age of 5 to 15 found that those consuming ≥ 2 servings (8 oz each) of sweetened beverage at age 5 were more likely to be significantly overweight and have greater waist circumference than girls with lower intakes.²² Several other studies support the findings that excess energy from sweetened beverages may be associated with increasing weight in children.^{19,23,24} Because children in the current study had lower intakes of SSBs than those observed in many other studies, it is very possible that within the ranges of intake found here (2.8, 5.8, and 10.7 oz/day across tertiles of intake at 3–9 years of age), there is no association with excess body fat. Data from the Avon Longitudinal Study of Parents and Children also found no association between SSB consumption at age 5 (mean SSB intake, 2.0 oz/day) or 7 years (mean SSB intake, 2.4 oz/day) and fat mass measured by DXA at 9 years of age.²⁵

Unsweetened/diet beverage consumption at 3–9 years of age was not consistently associated with body fat at 15–17 years. However, there was a tendency for those consuming the fewest diet beverages to have lower levels of body fat during the teen years. It is possible that the child's current level of body fat or that of the parents or other family members may be related to intake of unsweetened/diet beverages in the home, reflecting a form of confounding by indication. Vanselow and colleagues also found a similar positive association between low-calorie soft drink consumption and change in BMI in a 5-year longitudinal study of adolescents. However, after adjusting for dieting and parental weight-related concerns, the association between low-calorie beverages and change in BMI was attenuated.¹⁶ Another prospective study of 9- to 14-year-old boys followed for 1 year showed a 0.12-kg/m² increase in BMI per increase in daily serving of diet beverages, although intake levels were very low.²⁶ Finally, a study in adults demonstrated a positive dose-response relationship between artificially sweetened beverages and long-term weight gain.²⁷ It is possible that consumption of diet beverages with their low energy content may lead to overconsumption of other foods, leading to increases in body fat rather than decreases. The current study is limited by the low intakes of unsweetened/diet beverages and inadequate power to separate artificially sweetened beverages from unsweetened ones.

Several possible mechanisms may underlie these results, including greater satiety associated with milk consumption. Dietary calcium and dairy have been associated with increases in fat oxidation.^{28,29} Additionally, it has been

suggested that leucine, conjugated linoleic acid, and magnesium may also play roles in the partitioning of dietary energy and weight regulation.^{30–32} The higher fiber content of many fruit and vegetable juices may also have beneficial effects on satiety pathways. Finally, it is possible that consumption of milk and juices may reflect a dietary pattern that is healthier in general, thereby conveying beneficial effects on obesity risk.

There are several important strengths of this longitudinal study. The FCS provides detailed and repeated measures of diet, anthropometry, and relevant covariates, which allows for substantial precision around the estimated effects. Additionally, the prospective nature of this analysis, with dietary intake data stemming from early childhood, reduces the likelihood of reporting bias.

There are some important limitations of the current study, including the small sample size and homogeneity of the FCS. Even though the families were followed intensively for 12 years, statistical power is limited as is our ability to stratify the analysis by various dietary and lifestyle factors. Whereas it is possible that the beverage data collected in this study do not reflect current beverage consumption patterns, it is equally true that different population groups studied during any time period will have very different patterns of beverage consumption. Therefore, no single study's results will be generalizable to all population groups. For example, the absence of an adverse effect of SSB consumption in the current study may reflect the lower levels of intake in this population.

As in all observational studies of diet, it is possible that beverage intake was reported with some degree of error. Children in particular have difficulty in reporting portion sizes, which would most likely lead to nondifferential error in the estimated effects. Biased reporting is also a possibility, resulting from the current level of body fat of either the child or a parent. The baseline data, however, suggest that this is unlikely. Finally, confounding by unmeasured factors can never be ruled out.

Conclusion

Although causality cannot be assessed in a small observational study such as this, the findings suggest that beverage intake patterns during childhood may have important effects on subsequent levels of body fat in adolescence. In addition, modest intakes of SSBs may not adversely affect body fat change, whereas adequate intakes of milk and fruit and vegetable juices during early childhood may reduce the risk of excess body fat in later childhood and adolescence.

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Author Disclosure Statement

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