ARTICLE

Impact of Change in Sweetened Caloric Beverage Consumption on Energy Intake Among Children and Adolescents

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Objective: To estimate the net caloric impact from replacing sugar-sweetened beverages (SSBs) with alternatives in children and adolescents in naturalistic settings.

Design: Secondary analysis based on nationally representative cross-sectional study.

Setting: Fixed-effect regression analysis of 2 nonconsecutive 24-hour dietary recalls from the 2003-2004 National Health and Nutrition Examination Survey data.

Participants: Children and adolescents 2 to 19 years of age (N=3098).

Main Exposures: Within-person beverage consumption between 2 surveyed days.

Main Outcome Measures: The association between changes in the consumption of SSBs and other beverages and changes in total energy intake (TEI) of the same individual.

Results: Each additional serving (8 oz) of SSB corresponded to a net increase of 106 kcal/d ($P<.001$; 95% confidence interval [CI], 91 to 121 kcal/d), holding other beverages constant. Increases were also seen (all $P<.001$) for each additional serving of whole milk (169 kcal/d; 95% CI, 143 to 195 kcal/d), reduced-fat milk (145 kcal/d; 95% CI, 118 to 171 kcal/d), and 100% juice (123 kcal/d; 95% CI, 90 to 157 kcal/d). No net increases in TEI were seen for water (8 kcal/d; $P=.27$; 95% CI, −6 to 22 kcal/d) or diet drinks (47 kcal/d; $P=.20$; 95% CI, −23 to 117 kcal/d). Substituting SSBs with water was associated with a significant decrease in TEI, controlling for intake of other beverages, total beverage and nonbeverages, and fast-food and weekend effects. Each 1% of beverage replacement was associated with 6.6-kcal lower TEI, a reduction not negated by compensatory increases in other food or beverages. We estimate that replacing all SSBs with water could result in an average reduction of 235 kcal/d.

Conclusion: Replacing SSB intake with water is associated with reductions in total calories for all groups studied.

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SUGAR-SWEETENED BEVERAGE (SSB) intake is considered an important contributing factor to obesity in childhood.[1-5] Since the late 1970s, consumption of SSBs by children and adolescents has increased substantially.[6,7] Data from national surveys indicate that energy intake from sweetened beverages increased 135% between 1977 and 2001.[6] During a similar period, rates of obesity more than doubled in children aged 2 to 11 years and tripled in adolescents 12 to 19 years of age.[1,8] Recent data suggest that approximately 90% of US children and adolescents consume sweetened caloric beverages on any given day, and SSBs alone can contribute to more than 10% of total energy consumed.[9] Replacing these liquid calories with calorie-free beverage alternatives therefore represents a key strategy to eliminate excess calories and to prevent obesity in childhood.

A number of mechanisms have been proposed to explain the observed link between SSB consumption and higher total energy intake (TEI). Most commonly cited is the incomplete compensation for caloric intake in liquid forms, that is, individuals do not sufficiently reduce energy intake throughout the day in response to calories ingested from beverages.[10,11] In a review study, Almiron-Roig et al[12] found that the impact of liquid vs solid calories on satiety (most studies conducted in adults) is inconclusive. They cited studies that found solids to be more satiating than liquids,[10,13-17] as well as studies suggesting the opposite[18-25] or no difference.[26,27]

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In a recent meta-analysis on the effects of soft drink consumption, however, Vartanian et al[28] found clear and consistent evidence that individuals do not compensate for the added energy consumed from soft drinks. Furthermore, Stookey et al[29] found evidence that replacing sweetened caloric beverages with water was associated with sustained caloric deficit among women in a weight loss clinical trial over 12 months.

Experimental work examining the ability of children and adolescents to compensate for liquid calories is limited.[11] Early work on energy regulation found that children showed clearer evidence for caloric compensation than did adults,[30] although high interindividual variation in compensation in children has been observed.[31] Moreover, the effect of changing SSB consumption in free-living children has not been extensively studied, although an environmental intervention did significantly reduce body mass index (BMI) (calculated as weight in kilograms divided by height in meters squared) among the most overweight adolescents (BMI ≥ 25.6) enrolled.[32] Examining the impact on TEI among children and adolescents in their natural environment (not under experimental conditions) who drink more or less of certain beverages on different days can provide critical insight on the impact of targeting SSBs as a focus area to reduce excess calories.

This study aimed to estimate the extent to which caloric beverages link to higher daily energy intake in the pediatric population. Specifically, we describe the shorter-term (several days to a week) differences in TEI of the same individuals who reported different beverage consumptions on different days. We used regression models to control for characteristics of the day that have significant impact on children's energy intake: on weekends[33] and days when children eat at fast-food establishments.[34] Further, to inform policy and clinical recommendations, we estimated the impact of replacing SSBs with another caloric or noncaloric beverage, especially water. We further controlled for overall intake of grams of nonbeverages. We also stratified our analyses by age groups (2-5, 6-11, and 12-19 years).

METHODS

DATA

We obtained dietary recall data for children and adolescents (2-19 years of age) from the nationally representative National Health and Nutrition Examination Survey (NHANES) 2003-2004. NHANES is an ongoing series of nationwide surveys and clinical examinations conducted by the National Center for Health Statistics. The surveys use a multistage, clustered probability sampling strategy to select households and individuals to provide national estimates representative of the civilian, noninstitutionalized US population. Complete description of data collection procedures and analytic guidelines are on the National Center for Health Statistics Web site (http://www.cdc.gov/nchs/nhanes.htm).

The 24-hour dietary recall interview component of the NHANES provides estimates of total daily energy intake, nutrients, and nonnutrient dietary components as well as dietary behaviors regarding the type, quantity, and location of each food and beverage consumption occasion. Survey respondents reported all food and beverages consumed in a prior 24-hour period (midnight to midnight) at mobile examination centers during the interview. Proxy respondents were used for survey examinees younger than 6 years, and children aged 6 to 11 years underwent assisted interviews. In NHANES 2003-2004, a computer-assisted system was used to automate data collection. The 2003-2004 survey collected dietary data from the same respondent on 2 nonconsecutive days. The first day (day 1) was collected at the mobile examination center and the second day was collected by telephone 3 to 10 days later. Most mobile examination center participants (87%) in NHANES 2003-2004 had 2 days of complete and reliable intake reports.

On completion of interviews, all reported items were systemically coded using the US Department of Agriculture Food and Nutrient Database, which provides nutritional contents based on standardized recipes. Caloric content from each consumed food or beverage item was subsequently calculated based on the quantity of food and beverages reported by the respondents.

INCLUSION AND EXCLUSION CRITERIA

We included children and adolescents aged 2 to 19 years who completed 2 dietary interviews in NHANES 2003-2004. Sample size for the "other race" category was small; therefore, our trend analyses are only carried out for non-Hispanic white, non-Hispanic black (hereafter referred to as "white" and "black"), and Mexican American youths. Three age categories were defined to generally reflect time spent between home and school environment: preschool, age 2 to 5 years; primary school, age 6 to 11 years; and high school or higher, age 12 to 19 years.

To maximize the comparability of dietary intake patterns between the days surveyed, we excluded subjects who reported yes to the "Are you on a special diet?" question (n=140) and subjects with zero energy intake on any of the surveyed days (n=3). Respondents with incomplete or unreliable dietary recall status and those being breastfed or pregnant at the time of the survey were excluded from our analysis. We also excluded subjects with estimated TEI in the top 1% or the bottom 1% within the age group. The cutoff values were 3581 (high) and 630 (low) kcal for ages 2 to 5 years (14 excluded), 4706 (high) and 644 (low) kcal for ages 6 to 11 years (16 excluded), and 5728 (high) and 617 (low) kcal for ages 12 to 19 years (36 excluded). The final data set contained 3098 subjects.

BEVERAGE CONSUMPTION

From 453 nonalcoholic beverage items reported by the NHANES 2003-2004 respondents, we identified 5 mutually exclusive beverage categories: SSBs (including soda, sport drinks, fruit drinks and punches, low-calorie drinks, sweetened tea, and other sweetened beverages), diet beverages, milk (including flavored milk), 100% fruit juice, and other drinks (including unsweetened tea, coffee, and other beverages) (details on coding beverages can be found in the appendix of our previously published article[9]). Plain water consumption was estimated from the question "total plain water drank yesterday, including plain tap water, water from a drinking fountain, water from a water cooler, bottled water, and spring water." We defined a standard serving of any beverage as 8 oz (two-thirds of a regular soda can). We also quantified the total weight of beverages and water (in grams) as a proxy for total fluid intake, thirst, and/or physical activity (as physical activity measures are not available for the recalled days).

CONSUMPTION OF NONBEVERAGES

In addition to total beverage intake, we also controlled for total grams of nonbeverage intake in our assessment of beverage-replacement effect on TEI. Nonbeverage items include all food intakes except for the items falling into any of the 5 beverage categories or water. As a result, some liquid-form or semiliquid-form caloric sources such as soup, milkshakes, and porridge are categorized as nonbeverages.

FAST-FOOD AND WEEKEND VS WEEKDAY INTAKE

Previous research has established a link between fast-food consumption and higher energy intake and lower diet quality.[35] Fast-food establishments are also an important source of children's SSB intake.[9] For our analysis, we created a variable to indicate whether the surveyed day was a "fast-food day," when the location for at least 1 consumption occasion occurred in a fast-food restaurant. Similarly, as children on average consume more calories on weekends than during the week,[33] we controlled for the weekend vs weekday variable to reduce confounding effects associated with days during which more beverage, food, and total energy is consumed.

ASSESSMENT OF WEIGHT STATUS AND INCOME

In both surveys, weight and height were measured using standard procedures in the mobile examination center. Overweight is defined as a BMI greater or equal to the age- and sex-specific 85th percentile on the Centers for Disease Control and Prevention growth charts. Income levels are based on parent-reported or proxy-reported annual family income, which we dichotomized to "higher income" or "lower income" based on 130% of the poverty level, which defines eligibility for food-stamp programs.

STATISTICAL ANALYSIS: WITHIN-PERSON IMPACT ON ENERGY INTAKE

We fit multivariate fixed-effects regression models to estimate the impact of change in SSB consumption level on change in TEI (eAppendix, http://www.archpediatrics.com). The dependent variable of the model is the change in reported TEI throughout the surveyed day (day 2–day 1), and the main independent variable is the change in servings of SSB consumed. We controlled for changes in the consumption of other beverages. We also included other time-varying covariates that are correlated with daily energy intake in youth: intake day as a weekday vs a weekend,[9] fast-food intake (yes/no),[34] and total nonbeverage intake (in grams). Since there are only 2 points, the resulting fixed-effects model is identical to a difference model.[29] Because each individual acts as his or her own control, the fixed-effects model is a powerful strategy to control for time-invariant factors such as age, sex, and other individual-level characteristics.[35,36] In addition, we fit a second fixed-effects model that estimated the effect on net caloric consumption from replacing different caloric beverages with other alternatives, controlling for concurrent changes in other beverage intake (percentage of all beverages) and total beverage intake and total nonbeverage intake (both in grams). This approach is similar to the replacement models used by Stookey et al.[29] The resulting model estimates the average difference in TEI associated with replacing 1 unit of SSB (1% of beverages) with water. Using the coefficient estimates, we predicted the expected differences in TEI from hypothetically replacing all or half of SSBs consumed by NHANES subjects with water using the average share of SSBs of all beverages (percentage). Further details of both fixed-effects models are included in the eAppendix.

All statistical procedures were carried out in SAS software (Version 9.1; SAS Institute, Cary, North Carolina) (SURVEYMEANS and SURVEYREG procedures). All statistics are weighted to adjust for unequal probabilities of sampling. Variance estimates from the NHANES analyses are adjusted for the complex sample structure, including stratification and clustering, using the robust variance estimation method.[37]

RESULTS

The characteristics of the 3098 respondents who completed 24-hour dietary recall interviews on 2 nonconsecutive days in NHANES 2003-2004 are summarized in **Table 1**. On average, youth aged 2 to 19 years reported 2118-kcal TEI over the 24-hour period. Mean energy intakes (on day 1) were significantly different by sex (P value $<.001$) and age (P value $<.001$) but were not significantly different by income (P value $=.57$), race/ethnicity (P value $=.89$), or BMI (P value $=.20$). Average TEI increased with age and was higher in boys than girls. Survey respondents reported lower TEI on day 2, which was conducted over the telephone, likely reflecting underreporting bias. Of the 3098 NHANES subjects, 2874 (93%, or 91% after applying sampling weights) had at least 1 SSB on either or both recall days.

In addition, Table 1 summarizes the average intake in grams of total beverages and 3 caloric beverage categories (SSB, milk, and juice) on the 2 survey days. We found that while population mean consumption did not largely differ by sex, race, income, or BMI status, older age groups tended to consume more beverages, especially SSBs. Within-person variability between the 2 intake days was substantial, suggesting that total beverage intake is not always tightly regulated from day to day (Pearson correlation coefficient between day 1 and day 2=0.49) and should be controlled for in examining the relationship between intake of a particular beverage and TEI.

BEVERAGE CONSUMPTION AND TEI: WITHIN-SUBJECT ANALYSES

Using number of servings consumed as independent variables, **Table 2** presents the coefficient estimates for within-person changes in TEI as a function of changes in consumption of each of the 5 beverage categories. The β coefficient estimate associated with each beverage category represents the net caloric impact of an additional serving consumed. The fully adjusted model controlled for the intake of other beverages, intake of nonbeverage items, and effects of weekend and fast-food intake.

Each additional serving of SSB was associated with a net increase in intake of 106 kcal on that day (95% confidence interval [CI], 91 to 121 kcal; $P<.001$), similar to the 100 kcal found in an 8-oz serving of colas and lemon-lime sodas, suggesting little or no compensation. In other words, if 8 oz of SSB is consumed, the TEI is higher, and there is no evidence that other intake is reduced to compensate for the extra

Table 1. Socioeconomic and Demographic Characteristics of NHANES 2003-2004 Subjects Aged 2 to 19 Years With 2 Complete 24-Hour Dietary Recall Surveys

		Mean (SE)									
		Total Daily Energy Intake, kcal		Beverage Intake, g		SSB Intake, g		Milk Intake, g		Juice Intake, g	
Variable	No. (Weighted %)	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
Overall	3098 (100)	2118 (24)	2021 (24)	1784 (62)	1591 (55)	606 (27)	495 (17)	333 (18)	329 (19)	115 (11)	106 (9)
Sex											
M	1532 (53)	2276 (40)	2192 (36)	1904 (83)	1682 (75)	692 (44)	553 (29)	376 (20)	356 (21)	119 (15)	116 (12)
F	1566 (47)	1940 (22)	1830 (25)	1649 (60)	1488 (42)	511 (28)	430 (21)	284 (19)	300 (18)	111 (11)	94 (8)
Race/ethnicity											
Non-Hispanic white	931 (69)	2122 (31)	2026 (35)	1857 (78)	1653 (71)	610 (39)	494 (25)	366 (20)	363 (19)	113 (14)	90 (11)
Non-Hispanic black	1147 (17)	2114 (44)	1999 (41)	1607 (60)	1385 (61)	609 (18)	497 (24)	214 (15)	195 (17)	119 (14)	135 (17)
Hispanic	1020 (14)	2099 (38)	2028 (52)	1642 (39)	1542 (38)	583 (49)	499 (34)	318 (14)	329 (23)	124 (12)	147 (15)
Age, y											
2-5	615 (21)	1704 (33)	1665 (33)	1289 (38)	1172 (33)	315 (26)	272 (25)	415 (27)	393 (18)	172 (21)	147 (15)
6-11	733 (33)	2089 (49)	2053 (39)	1501 (69)	1431 (56)	519 (44)	414 (16)	351 (22)	365 (30)	100 (12)	100 (14)
12-19	1750 (45)	2333 (46)	2165 (48)	2224 (78)	1905 (84)	808 (33)	660 (24)	281 (23)	273 (25)	99 (13)	91 (11)
Income											
Lower income[a]	1494 (37)	2139 (48)	2005 (43)	1757 (72)	1498 (55)	608 (35)	485 (30)	349 (22)	309 (21)	126 (16)	110 (9)
Higher income[a]	1604 (63)	2105 (29)	2030 (35)	1800 (74)	1646 (60)	606 (34)	501 (20)	323 (22)	341 (21)	109 (10)	103 (11)
BMI											
<85th percentile[b]	1983 (68)	2144 (30)	2021 (29)	1766 (71)	1542 (56)	583 (34)	469 (20)	329 (18)	326 (19)	126 (13)	110 (10)
≥85th percentile[b]	1058 (32)	2076 (39)	2042 (40)	1833 (68)	1708 (70)	665 (27)	558 (28)	332 (23)	331 (23)	91 (11)	96 (13)
SSB intake											
Had SSB on both days	2151 (64)	2221 (36)	2126 (30)	1842 (60)	1643 (60)	792 (22)	706 (18)	287 (17)	276 (16)	91 (9)	75 (7)
Had SSB on 1 but not both days	723 (26)	2002 (38)	1903 (45)	1532 (100)	1385 (110)	0	0	419 (35)	393 (34)	218 (30)	207 (39)
Had no SSB on either day	224 (9)	1733 (81)	1629 (57)	1731 (96)	1537 (78)	366 (50)	155 (21)	414 (29)	437 (27)	138 (25)	145 (15)

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); NHANES, National Health and Nutrition Examination Survey; SSB, sugar-sweetened beverage.
[a] Income status is dichotomized using 130% poverty level, the eligibility for food-stamp programs.
[b] Equal to or greater than the age- and sex-specific 85th percentile (as defined by the Centers for Disease Control and Prevention growth charts). Value missing in 57 respondents.

Table 2. Effect per 8-oz Serving of Beverage Consumption on Total Energy Intake: Coefficient Estimates From the Fixed-effects Regression (Difference) Model

	Unadjusted Model		Partially Adjusted Model A		Partially Adjusted Model B		Fully Adjusted Model	
Independent Variable	β (SE)	*P* Value	β (SE)	*P* Value	β (SE)	*P* Value	β (SE)	*P* Value
Intercept	−48.3 (19.4)	.02	−20.2 (14.4)	.18	−85.0 (17.8)	<.001	−66.8 (13.5)	<.001
Change in consumption, per serving[a]								
SSBs	98.8 (7.1)	<.001	116.4 (10.8)	<.001	84.0 (7.6)	<.001	106.0 (7.8)	<.001
Diet drinks			56.3 (29.1)	.07			46.9 (35.8)	.20
Whole milk			198.2 (16.2)	<.001			168.9 (13.1)	<.001
Reduced-fat milk			159.5 (23.2)	<.001			144.6 (13.7)	<.001
100% Juice			152.6 (18.0)	<.001			123.2 (17.0)	<.001
Other beverages			35.4 (22.3)	.13			87.6 (34.7)	.02
Water			17.9 (9.0)	.06			8.0 (6.9)	.27
Weekend vs weekday			93.2 (35.7)	.02	−10.0 (30.9)	.80	31.6 (25.0)	.20
Fast-food day (yes/no)			106.3 (24.5)	.001	142.9 (37.6)	.002	149.4 (28.1)	<.001
Change in total nonbeverage consumption, per g					1.3 (0.1)	<.001	1.3 (0.1)	<.001
R^2	0.09		0.23		0.52		0.62	

Abbreviation: SSBs, sugar sweetened beverages.
[a] One serving = 8 fluid oz. Dependent variable in all models is change in total energy intake from day 1 to day 2. The β coefficient estimate associated with each beverage category represents the net caloric impact of an additional serving consumed. The unadjusted model contains only within-person change in SSB servings. Partially adjusted model A controls for changes in all other beverage categories. Partially adjusted model B controls for intake of nonbeverages. The fully adjusted model controlled for the intake of other beverages, intake of nonbeverage items, and effects of weekends and fast-food intake.

liquid calories. Similarly, significant effects were observed for 2 other caloric-containing beverages, milk and 100% fruit juice. Each serving increase of whole milk was associated with an increase of 169 kcal/d (95% CI, 143 to 195 kcal/d; $P<.001$) while each serving increase of reduced-fat milk was associ-

Table 3. Coefficient Estimates From Fixed-effects Regression Models for Associations Between Beverage Replacement and Total Energy Intake[a]

	Total Energy Intake, β (SE)		
	Model 1 Replacing SSB	Model 2 Replacing Juice	Model 3 Replacing Water
Replacement beverage			
SSBs	1 [Reference]	−0.5 (1.3)	6.6 (0.7)[b]
Diet drinks	−3.8 (2.6)	−4.3 (3.0)	2.8 (2.8)
100% Juice	0.5 (1.3)	1 [Reference]	7.0 (1.3)[b]
Whole milk	3.1 (0.6)[b]	2.7 (1.5)	9.7 (1.0)[b]
Reduced-fat milk[c]	2.8 (1.0)[b]	2.3 (2.0)	9.3 (1.2)[b]
Other drinks[d]	−0.9 (3.2)	−1.4 (3.3)	5.6 (3.5)
Plain water	−6.6 (0.6)[b]	−7.0 (1.3)[b]	1 [Reference]
Covariates, change in:			
Total beverage consumption	0.3 (0.03)[b]	0.3 (0.03)[b]	0.3 (0.03)[b]
Total nonbeverage consumption	1.3 (0.06)[b]	1.3 (0.06)[b]	1.3 (0.06)[b]
Weekday vs weekend consumption	36.6 (29.5)	36.6 (29.5)	36.6 (29.5)
Fast-food consumption	165.4 (30.3)[b]	165.4 (30.3)[b]	165.4 (30.3)[b]

Abbreviation: See Table 2.
[a]Total energy intake was measured in kilocalories per day; replacement beverages, in percentage of beverage in grams; total beverage and nonbeverage consumption, in grams.
[b]Statistically significant at $P = .05$ level.
[c]Defined as plain or flavored milk made with 2%, 1%, or nonfat milk.
[d]Includes unsweetened tea, coffee, alcohol, and other unsweetened beverages.

Table 4. Age-Specific Coefficients From Fixed-effect Regression Models for Associations Between Beverage Replacement and Total Energy Intake (Model 1 in Table 3)[a]

	Total Energy Intake From Model 1, β (SE)		
	Ages 2-5 y	Ages 6-11 y	Ages 12-19 y
Replacing SSBs with:			
SSBs	1 [Reference]	1 [Reference]	1 [Reference]
Diet drinks	−3.2 (5.7)	−3.9 (4.0)	−2.6 (5.2)
100% Juice	−0.6 (1.2)	−1.4 (2.9)	2.8 (1.6)
Whole milk	0.1 (1.6)	5.0 (1.9)[b]	3.1 (1.1)[b]
Reduced-fat milk[c]	−2.6 (1.6)	4.5 (1.8)[b]	3.5 (1.1)[b]
Other drinks[d]	−5.5 (5.2)	−0.3 (4.3)	−0.8 (3.4)
Plain water	−6.9 (1.0)[b]	−5.3 (1.5)[b]	−7.6 (0.9)[b]
Covariates			
Total beverage consumption	0.4 (0.08)[b]	0.3 (0.05)[b]	0.3 (0.03)[b]
Total nonbeverage consumption	1.2 (0.1)[b]	1.3 (0.1)[b]	1.3 (0.08)[b]
Weekday vs weekend consumption	69.5 (32.7)	51.0 (67.1)	20.1 (40.5)
Fast-food consumption	82.0 (37.1)[b]	145.4 (66.7)[b]	198.1 (39.9)[b]

Abbreviation: See Table 2.
[a]Total energy intake was measured in kilocalories per day; replacement beverages, in percentage of beverage in grams; total beverage and nonbeverage consumption, in grams.
[b]Statistically significant at $P = .05$ level.
[c]Defined as plain or flavored milk made with 2%, 1%, or nonfat milk.
[d]Includes unsweetened tea, coffee, alcohol, and other unsweetened beverages.

ated with an increase of 145 kcal/d (95% CI, 118 to 171 kcal/d; $P < .001$). Each serving of 100% juice was associated with an increase of 123 kcal/d (95% CI, 90 to 157 kcal/d; $P < .001$). In contrast, 8 oz of milk contains 120 kcal (2%) to 160 kcal (whole), and one serving of 100% juice (orange or apple) contains 110 to 120 kcal. There was no significant association between intakes of diet beverages and plain water on total energy (P value = .20 and .27, respectively). Additionally, we found a net difference of 149-cal/d (95% CI, 94 to 204 kcal/d; $P < .001$) higher energy intake on a fast-food day vs a non–fast-food day, similar to an earlier report.[34]

REPLACING CALORIC BEVERAGES WITH ALTERNATIVES

To further investigate the potential effect on TEI of replacing one beverage for another, we fit fixed-effects models predicting within-person change in TEI associated with replacing 1% of each beverage with other options. We controlled for changes in other beverage consumption, changes in total grams of beverage and nonbeverage consumption, and weekend and fast-food effects. The method is similar to the replacement model noted in another study.[29] Results from 3 different models of replacement are summarized in **Table 3**. The regression coefficients represent the difference in TEI when SSBs are replaced with other beverages (model 1), when juice is replaced with other beverages (model 2), and when water is replaced with other beverages (model 3). These coefficients are not directly comparable with the dose-response models in Table 2 because results are expressed in terms of percentage change.

Each percentage unit of SSB replaced by drinking water (model 1) was associated with a 6.6-kcal (95% CI, 5.4 to 7.8 kcal; $P < .001$) lower energy intake. This estimate did not differ significantly by race/ethnicity, income, or BMI status in tests for interaction. Replacing SSBs with diet drinks did not show a statistically significant caloric benefit. There was no difference in TEI when replacing SSBs with 100% juice (0.5 kcal; $P = .70$) and a small but significant increase when SSBs were replaced with whole milk (3.1 kcal; 95% CI, 1.6 to 4.6 kcal; $P = .001$) and reduced-fat milk (2.8 kcal; 95% CI, 0.7 to 4.8 kcal; $P = .02$). Replacing juice with other alternatives (model 2) showed similar net caloric effects as SSBs.

Although the fixed-effects model controls for time-constant variables, we also examined whether the associations varied by age by fitting age-stratified models. Average intake patterns varied greatly by age, as shown in Table 1. **Table 4** shows coefficient estimates for replacing SSBs with alternatives (model 1 in Table 3) for children aged 2 to 5, 6 to 11, and 12 to 19 years. The key finding was that replacing SSBs with water will result in a substantial reduction in TEI for all the age groups. There were some differences by age: among children aged 2 to 5 years, there was no evidence for change in TEI when replacing water with either whole or low-fat milk, whereas for children 6 years and older, it appears that replacing SSBs with milk will tend to increase TEI.

Table 5. SSB Consumption Pattern and Predicted Impact of Replacing SSB With Water, by Age Group

	Mean (SE)			
	Ages 2-19 y	Ages 2-5 y	Ages 6-11 y	Ages 12-19 y
Beverage consumption that is SSBs, %	35 (1)	25 (2)	35 (2)	40 (2)
Consumption of beverages, g/d	1784 (62)	1289 (38)	1501 (69)	2224 (78)
SSB consumption, g/d	606 (27)	315 (26)	518 (44)	808 (33)
Replacement beverage, β (SE)	−6.6 (0.6)	−6.9 (1.0)	−5.3 (1.5)	−7.6 (0.9)
Replacement scenario	Expected Impact on TEI, kcal/d (95% CI)			
100% (All SSBs replaced with water)	−235 (−255 to −215)	−172 (−194 to −150)	−183 (−203 to −163)	−302 (−333 to −271)
50% (Half of SSBs replaced with water)	−117 (−127 to −108)	−86 (−97 to −75)	−92 (−101 to −82)	−151 (−167 to −135)

Abbreviations: CI, confidence interval; SSB, sugar-sweetened beverage; TEI, total energy intake.

PREDICTED IMPACT OF REPLACING SSBs WITH WATER, BY AGE

We further applied the results of the beverage replacement model to simulate potential policy and environmental initiatives to promote replacing SSBs with plain water. In **Table 5**, we predicted the potential net reduction in TEI among NHANES respondents based on (1) age-specific coefficients of replacing 1% of SSBs with water, as shown in Table 4, and (2) share of SSBs (in grams) in all beverages (including water) consumed by each respondent on day 1. Overall, because SSBs represent 35% of all beverage weight consumed, replacing all SSBs among NHANES respondents with water would translate to a net reduction of 235 kcal/d (95% CI, 215 to 255 kcal/d) in TEI, on average. The reduction of such hypothetical complete replacement is expected to be 172 kcal/d (95% CI, 150 to 194 kcal/d), 183 kcal/d (95% CI, 163 to 203 kcal/d), and 302 kcal/d (95% CI, 271 to 333 kcal/d) for youth aged 2 to 5, 6 to 11, and 12 to 19 years, respectively.

COMMENT

In this study, we used fixed-effects regressions to estimate the within-person net caloric impact of changes in SSB intake on changes in TEI. Between the 2 recalled days, each additional 8-oz serving of SSB corresponds to 106-kcal/d higher TEI. This increase is similar to the caloric content of an 8-oz soda and suggests little or no compensation. Our results also indicate that replacing SSBs with water is associated with a significant decrease in TEI. Each 1% of such replacement is associated with 6.6-kcal lower daily calories consumed and this reduction was not negated by compensatory increase in other food or beverages. We estimate that replacing all SSBs with water would therefore result in an average net reduction of 235 kcal/d.

Replacing SSBs with other caloric drinks such as milk, however, may have effects that vary with age. We see no significant change in TEI among young children but significant increases in calories among those 6 years and older, although there is a potential nutritional benefit for growing children when SSBs are replaced with nutrient-rich, reduced-fat milk.[38]

We did not find statistically significant reduction in TEI when SSBs were replaced with diet drinks. This may in part be because of the small number of children and adolescents who consume diet drinks, resulting in greater variability, large standard errors, and insufficient power to detect a difference. Stookey and colleagues[29] also found no difference in TEI from replacing sweetened caloric beverages with noncaloric beverages over 2 months of intervention among overweight women in the weight loss trials. At 12 months, however, they reported a 30% smaller caloric reduction from replacing SSBs with noncaloric beverages than with plain water.[29] Nonnutritive sweeteners used in most diet drinks (eg, aspartame and sucralose) are considered safe for children by the Food and Drug Administration, and studies have not shown a paradoxical effect to increase appetite and food intake,[39] although there is limited long-term evaluation. However, given the possible perverse effect of diet beverages on health[40,41] as well as the potential long-term effect of maintaining a highly sweet food environment through appetite, intake, and energy regulation mechanisms, pediatricians and parents may wish to remain prudent in using diet drinks as the main alternative to SSBs.[39]

Our study has the following limitations: (1) The recall method is subject to inaccuracy and bias in enlisting all food ingested and quantifying portion size—a systematic underreporting of up to 25% has been documented in adults.[42,43] The underreporting may be considerably greater among those who consume more than average.[44] It is uncertain whether underreporting of SSB intake is of lesser extent than other food and beverages; however, such bias can make the observed SSB-TEI association appear more significant. The extent of underreporting in children and adolescents is less studied and requires further research. Dietary recall conducted over the telephone tends to be less accurate. Our fixed-effects model (predicting the net change in TEI on day 2–day 1), however, addresses this issue and eliminates this bias from the β estimates. (2) An individual's diet may vary greatly from one day to another. Although two 24-hour dietary recalls provide stronger basis for inferences than a single recall, our results may not reliably represent the long-term dietary intake pattern. (3) Although we used multivariate regression models to adjust for time-varying variables such as weekday vs weekend intake, fast food, and total beverage and nonbeverage (in grams) consumption, our inferences on net caloric impact from beverage choices may remain constrained by residual confounding effect from other unavailable variables, such as physical activity.

More experimental work examining the impact of reducing SSB consumption in children and adolescents is warranted. To date, the 2 experimental studies that have examined interventions aimed at reducing SSB consumption have demonstrated promising results.[32,45] In the randomized study of Ebbeling et al,[32] the intervention group received weekly home deliveries of noncaloric drinks for 25 weeks. No significant difference in the primary end point, change in BMI from baseline to follow-up, was detected between the intervention and control groups; however, baseline BMI was found to be an effect modifier.[32] These findings suggest that reducing SSB consumption may be an effective weight reduction strategy for overweight adolescents, but widespread recommendations to decrease SSB consumption are unlikely to lead to unnecessary or harmful weight loss in normal-weight or underweight teens. In our analysis, we did not find significant differences in the impact of replacing SSBs with plain water by BMI status.

In conclusion, reducing SSB intake can be an important strategy to eliminate excess caloric intake; however, the choice of replacement beverage is crucial. Water can be recommended as a clear replacement choice that is also low in cost if tap water is used.

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Additional Information: The eAppendix can be found at http://www.archpediatrics.com. The study was deemed exempt by the Harvard School of Public Health Human Subjects Committee.

REFERENCES

1. Malik VS, Schulze MB, Hu FB. Intake of sugar-sweetened beverages and weight gain: a systematic review. *Am J Clin Nutr*. 2006;84(2):274-288.
2. Berkey CS, Rockett HRH, Field AE, Gillman MW, Colditz GA. Sugar-added beverages and adolescent weight change. *Obes Res*. 2004;12(5):778-788.
3. Ludwig DS, Peterson KE, Gortmaker SL. Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. *Lancet*. 2001;357(9255):505-508.
4. Phillips SM, Bandini LG, Naumova EN, et al. Energy-dense snack food intake in adolescence: longitudinal relationship to weight and fatness. *Obes Res*. 2004;12(3):461-472.
5. Welsh JA, Cogswell ME, Rogers S, Rockett H, Mei Z, Grummer-Strawn LM. Overweight among low-income preschool children associated with the consumption of sweet drinks: Missouri, 1999-2002. *Pediatrics*. 2005;115(2):e223-e229. http://pediatrics.aappublications.org/cgi/content/full/115/2/e223.
6. Nielsen SJ, Popkin BM. Changes in beverage intake between 1977 and 2001. *Am J Prev Med*. 2004;27(3):205-210.
7. French SA, Lin B-H, Guthrie JF. National trends in soft drink consumption among children and adolescents age 6 to 17 years: prevalence, amounts, and sources, 1977/1978 to 1994/1998. *J Am Diet Assoc*. 2003;103(10):1326-1331.
8. Flegal KM, Carroll MD, Ogden CL, Johnson CL. Prevalence and trends in obesity among US adults, 1999-2000. *JAMA*. 2002;288(14):1723-1727.
9. Wang YC, Bleich SN, Gortmaker SL. Increasing caloric contribution from sugar-sweetened beverages and 100% fruit juices among US children and adolescents, 1988-2004. *Pediatrics*. 2008;121(6):e1604-e1614. http://pediatrics.aapublications.org/cgi/content/full/121/6/e1604.
10. DiMeglio DP, Mattes RD. Liquid versus solid carbohydrate: effects on food intake and body weight. *Int J Obes Relat Metab Disord*. 2000;24(6):794-800.
11. Mourao DM, Bressan J, Campbell WW, Mattes RD. Effects of food form on appetite and energy intake in lean and obese young adults. *Int J Obes (Lond)*. 2007;31(11):1688-1695.
12. Almiron-Roig E, Chen Y, Drewnowski A. Liquid calories and the failure of satiety: how good is the evidence? *Obes Rev*. 2003;4(4):201-212.
13. Hulshof T, Degraaf C, Weststrate JA. The effects of preloads varying in physical state and fat-content on satiety and energy-intake. *Appetite*. 1993;21(3):273-286.
14. Haber GB, Heaton KW, Murphy D, Burroughs LF. Depletion and disruption of dietary fibre: effects on satiety, plasma glucose, and serum insulin. *Lancet*. 1977;2(8040):679-682.
15. Bolton RP, Heaton KW, Burroughs LF. The role of dietary fiber in satiety, glucose, and insulin—studies with fruit and fruit juice. *Am J Clin Nutr*. 1981;34(2):211-217.
16. Tournier A, Louissylvestre J. Effect of the physical state of a food on subsequent intake in human subjects. *Appetite*. 1991;16(1):17-24.
17. de Graaf C, Hulshof T. Effects of weight and energy content of preloads on subsequent appetite and food intake. *Appetite*. 1996;26(2):139-152.
18. Jordan HA, Levitz LS, Utgoff KL, Lee HL. Role of food characteristics in behavioral change and weight loss. *J Am Diet Assoc*. 1981;79(1):24-29.
19. Kissileff HR, Gruss LP, Thornton J, Jordan HA. The satiating efficiency of foods. *Physiol Behav*. 1984;32(2):319-332.
20. Rolls BJ, Bell EA, Thorwart ML. Water incorporated into a food but not served with a food decreases energy intake in lean women. *Am J Clin Nutr*. 1999;70(4):448-455.
21. Rolls BJ, Fedoroff IC, Guthrie JF, Laster LJ. Foods with different satiating effects in humans. *Appetite*. 1990;15(2):115-126.
22. Santangelo A, Peracchi M, Conte D, Fraquelli M, Porrini M. Physical state of meal affects gastric emptying, cholecystokinin release and satiety. *Br J Nutr*. 1998;80(6):521-527.
23. Spiegel TA, Hubert CD, Fried H, Peikin SR, Siegel JA, Zeiger LS. Contribution of gastric and postgastric feedback to satiation and satiety in women. *Physiol Behav*. 1997;62(5):1125-1136.
24. Spiegel TA, Kaplan JM, Alavi A, Kim PSY, Tse KKM. Effects of soup preloads on gastric emptying and fullness ratings following an egg sandwich meal. *Physiol Behav*. 1994;56(3):571-575.
25. Himaya A, Louis-Sylvestre J. The effect of soup on satiation. *Appetite*. 1998;30(2):199-210.
26. Mustad VA, Jonnalagadda SS, Smutko SA, et al. Comparative lipid and lipoprotein responses to solid-food diets and defined liquid-formula diets. *Am J Clin Nutr*. 1999;70(5):839-846.
27. Pliner PL. Effect of liquid and solid preloads on eating behavior of obese and normal persons. *Physiol Behav*. 1973;11(3):285-290.
28. Vartanian LR, Schwartz MB, Brownell KD. Effects of soft drink consumption on nutrition and health: a systematic review and meta-analysis. *Am J Public Health*. 2007;97(4):667-675.
29. Stookey JD, Constant F, Gardner CD, Popkin BM. Replacing sweetened caloric beverages with drinking water is associated with lower energy intake. *Obesity (Silver Spring)*. 2007;15(12):3013-3022.

30. Birch LL, Deysher M. Caloric compensation and sensory specific satiety: evidence for self regulation of food intake by young children. *Appetite*. 1986;7(4):323-331.
31. Cecil JE, Palmer CN, Wrieden W, et al. Energy intakes of children after preloads: adjustment, not compensation. *Am J Clin Nutr*. 2005;82(2):302-308.
32. Ebbeling CB, Feldman HA, Osganian SK, Chomitz VR, Ellenbogen SJ, Ludwig DS. Effects of decreasing sugar-sweetened beverage consumption on body weight in adolescents: a randomized, controlled pilot study. *Pediatrics*. 2006;117(3):673-680.
33. Haines PS, Hama MY, Guilkey DK, Popkin BM. Weekend eating in the United States is linked with greater energy, fat, and alcohol intake. *Obes Res*. 2003;11(8):945-949.
34. Ebbeling CB, Sinclair KB, Pereira MA, Garcia-Lago E, Feldman HA, Ludwig DS. Compensation for energy intake from fast food among overweight and lean adolescents. *JAMA*. 2004;291(23):2828-2833.
35. Bowman SA, Gortmaker SL, Ebbeling CB, Pereira MA, Ludwig DS. Effects of fast-food consumption on energy intake and diet quality among children in a national household survey. *Pediatrics*. 2004;113(1, pt 1):112-118.
36. Allison PD. *Fixed Effects Regression Methods for Longitudinal Data Using SAS*. Cary, NC: SAS Institute, Inc; 2005.
37. Lohr SL. *Sampling: Design and Analysis*. Pacific Grove, CA: Duxbury Press; 1999.
38. Gidding SS, Dennison BA, Birch LL, et al; American Academy of Pediatrics. Dietary recommendations for children and adolescents: a guide for practitioners: consensus statement from the American Heart Association [published correction appears in *Circulation*. 2006;113(23):e857]. *Circulation*. 2005;112(13):2061-2075.
39. American Dietetic Association. Position of the American Dietetic Association: use of nutritive and nonnutritive sweeteners. *J Am Diet Assoc*. 2004;104(2):255-275.
40. Tucker KL, Morita K, Qiao N, Hannan MT, Cupples LA, Kiel DP. Colas, but not other carbonated beverages, are associated with low bone mineral density in older women: the Framingham Osteoporosis Study. *Am J Clin Nutr*. 2006;84(4):936-942.
41. Lutsey PL, Steffen LM, Stevens J. Dietary intake and the development of the metabolic syndrome: the Atherosclerosis Risk in Communities Study. *Circulation*. 2008;117(6):754-761.
42. Bingham SA, Gill C, Welch A, et al. Comparison of dietary assessment methods in nutritional epidemiology: weighed records v. 24 h recalls, food-frequency questionnaires and estimated-diet records. *Br J Nutr*. 1994;72(4):619-643.
43. Briefel RR, Sempos CT, McDowell MA, Chien S, Alaimo K. Dietary methods research in the third National Health and Nutrition Examination Survey: underreporting of energy intake. *Am J Clin Nutr*. 1997;65(4)(suppl):1203S-1209S.
44. Faggiano F, Vineis P, Cravanzola D, et al. Validation of a method for the estimation of food portion size. *Epidemiology*. 1992;3(4):379-382.
45. James J, Thomas P, Cavan D, Kerr D. Preventing childhood obesity by reducing consumption of carbonated drinks: cluster randomised controlled trial. *BMJ*. 2004;328(7450):1237.

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