Contributors of water intake in US children and adolescents: associations with dietary and meal characteristics—National Health and Nutrition Examination Survey 2005–2006[1–3]

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ABSTRACT

Background: Little is known about the association of contributors of total water intake with dietary characteristics in US children.

Objective: We examined intakes of total water and its contributors and their associations with diet and meal reporting in children and adolescents.

Design: Dietary data for children 2–19 y of age (n = 3978) from the National Health and Nutrition Examination Survey 2005–2006 were used to compute usual intake of total water. The association of total water and its contributors with sociodemographic characteristics and dietary and meal attributes was examined by using multiple regression analysis.

Results: The adjusted mean intakes of total water in Americans aged 2–5, 6–11, and 12–19 y were 1.4, 1.6, and 2.4 L, respectively. The mean usual intake of total water was generally less than the Adequate Intake; overall, more boys reported intakes of at least the Adequate Intake. The percentage of total water intake from plain water increased with age. Plain water intake was inversely associated with the intake of beverage moisture and the energy density of foods; conversely, beverage moisture was positively associated with dietary energy, fat, and the energy density of foods. Associations of water contributors with meal patterns (number of eating occasions, reporting of breakfast or snack) were inconsistent across age groups. Nearly 80% of food moisture, >66% of beverage moisture, and ≈30% of plain water were reported with main meals.

Conclusions: Intake of total water over 24 h from different contributors varied by age. Qualitative differences in dietary intake in association with the amount of plain water and beverage moisture in the recalls were observed. American children and adolescents consumed more than two-thirds of their daily beverages with main meals. *Am J Clin Nutr* 2010;92:887–96.

INTRODUCTION

Water is an essential nutrient for all ages, and disturbance of the water balance results in adverse consequences within hours (1). The physiologic need for water is primarily met through the intake of plain water and from the moisture content of foods and beverages consumed. Water intake contributor patterns in younger children probably reflect caregiver preferences and beliefs; in older children and adolescents, water intake contributors may differ with increasing autonomy and access to various food environments. Despite widely held beliefs about how much plain water needs to be consumed daily (2), possible associations of water consumption with cognition in children (3, 4) and expressed concerns about the increasing role of sweetened beverages in the American diet (5–9), there has been relatively little systematic study of dietary contributors of total water intake and its correlates in the US population.

We recently reported the differential associations of various contributors of water intake with energy, nutrient profiles, and the energy density of diets consumed by free-living adult Americans (10). However, whether similar associations exist in children and adolescents is not known. The 2005 Institute of Medicine (IOM) report on water also mentioned that there was a paucity of "studies in water consumption and retention patterns due to meal schedules and diet" (1). Understanding the relative contributions of different sources of water and their associations with other dietary characteristics is important to identify contributors related to diet behaviors potentially amenable to intervention. To fill these research gaps, we used nationally representative dietary data for US children and adolescents 2–19 y of age to examine *1*) usual intakes of total water, *2*) respondent characteristics associated with contributors of daily water intake, and *3*) the association of 24-h dietary and meal attributes with contributors of water intake.

METHODS

The data for this study were from the 2005–2006 National Health and Nutrition Examination Surveys (NHANES) conducted by the National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention (11). The present study used public domain NHANES data and was approved by the Queens College institutional review board for the protection of human subjects with an exempt review.

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[2] Supported in part by the intramural research program of the Department of Health and Human Services, National Cancer Institute, NIH (to BIG).

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Received April 22, 2010. Accepted for publication June 30, 2010.

First published online August 4, 2010; doi: 10.3945/ajcn.2010.29708.

Each NHANES is a complex, multistage, probability sample of the civilian, noninstitutionalized US population. Beginning with 1999, the NHANES became a continuous annual survey with data released in 2-y aggregates (11). The surveys include a sample person interview at home and a complete medical examination in the mobile examination center (MEC). Anthropometric measurements (eg, height and weight) and a dietary interview were obtained in the MEC following standardized procedures. The unweighted response rate for the MEC-examined sample (all ages) in the NHANES 2005–2006 was 77%. The response rates for the ages examined in the present study (2–19 y) were >80% (12).

Analytic sample

All respondents 2–19 y of age, with a complete and reliable 24-h dietary recall, were eligible for inclusion in our study (*n* = 4029). We excluded pregnant and lactating respondents (*n* = 51) from the eligible sample; the final analytic sample included 3978 respondents.

Assessment of water intake

NHANES 1999–2006 collected dietary information using an interviewer-administered, computer-assisted 24-h dietary recall interview. For children 2–5 y of age, the recall was provided by parents or other caregivers, recalls of children 6–11 y of age were self-reported with assistance from parents or other caregivers, and 12–19-y-old adolescents self-reported their intake (12). We limited our analyses to the 2005–2006 survey because the methods used to collect plain water information in surveys conducted from 1999 to 2004 differed from those used in the 2005–2006 survey. In the 2005–2006 survey, the water intake (plain or carbonated) questions were integrated within the automated multiple-pass method (AMPM) used for collecting the 24-h recall; however, in the 1999–2004 surveys, respondents were asked "How much plain water did you drink yesterday?" *after* collection of the 24-h dietary recall (12). The 24-h diet recall method also changed in the middle of the 1999–2004 surveys (11, 12).

The public release dietary data for NHANES 2005–2006 include variables for plain water and total water (sum of plain water and moisture in all foods and beverages reported in the recall) for each respondent. For each 24-h recall, we examined 6 different types of water variables for this study: *1*) intake of plain water (defined by the NCHS to include tap water, water from a water cooler or drinking fountain, spring water, and noncarbonated bottled water), *2*) moisture in foods, *3*) moisture in *all* beverages, *4*) moisture in nutritive beverages, *5*) total water intake, and *6*) total water intake/kcal of reported energy intake. We considered all types of fluid milk, infant formula, fruit or vegetable juices, juice drinks, carbonated and noncarbonated sweetened or unsweetened drinks, coffee, tea, hot chocolate shakes, all alcoholic drinks, and carbonated water as beverages. From this list, all types of fluid milk, infant formula, and 100% fruit or vegetable juices were considered nutritive beverages, and the remaining beverages were considered nonnutritive. Individual food items that were identified as part of beverage combinations in the recall (eg, coffee with powdered whitener and sugar) were collectively considered as a beverage to reflect what respondents considered a beverage.

Nutrient variables

The IOM report discussed the possible modulating effects of dietary protein, fiber, and sodium on total water requirements (1). Therefore, we examined the 24-h dietary intakes of macronutrients, fiber, and sodium in relation to water intake in the present study. Two additional dietary characteristics examined were intake of total sugars and the energy density of nonbeverage foods [energy content (kcal)/g of foods]. Total sugars included both intrinsic and added sugars and were included because sweetened beverages contribute this nutrient. Because foods high in water (mostly fruit and vegetables) tend to have a lower energy density, the overall energy density of foods in the diet provides additional information about the nature of foods consumed in the recall.

Meal intake variables

We created several meal-pattern variables from the reported 24-h recall using methods that we described previously (10, 13). Briefly, the number of eating occasions reported on the day of dietary intake was determined from the number of discrete clock times any food or beverage was reported in the recall. Several foods, beverages, or their combinations reported at one clock time (eg, as part of a meal) were considered as one eating occasion. When the only reported item in an eating occasion was plain tap or unsweetened bottled water it was not considered an eating occasion.

Per previously described methods (14), eating occasions designated by the recall respondent as breakfast, *desayuno*, or *almuerzo* were considered breakfast. This definition of breakfast was consistent with that used by the US Department of Agriculture (15). Eating occasions designated as snack, drink, *merienda*, *entre comida*, *botana*, *bocadillo*, *tentempie*, and *bebida* were considered a snack. Eating occasions not named as a snack or other (other occasions were those not named as a meal or a snack by the recall respondent) were considered to constitute "main meals" and included breakfast, brunch, lunch, dinner, and supper (or their equivalents in Spanish).

Potential covariates

The potential covariates examined included the following: sex, race-ethnicity (non-Hispanic white, non-Hispanic black, Mexican American, or other), age category (2–5, 6–11, or 12–19 y), weekday of dietary intake recall (Monday–Thursday or Friday–Sunday), body mass index (BMI; in kg/m^2) for sex-age–specific percentile category (<85th, 85th to <95th, or ≥95th) (16), hours of screen time, the reported level of physical activity, and the season in which the MEC exam was conducted (May–October or November–April). The hours of screen time were determined from questions on television/video watching (h/d) or computer use over the past 30 d. The available physical activity questions differed by age group. For respondents 2–11 y of age, we examined the answer to a question on the number of times weekly that the child played enough to breathe hard or sweat. For respondents 12–19 y of age, we examined the reporting of any vigorous, moderate, or muscle-strengthening activity lasting ≥10 min in the past 30 d. We also examined the available physical activity monitor data (as mean intensity counts/min) for children 6–19 y of age (physical activity monitor data were not collected from children aged 2–5 y) using published methods and criteria of data validity (17, 18). These criteria included wearing of the activity monitor for ≥10 h/d for ≥4 d. Valid data were missing for ≈17% of 6–11-y-olds and ≈22% of 12–19-y-olds.

Statistical analyses

NHANES 2005–2006 also collected a second 24-h dietary recall, via telephone, 3–10 d after the first recall (12). We used this replicate recall along with the first recall to determine the "usual intake" of total water using methods developed by the National Cancer Institute (19). An amount only model, which estimates within- and between-person components of variation in nutrient intake to adjust for the within-person variance and effects due to covariates, was used for the current analyses. The rationale and SAS macros needed for these analyses are available on the National Cancer Institute website (19). These methods allowed adjustment for the day of week of dietary intake (weekday compared with weekend), season of MEC exam, and race-ethnicity. The mean amount of total water was estimated from the usual intake distributions for each sex-age category for our sample. The estimated usual intake of total water of each individual was compared with the sex-age specific Adequate Intake (AI) levels mentioned in the recent IOM report (1), and the percentage of all children in a sex-age category that met the AI was computed. The SEs used to compute 95% CIs for means and the percentage of children meeting the AI levels of water intakes were computed by using the Fay replicate weight method based on balanced half-sample repeated replication (20). A *t* distribution with 15 df was used to establish the 95% confidence limits. The df values were determined by the complex, multistage, stratified, cluster sample design of the NHANES survey (20).

The usual intakes of total water in this study were examined by age categories used in the IOM report so that estimate of usual intake could be compared with the AI and the percentage of children meeting the AI of water in each sex-age category (within the 2–19 y age range) could be determined. Because we did not examine children <2 y of age or adults >19 y of age, these age categories were as follows: 2–3, 4–8, 9–13, 14–18, and 19 y. All other analyses that examined the various water contributors and their associations with dietary and meal characteristics, grouped age as 2–5, 6–11, and 12–19 y. The choice of these age categories in our analyses reflects the NHANES sample design age groups and analytic recommendations (11). These age groups are also consistent with age respondent rules used for the dietary recall interview. Moreover, most published analyses using the NHANES data with weight and physical activity as principal outcomes of interest use these age groups (18, 21).

We examined the independent association of sociodemographic and lifestyle variables with various contributors of water intake using multiple linear regression analyses with each water contributor as a continuous dependent variable. The independent variables in these models included the following: sex, race-ethnicity, age group, the day of week of dietary intake, BMI-for-sex-age percentile category, hours of television and computer use, the reported level of physical activity, and the season of MEC exam. For these analyses, we present the covariate-adjusted mean and SE of each contributor of water intake by category of sociodemographic/lifestyle characteristic. The adjusted means are predicted margins from multiple regression models (20, 22).

The association of water contributions with dietary nutrient and meal pattern variables was similarly examined by using multiple linear regression methods that included each dietary or meal pattern variable as an independent variable (along with other covariates), with each water contributor as a continuous dependent variable. We examined whether age modified the association of water intake contributors with each unique dietary independent variable by testing the interaction of age with each dietary predictor. The interaction terms were generally significant ($P < 0.05$); therefore, further analyses were stratified by age group (ie, we conducted separate regression models for the age groups 2–5, 6–11, and 12–19 y). We examined all associations with inclusion of all covariates mentioned above; however, the results from these models were not different from parsimonious models that included only sex, race-ethnicity, age, day of week of dietary intake, season of MEC exam, and BMI-for-age percentile as covariates. Therefore, the results presented are from parsimonious multiple regression models with and without adjustment for energy intake. For these analyses, we present the regression coefficient, its SE, and the *P* value associated with each dietary or meal pattern independent variable. The dietary independent variables in these analyses were expressed in meaningful amounts (eg, 100 kcal or 5% of energy from macronutrients) to allow easy interpretation.

All statistical analyses used SAS (version 9.02; SAS Institute, Cary, NC) and SAS-callable SUDAAN (23). The SUDAAN software is designed for use with complex surveys to enable estimation of variances with adjustment for the multistage, stratified, cluster probability design of NHANES. Sample weights to further adjust for nonresponse, noncoverage, and sampling bias were used in all analyses. All reported *P* values for testing for significant association from regression models used the *F* statistic with a Satterthwaite correction for the df (24). Two-sided *P* values <0.5 were considered significant.

RESULTS

Usual intake of total water in children and adolescents

The mean usual intake of total water was less than the AI for all children and adolescents except those 2–3 y of age (**Table 1**). For boys, 15–60% had usual intakes that met or exceeded the AI; for girls, the corresponding estimates were 10–54%.

Sociodemographic and lifestyle correlates of contributors of water intake in children and adolescents

Not surprisingly, relative to boys, girls reported lower intakes of water from all sources; however, the percentage of beverage moisture contributed by nutritive beverages did not differ by sex and the total water intake (g)/energy intake (kcal) was higher in girls ($P = 0.01$) (**Table 2**). Race-ethnicity was a significant independent correlate of moisture in beverages, foods, and total water ($P \leq 0.01$). The reported intake of water from all sources increased with increasing age; however, the percentage of beverage moisture from nutritive beverages declined with age ($P < 0.0001$). Educational level of the household reference person was a weak correlate of food moisture ($P = 0.04$), but not of total

TABLE 1
Usual intake of total water by American children and adolescents 2–19 y of age and the percentage of the population that met the Adequate Intake (AI) of total water: National Health and Nutrition Examination Survey (NHANES) 2005–2006

	Boys (n = 1983)				Girls (n = 1995)			
Age group	AI	n	Mean usual intake (95% CI)[1]	≥AI (95% CI)	AI	n	Mean usual intake (95% CI)[1]	≥AI (95% CI)
	L		*L*	%	*L*		*L*	%
2–3 y	1.3	250	1.41 (1.32, 1.51)	60 (51, 69)	1.3	247	1.37 (1.29, 1.45)	54 (44, 63)
4–8 y	1.7	431	1.58 (1.47, 1.68)	34 (24, 44)	1.7	468	1.39 (1.30, 1.48)	13 (2, 25)
9–13 y	2.4	522	1.88 (1.73, 2.03)	15 (6, 23)	2.1	525	1.79 (1.64, 1.94)	26 (16, 36)
14–18 y	3.3	654	2.89 (2.65, 3.13)	29 (19, 39)	2.3	643	1.97 (1.84, 2.10)	24 (16, 32)
19 y	3.7	126	3.35 (3.07, 3.63)	33 (24, 43)	2.7	112	2.02 (1.82, 2.21)	10 (3, 17)

[1] Usual intakes were estimated by using 2 dietary recalls per the National Cancer Institute method, separately for each sex-age group. Usual intakes were adjusted for season of the mobile examination center exam (November–April or May–October), day of the week of dietary intake (Monday–Thursday or Friday–Sunday), and race-ethnicity (non-Hispanic white, non-Hispanic black, Mexican American, or other).

water. The physical activity variable was weakly associated with plain water intake, but not with beverage moisture or total water intake. We also repeated our analyses using age group–stratified regressions with data from physical activity monitors (an alternate measure of physical activity) as an independent variable in parsimonious models; the results were unchanged. (For age group–specific results of regression analyses with physical activity monitor data as an independent variable for 2–5-, 6–11-, and 12–19-y-old respondents, *see* Supplemental Tables 1–3 under "Supplemental data" in the online issue.) The percentage of beverage moisture from nutritive beverages was lower on weekends (P = 0.002) and in association with hours of screen time (P = 0.01); however, total beverage moisture and total water intake were not associated with day of week of dietary intake or screen time. A higher BMI-for-age percentile was associated with higher intakes of plain water (P = 0.01), total water (P = 0.001), and total water (g)/energy intake (kg) (P = 0.0006), but not with beverage or food moisture ($P > 0.05$). The age-specific parsimonious models also showed that the water-contributor associations with BMI-for-age percentiles differed by age group (*see* Supplemental Tables 1–3 under "Supplemental data" in the online issue). The adjusted mean percentages of respondents 2–5, 6–11, and 12–19 y of age reporting any plain water in the recall were 71%, 79%, and 75%, respectively (P for the age effect = 0.06).

Association of contributors of water intake with dietary and meal characteristics reported in a 24-h dietary recall

Associations noted in all age groups

The 24-h intake of plain water was inversely associated with beverage moisture and total sugars but positively with food moisture ($P < 0.05$) (**Tables 3–5**). Beverage moisture, food moisture, and total water intakes were positively related with 24-h energy intake ($P < 0.0001$) (Tables 3–5). Beverage moisture intake was positively associated with intakes (g) of all macronutrients ($P < 0.0001$); with energy adjustment (as % of energy), these associations became inverse for dietary fat and protein but remained positive for carbohydrate and total sugars. The energy density of foods also was positively associated with beverage moisture ($P < 0.03$). Food moisture was inversely associated with dietary energy density and with the percentage of energy from total sugars, but positively with dietary fiber and sodium intakes. Total moisture was inversely related to dietary energy density, but positively to dietary fiber and sodium. Breakfast reporting was not associated with any of the sources of water.

Associations that differed by age

In 2–5-y-old children, in models without energy adjustment, beverage moisture, food moisture, and total water increased with increasing number of eating occasions ($P \leq 0.002$). Mention of a snack in the recall also was associated with higher plain water, food moisture, and total water intakes in this age group. In children 6–11 and 12–19 y of age, plain water intake was related inversely with the percentage of energy from carbohydrates and energy density, but positively with dietary fiber intake. The energy-adjusted fiber intake was a positive correlate of total water intake only in 6–11-y-olds (P = 0.0004).

Meal sources of water intake

A mean of 57% of the total 24-h water was consumed with main meals by 2–5-y-old children, but was ≈49% in those 12–19 y of age (P for age effect = 0.001) (**Figure 1**). The percentage of 24-h beverage moisture and nutritive beverage moisture consumed with main meals differed between age groups (P = 0.04). More than 65% of the 24-h beverage moisture, ≈75% of the nutritive beverage moisture, and ≈61% of the nonnutritive beverage moisture were reported with main meals (Figure 1).

DISCUSSION

American children and adolescents 2–19 y of age reported a mean total water intake of ≈1.9 L in the 24-h recall. The percentage contribution of plain water to 24-h total water intake increased with age (from 22% in 2–5-y- olds to >33% in 12–19-y-olds). The highest percentage of the 24-h total water intake from beverages was reported by 2–5-y-olds (>52% of total), but nearly 70% of this came from nutritive beverages. In adolescents, the mean proportions of total water contributed by plain water, beverages, and foods were 33%, 47%, and 20%, respectively; these estimates are similar to those reported by adults in NHANES 2005–2006 (10).

In children and adolescents 4–19 y of age, the mean "usual" total water intakes were lower than the AI, and a correspondingly smaller percentage of the population met the AI. NHANES III

TABLE 2

Independent association (adjusted mean ± SE) of contributors of 24-h water intake with sociodemographic variables in American children and adolescents 2–19 y of age: National Health and Nutrition Examination Survey (NHANES) 2005–2006[1]

Independent variable	Plain water	Beverage moisture	Beverage moisture from nutritive beverages[2]	Food moisture	Total water	Total water
	g	*g*	*%*	*g*	*g*	*g/kcal*
All, unadjusted (*n* = 3978)	583 ± 30	907 ± 34	47 ± 1	430 ± 7	1920 ± 36	1.01 ± 0.01
All, adjusted for all covariates (*n* = 3867)	583 ± 28	912 ± 35	47 ± 1	431 ± 7	1926 ± 36	1.01 ± 0.01
Sex						
Boys (*n* = 1927)	624 ± 37	1058 ± 50	46 ± 1	463 ± 9	2145 ± 46	0.98 ± 0.02
Girls (*n* = 1940)	540 ± 23	763 ± 23	47 ± 2	398 ± 8	1701 ± 31	1.03 ± 0.01
P value[3]	0.008	<0.0001	0.5	<0.0001	<0.0001	0.01
Race-ethnicity						
Non-Hispanic white (*n* = 1033)	631 ± 47	967 ± 44	46 ± 2	434 ± 8	2032 ± 45	1.03 ± 0.02
Non-Hispanic black (*n* = 1209)	480 ± 39	767 ± 50	45 ± 2	389 ± 15	1636 ± 68	0.91 ± 0.03
Mexican American (*n* = 1272)	514 ± 37	912 ± 37	52 ± 2	462 ± 16	1889 ± 61	1.00 ± 0.03
Other (*n* = 353)	542 ± 44	814 ± 48	44 ± 3	434 ± 15	1791 ± 52	1.02 ± 0.04
P value[3]	0.07	0.006	0.3	0.01	0.0003	0.06
Age						
2–5 y (*n* = 866)	302 ± 18	723 ± 22	68 ± 2	350 ± 11	1376 ± 21	0.92 ± 0.02
6–11 y (*n* = 1004)	469 ± 39	745 ± 42	52 ± 2	431 ± 13	1644 ± 39	0.86 ± 0.02
12–19 y (*n* = 1997)	801 ± 46	1127 ± 53	32 ± 2	470 ± 9	2397 ± 66	1.16 ± 0.03
P value[3]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Family poverty-income ratio						
<1 (*n* = 1114)	563 ± 45	945 ± 41	47 ± 2	459 ± 17	1967 ± 58	1.02 ± 0.03
1 to <2 (*n* = 970)	534 ± 39	960 ± 68	46 ± 1	410 ± 15	1903 ± 70	0.97 ± 0.03
≥2 (*n* = 1623)	608 ± 33	888 ± 42	47 ± 1	427 ± 9	1923 ± 44	1.02 ± 0.02
Unknown (*n* = 160)	574 ± 51	828 ± 66	41 ± 7	482 ± 43	1884 ± 110	1.01 ± 0.06
P value[3]	0.2	0.4	0.7	0.1	0.8	0.5
Education of household reference person						
<12 y (*n* = 1156)	658 ± 69	851 ± 48	47 ± 2	422 ± 16	1933 ± 59	1.08 ± 0.05
12 y (*n* = 877)	546 ± 58	948 ± 51	46 ± 2	399 ± 13	1893 ± 37	0.98 ± 0.03
>12 y (*n* = 1667)	570 ± 23	911 ± 42	47 ± 1	447 ± 9	1928 ± 50	1.00 ± 0.02
Unknown (*n* = 167)	644 ± 76	968 ± 100	47 ± 4	458 ± 27	2069 ± 129	0.98 ± 0.07
P value[3]	0.4	0.4	0.9	0.04	0.5	0.3
BMI-for-age percentile						
<85 (*n* = 2552)	550 ± 33	873 ± 35	48 ± 1	439 ± 11	1861 ± 31	0.95 ± 0.02
85 to <95 (*n* = 570)	582 ± 52	979 ± 68	46 ± 3	410 ± 14	1969 ± 59	1.07 ± 0.04
≥95 (*n* = 745)	720 ± 44	1015 ± 71	41 ± 2	421 ± 11	2155 ± 81	1.18 ± 0.05
P value[3]	0.01	0.1	0.08	0.2	0.001	0.0006
Day of week of dietary intake						
Monday–Thursday (*n* = 1042)	615 ± 38	903 ± 51	50 ± 1	443 ± 11	1960 ± 48	1.03 ± 0.02
Friday–Sunday (*n* = 2825)	541 ± 24	924 ± 22	42 ± 1	416 ± 7	1881 ± 41	0.97 ± 0.01
P value[3]	0.08	0.6	0.002	0.08	0.2	0.03
Season of MEC exam						
November–April (*n* = 1978)	584 ± 33	896 ± 49	46 ± 2	430 ± 11	1911 ± 40	1.00 ± 0.02
May–October (*n* = 1889)	582 ± 39	924 ± 42	47 ± 1	432 ± 9	1937 ± 48	1.01 ± 0.02
P value[3]	1.0	0.6	0.7	0.9	0.6	0.6
Television and computer use						
0 h/d (*n* = 404)	682 ± 66	849 ± 54	51 ± 4	430 ± 13	1962 ± 93	1.03 ± 0.04
1 h/d (*n* = 662)	612 ± 36	890 ± 55	55 ± 3	434 ± 12	1935 ± 72	1.05 ± 0.04
2 h/d (*n* = 864)	583 ± 51	899 ± 41	45 ± 2	422 ± 12	1904 ± 49	1.02 ± 0.03
3 h/d (*n* = 632)	467 ± 33	974 ± 45	44 ± 2	438 ± 20	1879 ± 51	0.94 ± 0.03
≥4 h/d (*n* = 1305)	589 ± 29	927 ± 39	42 ± 1	434 ± 11	1950 ± 43	0.99 ± 0.03
P value[3]	0.06	0.3	0.01	0.8	0.7	0.3
Physical activity[4]						
None (*n* = 232)	379 ± 83	1173 ± 194	41 ± 4	417 ± 35	1969 ± 244	0.88 ± 0.04
A little (*n* = 554)	516 ± 79	842 ± 57	45 ± 2	423 ± 27	1780 ± 108	0.95 ± 0.04
Some (*n* = 948)	515 ± 39	881 ± 32	47 ± 2	412 ± 18	1808 ± 67	0.96 ± 0.04
A lot (*n* = 2133)	643 ± 31	917 ± 44	47 ± 1	442 ± 10	2003 ± 49	1.05 ± 0.02
P value[3]	0.03	0.2	0.3	0.5	0.2	0.06

[1] MEC, mobile examination center. The regression model for each water contributor included all of the abovementioned variables; those missing BMI, physical activity, or television and computer use information were excluded from the regression models (*n* = 111).

[2] Includes those with all covariate information who reported any beverage in the recall (*n* = 3778).

[3] Indicates the significance of the association of each independent variable (in the presence of all other variables in the model) from regression models by using the *F* statistic with a Satterthwaite correction for the df.

[4] The physical activity variable was created as follows—for 2–11-y-olds, the response to the question on the number of times per week that play or exercise was hard enough to induce sweat: 0 = none, 1–2 times = a little, 3–4 times = some, and ≥5 times = a lot; for 12–19-y-olds, the responses to 3 different questions on any leisure time vigorous, moderate, or muscle-strengthening activity lasting ≥10 min: no to all 3 = none, yes to 1 = a little, yes to 2 = some, and yes to all 3 = a lot.

TABLE 3

Independent association of dietary and meal pattern variables with contributors of 24-h water intake reported by American children 2–5 y of age: National Health and Nutrition Examination Survey (NHANES) 2005–2006[1]

Independent variable	Plain water	Beverage moisture	Food moisture	Total water
	g	*g*	*g*	*g*
Plain water (100 g)	—	−27 ± 6 (<0.0004)	5 ± 2 (0.05)	—
Moisture in beverages (100 g)	−21 ± 3 (<0.0001)	—	3 ± 3 (0.3)	—
Energy (100 kcal)	−2 ± 4 (0.6)	40 ± 4 (<0.0001)	17 ± 1 (<0.0001)	55 ± 4 (<0.0001)
Amount of foods only (100 g)	12 ± 5 (0.05)	14 ± 9 (0.1)	71 ± 1 (<0.0001)	96 ± 10 (<0.0001)
Energy density of foods (only) reported in the recall (kcal/g)[2]	−39 ± 20 (0.07)	75 ± 32 (0.03)	−214 ± 10 (<0.0001)	−177 ± 37 (0.0003)
Fat (5 g)	3 ± 4 (0.5)	26 ± 4 (<0.0001)	13 ± 1 (<0.0001)	42 ± 4 (<0.0001)
Energy from fat (5%)	19 ± 13 (0.2)	−33 ± 13 (0.02)	−6 ± 7 (0.3)	−20 ± 12 (0.1)
Protein (5 g)	5 ± 4 (0.3)	32 ± 4 (<0.0001)	22 ± 1 (<0.0001)	59 ± 4 (<0.0001)
Energy from protein (5%)	36 ± 18 (0.06)	−66 ± 15 (0.0007)	30 ± 15 (0.06)	−1 ± 21 (1.0)
Carbohydrate (10 g)	−4 ± 2 (0.1)	29 ± 3 (<0.0001)	10 ± 1 (<0.0001)	36 ± 3 (<0.0001)
Energy from carbohydrate (5%)	−18 ± 10 (0.1)	34 ± 10 (0.003)	−1 ± 6 (0.9)	15 ± 8 (0.1)
Total sugars (5 g)	−5 ± 2 (0.006)	27 ± 2 (<0.0001)	5 ± 1 (<0.0001)	27 ± 2 (<0.0001)
Energy from total sugars (5%)	−29 ± 7 (0.0007)	90 ± 8 (<0.0001)	−11 ± 4 (0.008)	50 ± 10 (0.0002)
Fiber (5 g)	8 ± 15 (0.6)	66 ± 20 (0.004)	100 ± 12 (<0.0001)	175 ± 26 (<0.0001)
Fiber (5 g), energy-adjusted	21 ± 13 (0.1)	−85 ± 18 (0.0003)	84 ± 17 (0.0001)	20 ± 21 (0.3)
Sodium (100 mg)	3 ± 2 (0.2)	9 ± 2 (<0.0001)	9 ± 1 (<0.0001)	21 ± 2 (<0.0001)
Sodium (100 mg), energy-adjusted	7 ± 2 (0.001)	−15 ± 3 (0.0003)	6 ± 1 (<0.0001)	−1 ± 4 (0.7)
Meal intake variables				
Number of eating occasions	6 ± 9 (0.5)	82 ± 16 (0.0001)	19 ± 5 (0.002)	107 ± 15 (<0.0001)
Number of eating occasions, energy-adjusted	8 ± 8 (0.3)	50 ± 14 (0.003)	4 ± 4 (0.4)	62 ± 10 (<0.0001)
Mentioned a snack in the recall	143 ± 44 (0.005)	115 ± 78 (0.2)	113 ± 29 (0.002)	370 ± 100 (0.002)
Mentioned a snack in the recall, energy-adjusted	150 ± 44 (0.004)	0.4 ± 63 (0.9)	65 ± 26 (0.02)	215 ± 84 (0.02)
Mentioned breakfast in the recall	155 ± 72 (0.05)	−5 ± 120 (1.0)	45 ± 31 (0.2)	194 ± 182 (0.3)
Mentioned breakfast in the recall, energy-adjusted	157 ± 75 (0.05)	−55 ± 76 (0.5)	24 ± 24 (0.5)	126 ± 118 (0.3)

[1] All values are βs ± SEs from the linear regression analyses associated with the units of measurement for each independent variable; *P* values are in parentheses. For example, for every 100-kcal increase in energy intake, the intake of plain water decreased by 2 g, the moisture in beverages increased by 40 g, the food-only moisture increased by 17 g, and the total water intake increased by 55 g. The multiple regression models included sex, race (non-Hispanic white, non-Hispanic black, Mexican American, or other), age (continuous), sex-specific BMI-for-age percentile (continuous), day of week of dietary intake (Monday–Thursday or Friday–Sunday), month of the mobile examination center exam (November–April or May–October), and each independent variable in the table (n = 869). Energy-adjusted models included energy intake (kcal) as a continuous variable. *P* values indicate the significance of the association of each independent variable (in the presence of all other variables in the model) from regression models by using the *F* statistic with a Satterthwaite correction for the df.

[2] Plain water and all beverages excluded.

(1988–1994) mean estimates of usual intake of total water reported in the 2005 IOM report (1) are generally higher than estimates in the present study, in every IOM age group. Although there are several methodologic differences between NHANES III and current estimates, given that the median reported amounts in the NHANES III form the basis of the 2005 reference AI levels for total water, these findings need to be replicated in future surveys. We caution that, given the basis for derivation of AI recommendations (lack of sufficient knowledge of distribution of water requirements) (25), these results cannot be used to estimate the prevalence of inadequacy in the population or to make comparisons between groups. Moreover, it is likely that the proportion meeting the AI may have been underestimated because of underreporting of dietary intakes (discussed below).

Apart from the abovementioned NHANES III estimates of water intake in the IOM report (1) and the estimates from NHANES 1999–2002 for the combined age group of 4–18 y (26), we are unaware of other published estimates of water intake in US children to allow comparisons with those reported here. In the 2004 Canadian Community Health Survey, the 24-h estimates of reported fluid intake (beverage moisture + plain water) of children 4–18 y of age were comparable with those reported here (27). However, a German and a French study have reported lower total water intakes in children (28, 29). In these reports, plain water and beverage moisture intakes were lower than those reported in the present study, but the food moisture intakes were higher. These differences possibly reflect differences in dietary patterns across countries along with different methods of dietary assessment.

Few sociodemographic or lifestyle factors were independently related to total water intake. The sex- and ethnicity-related differences in total water intake appeared to be related to energy intake (total food intake) because the differences were either eliminated (ethnicity) or changed direction (sex) when total water intake was expressed as g/kcal. The higher intake of plain water may be a contributor to higher total water intake in overweight children and adolescents and may reflect attempts at weight management. It is also apparent that higher plain water intake was

TABLE 4

Independent association of dietary and meal pattern variables with contributors of 24-h water intake reported by American children 6–11 y of age: National Health and Nutrition Examination Survey (NHANES) 2005–2006[1]

Independent variable	Plain water	Beverage moisture	Food moisture	Total water
	g	*g*	*g*	*g*
Plain water (100 g)	—	−22 ± 2 (<0.0001)	6 ± 2 (0.008)	—
Moisture in beverages (100 g)	−31 ± 5 (<0.0001)	—	−1 ± 3 (0.6)	—
Energy (100 kcal)	−2 ± 3 (0.4)	30 ± 3 (<0.0001)	14 ± 1 (<0.0001)	41 ± 4 (<0.0001)
Amount of foods (only) (100 g)	27 ± 6 (0.0001)	−3 ± 7 (0.7)	70 ± 2 (<0.0001)	94 ± 11 (<0.0001)
Energy density of foods (only) reported in the recall[2]	−97 ± 45 (0.05)	108 ± 30 (0.003)	−273 ± 13 (<0.0001)	−262 ± 50 (<0.0001)
Fat (5 g)	4 ± 5 (0.5)	15 ± 3 (<0.0001)	11 ± 2 (<0.0001)	30 ± 6 (<0.0001)
Energy from fat (5%)	38 ± 20 (0.1)	−54 ± 14 (0.001)	3 ± 8 (0.7)	−14 ± 20 (0.5)
Protein (5 g)	5 ± 3 (0.1)	20 ± 3 (<0.0001)	19 ± 2 (0.0001)	44 ± 6 (<0.0001)
Energy from protein (5%)	73 ± 27 (0.02)	−66 ± 16 (0.0008)	42 ± 12 (0.004)	48 ± 35 (0.2)
Carbohydrate (10 g)	5 ± 1 (0.004)	22 ± 2 (<0.0001)	8 ± 1 (<0.0001)	25 ± 2 (<0.0001)
Energy from carbohydrate (5%)	−36 ± 11 (0.005)	47 ± 10 (0.0003)	−7 ± 6 (0.2)	4 ± 14 (0.8)
Total sugars (5 g)	−9 ± 1 (<0.0001)	21 ± 2 (<0.0001)	3 ± 1 (0.001)	15 ± 2 (<0.0001)
% energy from total sugars (5%)	−67 ± 10 (<0.0001)	96 ± 11 (<0.0001)	−16 ± 7 (0.03)	13 ± 13 (0.3)
Fiber (5 g)	58 ± 15 (0.002)	14 ± 15 (0.4)	90 ± 9 (<0.0001)	162 ± 15 (<0.0001)
Fiber (5 g), energy-adjusted	89 ± 14 (<0.0001)	−83 ± 14 (<0.0001)	75 ± 9 (<0.0001)	81 ± 18 (0.0004)
Sodium (100 mg)	3 ± 2 (0.1)	4 ± 2 (0.1)	8 ± 1 (<0.0001)	15 ± 2 (<0.0001)
Sodium (100 mg), energy-adjusted	8 ± 4 (0.05)	−12 ± 4 (0.005)	6 ± 1 (0.0002)	2 ± 3 (0.4)
Meal intake variables				
Number of eating occasions	4 ± 17 (0.8)	27 ± 18 (0.1)	24 ± 9 (0.01)	55 ± 35 (0.1)
Number of eating occasions, energy-adjusted	6 ± 20 (0.8)	−0.04 ± 15 (1.0)	11 ± 7 (0.1)	17 ± 32 (0.6)
Mentioned a snack in the recall	−93 ± 94 (0.3)	−20 ± 94 (0.8)	34 ± 41 (0.4)	−79 ± 135 (0.6)
Mentioned a snack in the recall, energy-adjusted	−90 ± 93 (0.3)	−66 ± 90 (0.5)	11 ± 43 (0.8)	−145 ± 140 (0.3)
Mentioned breakfast in the recall	−23 ± 65 (0.7)	90 ± 100 (0.4)	6 ± 32 (0.8)	73 ± 80 (0.4)
Mentioned breakfast in the recall, energy-adjusted	−18 ± 68 (0.9)	18 ± 99 (0.8)	−31 ± 31 (0.3)	−31 ± 80 (0.7)

[1] All values are βs ± SEs from the linear regression analyses associated with the units of measurement for each independent variable; *P* values are in parentheses. For example, for every 100-kcal increase in energy intake, the intake of plain water decreased by 2 g, the moisture in beverages increased by 30 g, the food-only moisture increased by 14 g, and the total water intake increased by 41 g. The multiple regression models included sex, race (non-Hispanic white, non-Hispanic black, Mexican American, or other), age (continuous), sex-specific BMI-for-age percentile (continuous), day of week of dietary intake (Monday–Thursday or Friday–Sunday), month of the mobile examination center exam (November–April or May–October), and each independent variable in the table (n = 1009). Energy-adjusted models included energy intake (kcal) as a continuous variable. *P* values indicate the significance of the association of each independent variable (in the presence of all other variables in the model) from regression models by using the *F* statistic with a Satterthwaite correction for the df.

[2] Plain water and all beverages excluded.

not associated with lower beverage moisture in overweight and obese children (the trend in reported beverage moisture in association with adiposity was also positive but was not statistically significant). This finding suggests that the inverse association of plain water with beverage moisture observed for the total study population was absent in overweight children and adolescents who reported consuming more plain water in addition to their intake of beverages. We are unaware of other published studies in which plain water and beverage moisture were similarly examined in relation to BMI, to allow comparisons. Consistent with other reports (30), children reporting more screen time (television, video, computer) chose fewer nutritive beverages. Surprisingly, intakes of total water or beverage moisture were unrelated to physical activity variables (whether self reported or from physical activity monitor data). The extent to which these results reflect limitations of the methods for assessment of diet and physical activity is not known.

Substitution of sweetened beverages with plain water has been reported to lower energy intakes in adult women (31). Although plain water intake was an inverse predictor of beverage moisture, surprisingly, it did not relate with energy intake in our study. These results suggest that in the absence of an intentional substitution, drinking more plain water does not necessarily contribute to lower energy intake.

Overall, the quality of food selection was more favorable with plain water intake. In respondents 6–19 y of age, plain water intake was related to higher fiber intake, and, not surprisingly, with higher food moisture and lower energy density of foods. Conversely, beverage moisture was related to both quantitative (higher energy intake) and qualitative (eg, higher energy density and total sugars) dietary characteristics. The associations of beverage moisture with all examined dietary macronutrients were generally positive but became inverse (fat and protein) when adjusted for energy intake. Although beverage moisture in our study includes both nutritive and nonnutritive beverages, similar associations have been reported for sugar-sweetened beverages in German (32) and US (33) children. Therefore, our results suggest that energy adjustment–linked changes in the direction of the association of fat and protein with beverage moisture may be

TABLE 5

Independent association of dietary and meal pattern variables with contributors of 24-h water intake reported by American adolescents 12–19 y of age: National Health and Nutrition Examination Survey (NHANES) 2005–2006[1]

Independent variable	Plain water	Beverage moisture	Food moisture	Total water
	g	*g*	*g*	*g*
Plain water (100 g)	—	−13 ± 5 (0.02)	3 ± 1 (0.01)	—
Moisture in beverages (100 g)	−13 ± 6 (0.04)	—	6 ± 2 (0.006)	—
Energy (100 kcal)	−2 ± 4 (0.6)	49 ± 7 (<0.0001)	15 ± 1 (<0.0001)	62 ± 6 (<0.0001)
Amount of foods only (100 g)	15 ± 7 (0.05)	57 ± 13 (0.0005)	62 ± 2 (<0.0001)	134 ± 15 (<0.0001)
Energy density of foods (only) reported in the recall[2]	−169 ± 46 (0.002)	134 ± 45 (0.009)	−259 ± 16 (<0.0001)	−294 ± 63 (0.0003)
Fat (5 g)	0.02 ± 3 (1.0)	37 ± 6 (<0.0001)	15 ± 1 (<0.0001)	52 ± 6 (<0.0001)
Energy from fat (5%)	18 ± 18 (0.3)	−107 ± 25 (0.0007)	0.5 ± 7 (0.9)	−89 ± 23 (0.002)
Protein (5 g)	3 ± 3 (0.3)	43 ± 5 (<0.0001)	20 ± 2 (<0.0001)	66 ± 6 (<0.0001)
Energy from protein (5%)	112 ± 34 (0.006)	−131 ± 52 (0.02)	67 ± 11 (<0.0001)	47 ± 66 (0.5)
Carbohydrate (10 g)	4 ± 3 (0.2)	39 ± 5 (<0.0001)	10 ± 1 (<0.0001)	44 ± 4 (<0.0001)
Energy from carbohydrate (5%)	−43 ± 16 (0.02)	63 ± 28 (0.04)	−12 ± 4 (0.009)	7 ± 32 (0.8)
Total sugars (5 g)	−7 ± 2 (0.008)	35 ± 3 (<0.0001)	5 ± 1 (0.0002)	32 ± 3 (<0.0001)
Energy from total sugar (5%)	−93 ± 12 (<0.0001)	140 ± 26 (<0.0001)	−19 ± 3 (<0.0001)	28 ± 26 (0.3)
Fiber (5 g)	55 ± 17 (0.007)	120 ± 26 (0.0004)	99 ± 10 (<0.0001)	274 ± 41 (<0.0001)
Fiber (5 g), energy-adjusted	112 ± 21 (0.0001)	−157 ± 51 (0.007)	63 ± 10 (<0.0001)	17 ± 57 (0.7)
Sodium (100 mg)	4 ± 1 (0.003)	17 ± 3 (<0.0001)	9 ± 0.5 (<0.0001)	31 ± 3 (<0.0001)
Sodium (100 mg), energy-adjusted	17 ± 4 (0.0004)	−17 ± 5 (0.006)	7 ± 1 (<0.0001)	8 ± 8 (0.3)
Meal intake variables				
Number of eating occasions	19 ± 22 (0.4)	192 ± 20 (<0.0001)	55 ± 9 (<0.0001)	267 ± 30 (<0.0001)
Number of eating occasions, energy-adjusted	32 ± 25 (0.2)	40 ± 36 (0.3)	9 ± 6 (0.2)	81 ± 37 (0.04)
Mentioned a snack in the recall	137 ± 123 (0.3)	395 ± 92 (0.0006)	83 ± 22 (0.002)	614 ± 129 (0.0002)
Mentioned a snack in the recall, energy-adjusted	151 ± 131 (0.3)	141 ± 87 (0.1)	4 ± 24 (0.8)	297 ± 137 (0.05)
Mentioned breakfast in the recall	−67 ± 88 (0.5)	119 ± 102 (0.2)	18 ± 20 (0.4)	71 ± 106 (0.5)
Mentioned breakfast in the recall, energy-adjusted	−62 ± 83 (0.5)	−26 ± 83 (0.7)	−26 ± 18 (0.2)	−113 ± 78 (0.2)

[1] All values are βs ± SEs from the linear regression analyses associated with the units of measurement for each independent variable; *P* values are in parentheses. For example, for every 100-kcal increase in energy intake, the intake of plain water decreased by 2 g, the moisture in beverages increased by 49 g, the food-only moisture increased by 15 g, and the total water intake increased by 62 g. The multiple regression models included sex, race (non-Hispanic white, non-Hispanic black, Mexican American, or other), age (continuous), sex-specific BMI-for-age percentile (continuous), day of week of dietary intake (Monday–Thursday or Friday–Sunday), month of the mobile examination center exam (November–April or May–October), and each independent variable in the table (n = 2053). Energy-adjusted models included energy intake (kcal) as a continuous variable. *P* values indicate the significance of the association of each independent variable (in the presence of all other variables in the model) from regression models by using the *F* statistic with a Satterthwaite correction for the df.

[2] Plain water and all beverages excluded.

related to the higher contribution of sweetened beverages (which are usually devoid of fat and protein) with increasing beverage moisture. The same phenomenon may partially explain the divergence of association of beverage moisture and sodium intake with and without energy adjustment.

The associations of the reported meal patterns with most contributors of water intake were inconsistent across age groups. Moreover, the observed associations were likely related to overall food intake because of the marked attenuation observed after adjustment for energy intake. The main meals were the biggest contributors of 24-h food moisture (≈80%) and beverage moisture (>66%), but only a third of the plain water. These observations suggest that American children of all ages were more likely to consume beverages rather than plain water as accompaniments to their meals. Whether the consumption of beverages with main meals reflects preference or the availability of beverages over plain water could not be examined in the present study. Efforts to promote the use of plain water as an alternative to energy-containing beverages are likely to meet resistance if beverage consumption with meals is preferred over plain water. The findings of 2 European intervention trials to promote water consumption also support this argument (34, 35). In these trials, the intervention did increase water intake, but water consumption did not replace other sweetened beverages, because the consumption of these beverages remained unchanged.

We acknowledge that all methods of dietary assessment, including the 24-h recall used in NHANES, are prone to both systematic and random measurement errors (25). The NHANES dietary recall (AMPM) incorporates recent developments in the collection of the recall (36). In adult validation studies, the AMPM has been shown to improve the recall of food intake (37); however, we know of no validation studies of this method in children and adolescents. One widely recognized source of measurement error is inadvertent or intentional misreporting, mostly underreporting, of food intake. The extent of misreporting is also likely to differ by age group, with a higher prevalence in adolescents (38). Therefore, it is likely that underreporting may

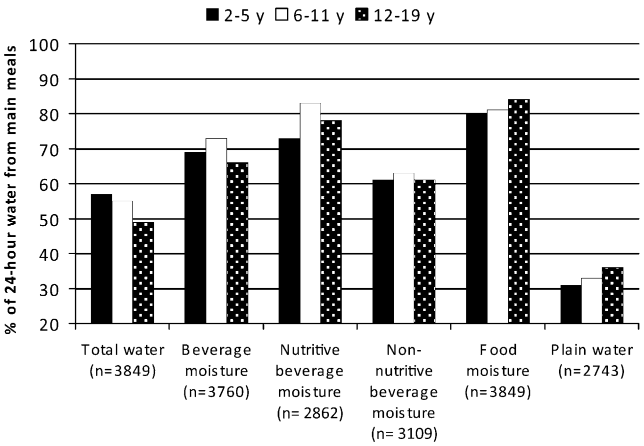

FIGURE 1. Adjusted mean percentages of contributors of water consumed with main meals reported in a 24-h recall by children and adolescents 2–19 y of age in the National Health and Nutrition Examination Survey (NHANES) 2005–2006. Adjusted means were obtained from multiple regression models that included sex, race-ethnicity, age group, sex-specific BMI-for-age percentile, educational level of household reference person, family income, level of physical activity, hours of screen time, day of week of dietary intake, and month of mobile examination center exam as independent variables with each water variable from main meals as a continuous dependent outcome. All regression models excluded those subjects with missing BMI, physical activity, and television and computer use data and those who reported no main meals in the recall (n = 129). All other analyses were limited to those who reported the examined water variable contributor. P values indicate the significance of the association of each independent variable (in the presence of all other variables in the model) from regression models by using the F statistic with a Satterthwaite correction for the df. The age effect was significant for total water (P = 0.001) and for beverage moisture and nutritive beverage moisture (P = 0.04).

have contributed to underestimation of water intake in the current study. It is also possible that, with increasing undesirability of the consumption of sugar-sweetened beverages, there may be differential underreporting of such beverages. Finally, because of within person variability in food intake, we estimated usual intakes of total water that adjusted for this variability using recently developed statistical methods (19). Our conclusions about the association of water contributors as dependent variables are interpreted within the context of a 24-h recall; as dependent variables, their within person variability is subsumed in the error terms of the regression models.

In conclusion, our results suggest age differences in the extent of water contributed by different sources to the diets of American children. The quality of food selections reported in association with plain water intake was better than that reported with increasing beverage moisture, and the strength of these associations varied with age. Finally, American children and adolescents are more likely to consume beverages with their main meals. Therefore, efforts to moderate the consumption of sweetened beverages and promote plain water intake should not only continue to promote plain water for snacks but also should recognize the importance of replacing nonnutritive beverages at meal time with plain water.

We thank Lisa L Kahle (IMS, Silver Spring, MD) for expert programming support, Kevin Dodd (National Cancer Institute, Rockville, MD) and Joseph Goldman (ARS, USDA, Beltsville, MD) for providing the replicate weights (used in usual intake estimations) for the 2005–2006 survey and for discussions about estimations of usual intakes, and Richard Troiano (National Cancer Institute, Rockville, MD) for providing the intensity counts/minute data from the physical activity monitors.

The authors' responsibilities were as follows—AKK: responsible for all aspects of this study, conceptualization of the study question, analytic strategy, data analysis, interpretation of the study results, and preparation of the manuscript; and BIG: involved in the conceptualization of the study question, analytic strategy, interpretation of study results, and editing of manuscript drafts for scientific content. Neither author declared a conflict of interest.

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