Association of food form with self-reported 24-h energy intake and meal patterns in US adults: NHANES 2003–2008[1–3]

Ashima K Kant, Barry I Graubard, and Richard D Mattes

ABSTRACT

Background: Laboratory studies suggest that food form (beverages compared with solid foods) evokes behavioral and physiologic responses that modify short-term appetite and food intake. Beverage energy may be less satiating and poorly compensated, which leads to higher energy intake.

Objective: We examined associations between 24-h energy consumed in beverages and a variety of meal and dietary attributes to quantify the contribution of beverage consumption to the energy content of diets in free-living individuals consuming their self-selected diets.

Design: We used dietary recall data for adults (n = 13,704) in NHANES 2003–2008 to examine the multiple covariate-adjusted associations between 24-h energy from beverages and nonbeverages and associations between beverage intake, eating behaviors, and the energy density of beverage and nonbeverage foods.

Results: In the highest tertile of 24-h beverage energy intake, beverages provided >30% of energy. Total 24-h energy and nonbeverage energy consumption and energy density (kcal/g) of both beverage and nonbeverage foods increased with increasing energy from beverages ($P < 0.0001$). With increasing 24-h beverage energy consumption, the reported frequency of all, snack, and beverage-only ingestive episodes and length of the ingestive period increased, whereas the percentage of energy from main meals decreased ($P < 0.0001$).

Conclusions: Higher 24-h beverage energy intake was related to higher energy intake from nonbeverage foods, quality of food selections, and distribution of 24-h energy into main meal and snack episodes. Moderation of beverage-only ingestive episodes and curtailing the length of the ingestion period may hold potential to lower uncompensated beverage energy consumption in the US population. *Am J Clin Nutr* 2012;96:1369–78.

INTRODUCTION

Multiple attributes of foods, including their physical form (beverages compared with solid foods) evoke behavioral and physiologic responses that modulate short-term feeding (1, 2). When consumed as a preload to a meal or as a meal accompaniment, beverages of various types elicit only a weak compensatory decline in energy intake from nonbeverage foods (3–7). This has led to the suggestion that beverages have weak satiating properties relative to solid foods of comparable energy and macronutrient composition. The possible association of consumption of sweetened beverages and body weight (8) may reflect this differential satiating property related to food form. Differences in cognitive, orosensory, gastric, and intestinal phase processes and endocrine responses and metabolism likely account for the differential appetitive responses to beverage compared with solid-food forms (9–14). Finally, although the nature of the available evidence cannot be used to infer causality, a direct association between eating and drinking has been documented (15–18).

Although some studies have not reported a differential in satiety effects of beverages and solid foods (19), the preponderance of evidence suggests that food form may be a determinant of short-term energy intake. However, physiology is only one facet of the complex array of effectors of ingestive behaviors of free-living individuals. Recent studies have added to our understanding of the powerful modulating role of environmental cues and social contexts in affecting the amount of food consumed (20, 21). Therefore, the likelihood that observed effects of manipulations of a single or limited number of meal characteristics in the laboratory will be replicated in free-living individuals is low. Not only are free-living individuals at liberty to include numerous possible combinations of meal characteristics, their ingestive behavior is likely to reflect the interactions of environmental and social cues along with constraints imposed by taste, food affordability and availability, and time schedules in deciding what and when to consume. Therefore, caution is required when interpreting data obtained from laboratory studies of acute feeding trials (3).

Prior studies have reported higher energy intakes (but inconsistent associations with body weight) with consumption of sweetened beverages, fruit juice, milk, and alcohol in free-living individuals (22–26). However, to our knowledge, little is known about whether beverage intake is related to the intake of nonbeverage foods, energy density, and meal attributes of

[1] From the Department of Family, Nutrition, and Exercise Sciences, Queens College of the City University of New York, Flushing, NY (AKK); the Division of Cancer Epidemiology and Genetics, Biostatistics Branch, National Cancer Institute, NIH, Bethesda, MD (BIG); and the Department of Nutrition Science, Purdue University, West Lafayette, IN (RDM).

[2] Supported in part by a research grant award from the Professional Staff Congress of the City University of New York (to AKK) and the intramural research program of the Department of Health and Human Services, National Cancer Institute, NIH (BIG).

[3] Address correspondence to AK Kant, Department of Family, Nutrition, and Exercise Sciences, Remsen Hall, Room 306E, Queens College of the City University of New York, Flushing, NY 11367. E-mail: ashima.kant@qc.cuny.edu.

Received June 18, 2012. Accepted for publication August 20, 2012.

First published online October 24, 2012; doi: 10.3945/ajcn.112.044974.

free-living individuals (18, 27). Information on meal and nonbeverage correlates of beverage intake can offer insights into interventions for moderation of energy intake. This analysis used data from the recent NHANES to examine the association between 24-h beverage energy and an array of meal and dietary attributes in a representative sample of US adults.

SUBJECTS AND METHODS

We used public domain data from the continuous NHANES 2003–2004, 2005–2006, and 2007–2008 for this study (28–31). NHANES is conducted by the National Center for Health Statistics (NCHS) of the CDC and forms the backbone of national nutrition monitoring activities. The study was approved by the Queens College institutional review board with an exempt review. The NHANES used in this study is a continuous annual survey, but data from 2 y are combined before release. Each NHANES is a multistage stratified probability sample of the US population and includes an at-home interview and an examination in a mobile examination center (MEC) (28). The MEC examination includes a complete medical examination, anthropometric measures, dietary intake interview, and collection of blood and urine samples by using standardized procedures. The unweighted response rate for the MEC-examined sample in each survey cycle was >75% (32).

Dietary-assessment methods in NHANES

The What We Eat in America component of NHANES used in this study collected dietary information by using an interviewer-administered 24-h recall that used automated multiple pass methodology developed by the USDA (33). A second recall, 3–10 d after the first recall, was obtained by using similar methods via telephone. Given the study aim to examine food form and meal and nutrient intake associations over the short term (within the 24-h period), our analysis used the information collected in the first dietary recall.

Dietary- and meal-attribute variables

Food form

To address the primary study question, all foods reported in the recall were grouped into beverage and nonbeverage foods by using methods described previously (34). We considered beverages to include all forms of liquid milk or alternatives, fruit and vegetable juices or juice drinks, sports drinks or sweetened bottled water, alcoholic beverages, carbonated and noncarbonated beverages (sweetened with sugar or alternative low-energy sweeteners), coffee/tea and substitutes, milkshakes, smoothies, and meal-replacement drinks but excluded plain tap or unsweetened bottled water. Nonbeverage ingredients added to the beverage before consumption (eg, addition of sugar or powdered nondairy creamer to coffee and tea or wheat germ added to a fruit smoothie) and reported as a beverage combination were considered as part of the beverage. Similarly, a liquid added to a food during its preparation (eg, milk added to soup) and reported as a food combination was considered a nonbeverage food. Milk consumed with cereals was considered a beverage, and cereal was considered a food (this decision reflects reporting of the milk and cereal combination by >20% of the analytic cohort and the fact that the form of milk remains unchanged in this combination). All types of liquid milk and alternatives, shakes, smoothies, 100% fruit or vegetable juices, and meal-replacement drinks were considered nutritive beverages. We created 4 variables to determine beverage consumption from the 24-h recall data: 24-h energy (kcal) from all beverages, amount (g) of all beverages, percentage of 24-h energy from beverages, and 24-h energy (kcal) from nutritive beverages.

Dietary energy density

We created dietary energy density (kcal/g) variables, similar to those we reported previously (35, 36), for nonbeverage foods [energy from all nonbeverage foods was divided by the weight (g) of all nonbeverage foods], and for beverages [energy from all beverages, as defined above, was divided by weight (g) of all beverages]. Plain tap or bottled water was not included in these computations.

Frequency of ingestive episodes and meal and snack intake behaviors

During the 24-h recall, respondents were asked to report the clock time of eating for each food and beverage recalled along with a name for the eating episode as breakfast, brunch, lunch, dinner/supper, or snack or their equivalents in Spanish. We considered meals identified by respondents as breakfast, brunch, lunch, supper, or dinner as main meals; all other episodes labeled snack, drink, or extended consumption were considered snack. To determine the frequency of eating on the recall day, we summed the number of unique eating episodes in the recall based on the clock time of eating regardless of the time interval between ingestive episodes (99.9% of respondents reported ingestive episodes that were ≥15 min apart). All items (foods or beverages) reported at one clock time were considered as part of one eating episode. In <4% of respondents, 2 differently named episodes were reported at the same time. In such a case, if an eating episode labeled as snack, drink, or extended consumption was reported at the same clock time as a main meal episode, it was considered as part of the main meal. Ingestive episodes for which the only reported item was plain tap or unsweetened bottled water were not considered as ingestive episodes. Ingestive episodes for which the only reported item was a beverage (as described above) were also identified for each respondent. The ingestive event variables included the number of eating occasions, mention of breakfast, mention of snack, number of snack episodes, duration of the eating period (from clock time of the first ingestive episode to clock time of the last reported ingestive event), and 24-h energy as main meals or as snacks. We previously used these methods to examine ingestive episode behaviors (37, 38).

Other dietary variables examined in this study—24-h intakes of energy, grams of total and saturated fat, total sugar, fiber, alcohol, plain water, and sodium (mg)—were available in the public domain total nutrient files for each survey.

Analytic sample

All respondents aged ≥20 y, with an in-person MEC-administered 24-h dietary recall, considered reliable by the NCHS, were eligible for inclusion in the study (*n* = 14,388). We excluded pregnant and lactating women (*n* = 682) and those reporting no energy intake in the recall (*n* = 2), for a final analytic sample of 13,704 (6959 men and 6745 women).

Statistical methods

The independent association of sociodemographic characteristics of respondents with 24-h beverage intake was examined by using sex-specific multiple linear regression analyses in which each beverage consumption outcome [24-h beverage energy (kcal), amount of beverages (g), and percentage of 24-h energy from beverages] was a continuous dependent variable. The sociodemographic variables in these models were age, race-ethnicity, family income as a percentage of the federal poverty threshold or poverty income ratio, years of education, day of the week of recalled intake, month of MEC examination, smoking status, any recreational physical activity, any self-reported chronic disease condition, BMI [as weight (kg)/height $(m)^2$], and survey cycle.

Our preliminary analysis confirmed previous reports of sex and age variation in beverage energy consumption (23, 38). Therefore, we created weighted sex-age tertiles of 24-h energy from beverages and examined the association of these tertiles with a variety of dietary and meal attributes reported in the recall using multiple regression methods. All analyses were stratified by sex and included the respondent characteristics listed above as covariates. For dietary nutrient outcomes (total and saturated fat, dietary fiber, and sodium), we also examined associations with energy from foods only as an additional covariate. We present adjusted means (sometimes called predicted margins) of various dietary and meal outcomes in the tables (39).

We used SAS (version 9.2; SAS Institute) and SAS-callable SUDAAN (version 10; Research Triangle Institute) for statistical analysis. The SUDAAN software allows statistical analyses to account for the complex survey design of the NHANES and appropriate NCHS-computed sample weights to correct for unequal probability of selection and nonresponse (40). Statistical tests were based on Wald F tests conducted in SUDAAN; 2-sided P values <0.05 were considered significant.

RESULTS

Sociodemographic and lifestyle correlates of beverage intake

In both men and women, intakes of 24-h energy from beverages, 24-h grams of beverages, and percentage of 24-h energy from beverages related inversely with age ($P < 0.0001$) (**Table 1**). Current smokers had higher 24-h beverage energy, amounts, and percentage of energy from beverages relative to nonsmokers ($P < 0.0001$). The 24-h beverage energy and the percentage of 24-h energy intake from beverages declined with increasing BMI in both men and women ($P \leq 0.02$).

In men, race-ethnicity, education, and recalled day of intake were related to all three 24-h beverage intake variables (Table 1). Non-Hispanic white men reported the highest 24-h beverage energy ($P < 0.0008$) and grams ($P < 0.0001$) consumed but not percentage of 24-h energy intake from beverages. Men with a college education or greater had the lowest 24-h beverage energy intake and grams and percentage of total energy from beverages ($P \leq 0.004$). The amount (g) of 24-h beverages reported increased with increasing BMI in men ($P = 0.003$). In men, the reported 24-h beverage intakes (energy, grams, and % of energy) were higher on weekends ($P \leq 0.006$).

In women, race-ethnicity was associated with 24-h grams ($P < 0.0001$) and percentage of 24-h energy from beverages ($P = 0.02$), but not with 24-h beverage energy intake (Table 1). Percentage of 24-h energy from beverages declined with increasing education ($P = 0.02$) and income ($P = 0.0001$) in women. Women with some recreational activity ($P = 0.04$) or report of any chronic disease ($P = 0.006$) reported lower 24-h beverage energy intakes.

The percentage of men and women, in categories of sociodemographic and lifestyle characteristics, by tertiles of 24-h energy from beverages are shown elsewhere (*see* Supplemental Tables 1 and 2 under "Supplemental data" in the online issue). These distributions agree with the findings reported in Table 1.

Association of 24-h beverage energy intake with dietary and meal intake behaviors

Energy intake

In both men and women, with increasing tertiles of 24-h beverage energy intake, the adjusted mean intakes of total energy, nutritive beverage energy, and food energy (only) increased, whereas percentage of 24-h energy from foods declined ($P < 0.0001$) (**Figure 1**; **Tables 2** and **3**).

Amount and number of foods in the 24-h recall

The reported mean 24-h beverage-only amount and number of unique beverages increased with tertiles of 24-h beverage energy intake in both sexes (Tables 2 and 3; $P < 0.0001$). In both men and women, the reported amount of nonbeverage foods was not related to 24-h energy from beverages. The number of unique nonbeverage foods was also not related to 24-h beverage energy intake in women; in men, a significant but weak association was noted ($P = 0.02$).

Eating frequency and meal and snack behaviors

The number of all ingestive episodes, snack episodes, and beverage-only episodes and the length of the eating period increased with tertiles of 24-h beverage energy intake in both sexes (Tables 2 and 3; $P < 0.0001$). With increasing 24-h beverage energy intake, the amount of energy from both nonbeverage foods and beverages reported as part of main meals increased, whereas the percentage of 24-h energy from main meals declined in both men and women ($P < 0.0001$). Similar trends were noted for 24-h food or beverage energy reported with snacks in men ($P \leq 0.0001$). In women, food-only energy from snacks was not related to tertiles of reported 24-h beverage energy intake.

Energy density of foods and beverages

The energy density of nonbeverage foods and beverages increased with increasing 24-h beverage energy intake in both men (Table 2) and women (Table 3) ($P < 0.0001$).

Intake of selected dietary nutrients, plain water, and alcohol

In both sexes (Tables 2 and 3), increasing 24-h beverage energy intake was directly associated with reported intakes of total and saturated fat, sugar, fiber, sodium, and alcohol ($P \leq 0.001$), whereas plain water intake decreased ($P \leq 0.003$). For dietary fiber, the association with beverage energy was no longer significant in models that included energy consumed as foods.

TABLE 1

Independent association of beverage intakes with sociodemographic and lifestyle characteristics among American adults: NHANES 2003–2008[1]

Sociodemographic/lifestyle characteristic	Men: 24-h Beverage energy	Men: 24-h Beverage amount	Men: 24-h Percentage of energy from beverages	Women: 24-h Beverage energy	Women: 24-h Beverage amount	Women: 24-h Percentage of energy from beverages
	kcal	*g*	*%*	*kcal*	*g*	*%*
All (unadjusted)[2]	551 ± 9	1905 ± 34	20.8 ± 0.25	322 ± 6	1294 ± 21	18.0 ± 0.36
All (adjusted)[3]	555 ± 9	1908 ± 35	20.8 ± 0.26	322 ± 7	1303 ± 22	17.9 ± 0.37
Race-ethnicity						
Non-Hispanic white	573 ± 11	2056 ± 40	20.9 ± 0.31	322 ± 8	1380 ± 23	17.7 ± 0.46
Non-Hispanic black	532 ± 15	1437 ± 37	21.3 ± 0.50	347 ± 14	1000 ± 32	19.5 ± 0.67
Mexican American	556 ± 15	1702 ± 41	21.7 ± 0.60	321 ± 17	1157 ± 47	18.3 ± 0.68
All others	427 ± 38	1462 ± 83	18.0 ± 1.0	292 ± 16	1177 ± 54	16.8 ± 0.77
P value (Wald *F*)	0.0008	<0.0001	0.02	0.1	<0.0001	0.02
Age group						
20–39 y	658 ± 17	2036 ± 52	22.8 ± 0.45	375 ± 12	1292 ± 31	19.6 ± 0.64
40–59 y	552 ± 15	2038 ± 51	20.6 ± 0.48	331 ± 10	1420 ± 32	18.3 ± 0.51
≥60 y	366 ± 16	1437 ± 43	17.3 ± 0.50	237 ± 8	1138 ± 29	14.9 ± 0.48
P value (Wald *F*)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Years of education						
<12 y	582 ± 20	1925 ± 80	22.3 ± 0.48	328 ± 17	1309 ± 53	18.8 ± 0.83
12 y	578 ± 19	1976 ± 61	20.8 ± 0.59	334 ± 15	1290 ± 34	18.6 ± 0.80
Some college	582 ± 19	1957 ± 45	21.7 ± 0.49	326 ± 11	1298 ± 32	17.9 ± 0.49
≥College	485 ± 14	1774 ± 43	18.6 ± 0.50	301 ± 9	1320 ± 31	16.6 ± 0.39
P value (Wald *F*)	<0.0001	0.004	<0.0001	0.2	0.8	0.02
Family poverty income ratio						
<130%	582 ± 20	1903 ± 53	21.0 ± 0.49	355 ± 14	1311 ± 34	20.5 ± 0.67
130–349%	542 ± 13	1826 ± 44	21.0 ± 0.36	327 ± 9	1295 ± 31	18.0 ± 0.48
≥350%	554 ± 12	1972 ± 49	20.5 ± 0.40	301 ± 10	1306 ± 28	16.5 ± 0.49
P value (Wald *F*)	0.2	0.02	0.6	0.01	0.9	0.0001
Day of recalled intake						
Monday–Thursday	523 ± 11	1827 ± 41	20.3 ± 0.33	315 ± 10	1281 ± 28	17.8 ± 0.49
Friday–Sunday	594 ± 11	2011 ± 38	21.3 ± 0.29	332 ± 8	1334 ± 25	18.1 ± 0.37
P value (Wald *F*)	<0.0001	<0.0001	0.006	0.2	0.1	0.5
Month of examination						
November–April	544 ± 12	1860 ± 38	20.5 ± 0.41	323 ± 11	1295 ± 35	17.9 ± 0.59
May–October	562 ± 12	1941 ± 45	21.0 ± 0.34	322 ± 8	1308 ± 25	17.9 ± 0.43
P value (Wald *F*)	0.2	0.1	0.3	0.9	0.7	0.9
BMI						
<25 kg/m^2	580 ± 16	1806 ± 38	21.2 ± 0.54	343 ± 10	1275 ± 28	19.1 ± 0.59
25–29.9 kg/m^2	571 ± 13	1971 ± 46	21.6 ± 0.39	310 ± 10	1299 ± 30	17.8 ± 0.52
≥30 kg/m^2	512 ± 17	1918 ± 49	19.4 ± 0.48	309 ± 10	1338 ± 33	16.7 ± 0.52
P value (Wald *F*)	0.007	0.003	0.001	0.02	0.3	0.01
Any recreational physical activity[4]						
Yes	555 ± 10	1883 ± 38	20.6 ± 0.28	314 ± 7	1302 ± 26	17.5 ± 0.38
No	554 ± 15	1961 ± 45	21.2 ± 0.44	337 ± 10	1305 ± 27	18.5 ± 0.59
P value (Wald *F*)	0.9	0.1	0.2	0.04	0.9	0.1
Smoking status						
Never	486 ± 10	1670 ± 35	19.0 ± 0.38	289 ± 7	1129 ± 24	16.3 ± 0.36
Former	531 ± 16	1832 ± 42	19.6 ± 0.52	318 ± 13	1331 ± 38	17.1 ± 0.70
Current	684 ± 23	2354 ± 67	24.7 ± 0.65	414 ± 14	1726 ± 38	22.8 ± 0.67
P value (Wald *F*)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Any chronic disease[5]						
Yes	541 ± 15	1959 ± 51	20.6 ± 0.49	301 ± 8	1257 ± 35	17.5 ± 0.61
No	561 ± 10	1882 ± 36	20.9 ± 0.35	335 ± 9	1329 ± 28	18.1 ± 0.45
P value (Wald *F*)	0.2	0.1	0.6	0.006	0.1	0.3
Survey cycle						
2003–2004	582 ± 16	1948 ± 66	21.7 ± 0.45	337 ± 10	1311 ± 33	18.4 ± 0.51
2005–2006	568 ± 14	1980 ± 54	20.8 ± 0.36	312 ± 14	1322 ± 31	17.7 ± 0.84
2007–2008	514 ± 15	1795 ± 43	19.8 ± 0.43	319 ± 9	1278 ± 33	17.6 ± 0.40
P value (Wald *F*)	0.003	0.006	0.006	0.2	0.5	0.5

[1] All values are means ± SEs.

[2] *n* = 6959 men and 6745 women.

[3] *n* = 6357 men and 6081 women. Estimates are adjusted values obtained from multiple linear regression models. Separate models were run for men and women and for each beverage outcome variable. All variables in the table were included as covariates in these models, and the estimates reflect the independent association of each demographic variable with each beverage variable after adjustment for all other variables in the model. Respondents with missing information on a covariate (602 men and 664 women) were excluded from these models.

[4] Any recreational activity lasting ≥10 min in the past 30 d (2003–2006) or without a specified period (2007–2008).

[5] Any self-reported diabetes, high blood pressure, heart disease, or stroke.

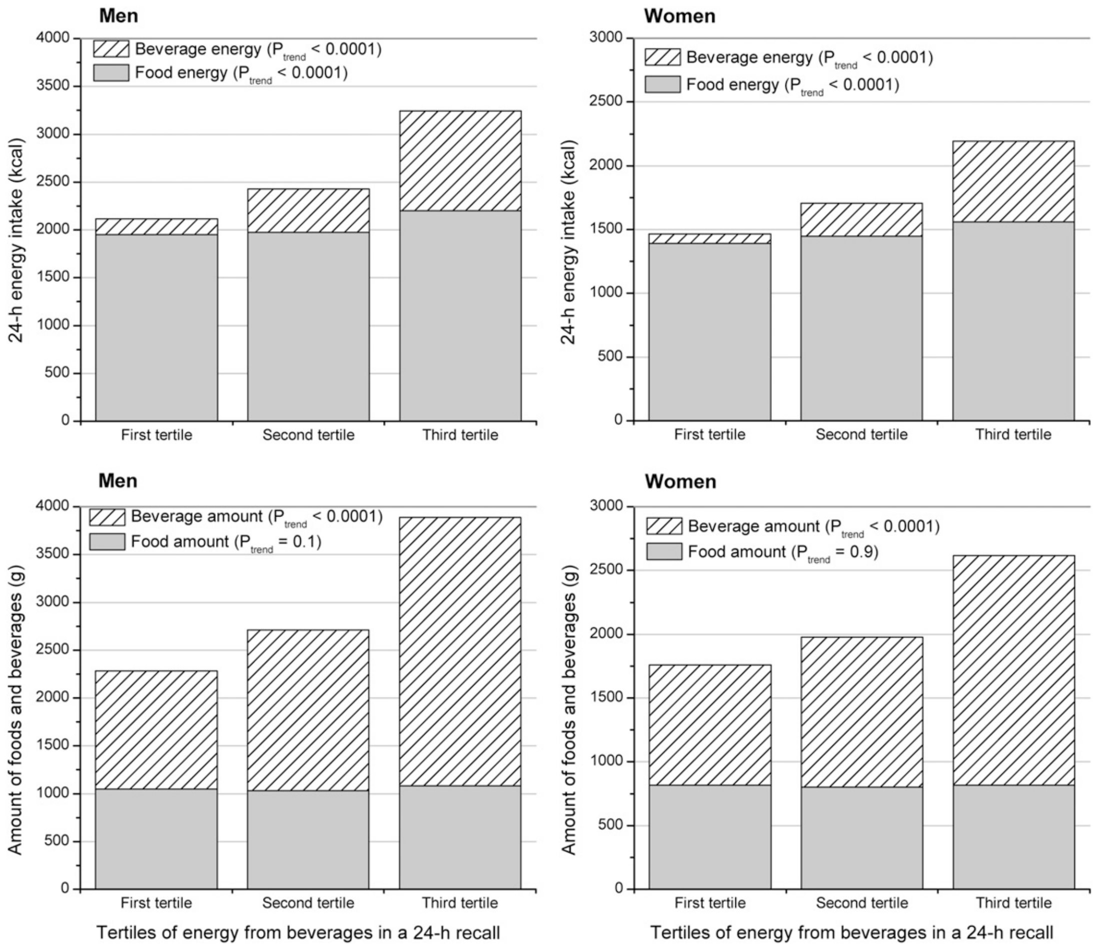

FIGURE 1. Reported 24-h energy intake and amount of foods and beverages consumed by tertiles of 24-h energy intake from beverages in American men and women: NHANES 2003–2008. Estimates are adjusted means from multiple linear regression models. The independent variables included age (continuous), race-ethnicity (non-Hispanic white, non-Hispanic black, Mexican American, or all others), years of education (<12 y, 12 y, some college, or ≥college), family poverty income ratio (<130%, 130–349%, or ≥350%), weekday of recalled intake (Monday–Thursday or Friday–Sunday), month of Mobile Examination Center exam (November–April or May–October), BMI (in kg/m^2; <25, 25–29.9, or ≥30), any self-reported recreational activity (yes or no), smoking status (never, former, or current smoker), any self-reported chronic disease (yes or no), and survey cycle (2003–2004, 2005–2006, or 2007–2008). Sex- and age-specific tertiles of 24-h beverage energy—men: tertile 1 of 24-h energy from beverages (<60 y, <340 kcal; ≥60 y, <169 kcal), tertile 2 of 24-h energy from beverages (<60 y, 340–697 kcal; ≥60 y, 169–394 kcal), tertile 3 of 24-h energy from beverages (<60 y, >697 kcal; ≥60 y, >394 kcal); women: tertile 1 of 24-h energy from beverages (<60 y, <174 kcal; ≥60 y, <112 kcal), tertile 2 of 24-h energy from beverages (<60 y, 174–409 kcal; ≥60 y, 112–257 kcal), tertile 3 of 24-h energy from beverages (<60 y, >409 kcal; ≥60 y, >257 kcal).

DISCUSSION

This analysis showed both quantitative and qualitative differences in food selection and ingestive behaviors of respondents with graded 24-h energy intake from beverages. Respondents with higher 24-h energy intake from beverages also reported *1*) a higher energy intake from nonbeverage foods; *2*) a higher energy density of both beverage and nonbeverage foods and total fat, saturated fat, sugar, alcohol, and sodium intakes; *3*) a greater quantity and number of beverage foods; and *4*) a greater number of ingestive episodes, snacking episodes, and beverage-only episodes with a longer duration of eating in the day. Collectively, these observations of a positive association between drinking and eating frequency, energy from food within meals, and the energy density of food suggest many ways in which beverages may contribute to higher energy intakes and promote positive energy balance.

Prior laboratory studies of beverage preloads to a meal and beverage accompaniment of a meal have documented poor compensation for beverage energy (5, 6, 41–43), and observational studies have also reported a higher energy intake in association with sweetened beverage, fruit juice, milk, and alcohol consumption (22, 24–26). Our results suggest that, under free-living conditions, high 24-h beverage energy reporters not only consumed the expected weakly compensated beverage energy, but also reported higher energy intake from nonbeverage foods. Because the reported amount and number of nonbeverage foods differed little with increasing 24-h beverage energy intake, higher energy density of these foods is the most likely reason for this increase, and our results support this argument. In women reporting higher 24-h beverage energy, the higher nonbeverage energy intake occurred mostly with main meals, but in men both main meal and snack energy from nonbeverage foods were higher. Moreover, higher total fat, sugar, and sodium intakes in conjunction with higher 24-h beverage energy intake, also suggest qualitative differences in types of foods selected. Our study cannot deduce whether a higher energy density or sodium content of foods lead to selection of energy-containing beverages or vice versa. Given the evidence of a direct association between eating and drinking (15–18), as well as salt and

TABLE 2

Adjusted self-reported values for dietary and meal attributes by sex- and age-specific tertiles of 24-h energy from all beverages in men: NHANES 2003–2008[1]

	Sex- and age-specific tertiles of 24-h energy from beverages[2]			
Dietary or meal attribute	1	2	3	P-trend (Wald F)[3]
Energy intake				
24-h Energy intake (kcal)	2118 ± 28	2426 ± 29	3246 ± 40	<0.0001
24-h Energy from beverages (kcal)	165 ± 3	453 ± 4	1044 ± 13	<0.0001
24-h Energy from nonbeverage foods (kcal)	1953 ± 28	1973 ± 28	2203 ± 32	<0.0001
24-h Energy from nutritive beverages (kcal)	50 ± 3	117 ± 5	258 ± 9	<0.0001
24-h Energy from beverages (%)	8.5 ± 0.2	20.4 ± 0.3	33.4 ± 0.3	<0.0001
24-h Energy from nonbeverage foods (%)	91.5 ± 0.2	79.6 ± 0.3	66.6 ± 0.3	<0.0001
Amount and number of foods in the 24-h recall				
Amount of beverages (g)	1235 ± 31	1679 ± 37	2807 ± 47	<0.0001
No. of unique beverage items in the recall	2.65 ± 0.05	3.52 ± 0.06	4.24 ± 0.06	<0.0001
Amount of nonbeverage food (g)	1050 ± 17	1030 ± 14	1081 ± 12	0.07
No. of unique nonbeverage foods only in the recall	10.48 ± 0.14	10.34 ± 0.16	10.88 ± 0.12	0.02
Eating frequency and meal and snack behaviors in the 24-h recall				
No. of ingestive episodes	4.57 ± 0.04	4.77 ± 0.05	5.33 ± 0.05	<0.0001
No. of snack episodes	1.92 ± 0.04	2.11 ± 0.03	2.58 ± 0.05	<0.0001
No. of beverage-only ingestive episodes	0.75 ± 0.02	1.01 ± 0.03	1.46 ± 0.03	<0.0001
Subjects reporting an episode with only beverage, no foods (%)	53 ± 1	64 ± 1	78 ± 1	<0.0001
24-h Energy consumed at beverage-only ingestive episodes (kcal)	52 ± 4	134 ± 4	458 ± 14	<0.0001
Length of ingestion period (h)	11.9 ± 0.1	12.4 ± 0.1	13.1 ± 0.1	<0.0001
Subjects reporting breakfast (%)	81 ± 1	80 ± 1	83 ± 1	0.2
24-h Food-only energy with main meals (kcal)	1611 ± 25	1632 ± 25	1782 ± 23	<0.0001
24-h Beverage-only energy with main meals (kcal)	108 ± 3	287 ± 6	529 ± 10	<0.0001
24-h Energy with main meals (%)	82 ± 0.5	79 ± 0.5	72 ± 0.5	<0.0001
24-h Beverage energy with main meals (%)[4]	71 ± 1.3	65 ± 0.9	54 ± 1.0	<0.0001
Nonbeverage energy from snacks (kcal)	342 ± 11	341 ± 13	420 ± 18	<0.0001
Beverage-only energy from snacks (kcal)	57 ± 3	165 ± 5	514 ± 15	<0.0001
Energy density of foods and beverages reported in the 24-h recall (kcal/g)				
Energy density of all nonbeverage foods (kcal/g)[5]	1.97 ± 0.02	2.01 ± 0.02	2.12 ± 0.02	<0.0001
Energy density of all beverages (kcal/g)[6]	0.18 ± 0.01	0.31 ± 0.01	0.40 ± 0.01	<0.0001
24-h Nutrient and alcohol intakes				
Total fat (g)	90 ± 2	93 ± 1	112 ± 2	<0.0001
Total fat adjusted for food energy (g)	95 ± 1	96 ± 1	104 ± 1	<0.0001
Saturated fat (g)	29 ± 0.6	31 ± 0.5	38 ± 0.7	<0.0001
Saturated fat adjusted for food energy (g)	30 ± 0.5	32 ± 0.4	35 ± 0.5	<0.0001
Total sugars (g)	88 ± 2	133 ± 2	199 ± 4	<0.0001
Total sugars adjusted for food energy (g)	92 ± 2	136 ± 2	192 ± 3	<0.0001
Fiber (g)	17 ± 0.3	17 ± 0.4	19 ± 0.3	<0.0001
Fiber adjusted for food energy (g)	18 ± 0.3	17 ± 0.4	18 ± 0.3	0.8
Sodium (mg)	3907 ± 69	3959 ± 54	4548 ± 71	<0.0001
Sodium adjusted for food energy (mg)	4066 ± 55	4083 ± 45	4266 ± 52	0.002
Alcohol (g)	1.6 ± 0.30	9.8 ± 0.58	37.7 ± 1.52	<0.0001
Plain water (g)[7]	1229 ± 42	1029 ± 34	1029 ± 44	0.003

[1] Estimates are adjusted means ± SEs from multiple linear or logistic regression models with each variable in the table as a continuous or dichotomous dependent variable. The independent variables included age (continuous), race-ethnicity (non-Hispanic white, non-Hispanic black, Mexican American, or all others), years of education (<12 y, 12 y, some college, or ≥college), family poverty income ratio (<130%, 130–349%, or ≥350%), recalled day of intake (Monday–Thursday or Friday–Sunday), month of Mobile Examination Center exam (November–April or May–October), BMI (in kg/m^2; <25, 25–29.9, or ≥30), any self-reported recreational activity (yes or no), smoking status (never, former, or current smoker), any self-reported chronic disease (yes or no), and survey cycle (2003–2004, 2005–2006, or 2007–2008). For dietary total fat, saturated fat, total sugars, fiber, and sodium, additional models included energy from all foods as an independent variable. n = 6357 for all variables, except as noted.

[2] Tertile 1 of 24-h energy from beverages (<60 y, <340 kcal; ≥60 y, <169 kcal), tertile 2 of 24-h energy from beverages (<60 y, 340–697 kcal; ≥60 y, 169–394 kcal), and tertile 3 of 24-h energy from beverages (<60 y, >697 kcal; ≥60 y, >394 kcal).

[3] P value across ordered tertiles of beverage energy intake.

[4] n = 6265.

[5] n = 6354.

[6] n = 6279.

[7] n = 6356.

TABLE 3
Adjusted self-reported dietary and meal attributes by age- and sex-specific tertiles of 24-h energy from all beverages in women: NHANES 2003–2008[1]

	Sex- and age-specific tertiles of 24-h energy from beverages[2]			
Dietary or meal attribute	1	2	3	*P*-trend (Wald *F*)[3]
Energy intake				
24-h Energy intake (kcal)	1468 ± 19	1707 ± 23	2193 ± 22	<0.0001
24-h Energy from beverages (kcal)	75 ± 2	260 ± 2	635 ± 10	<0.0001
24-h Energy from nonbeverage foods (kcal)	1393 ± 18	1446 ± 22	1558 ± 22	<0.0001
24-h Energy from nutritive beverages (kcal)	21 ± 2	89 ± 3	192 ± 6	<0.0001
24-h Energy from beverages (%)	6.1 ± 0.2	17.3 ± 0.3	30.4 ± 0.5	<0.0001
24-h Energy from nonbeverage foods (%)	94 ± 0.2	83 ± 0.3	70 ± 0.5	<0.0001
Amount and number of foods in the 24-h recall				
Amount of beverage (g)	942 ± 36	1176 ± 22	1797 ± 29	<0.0001
No. of unique beverage foods	2.46 ± 0.05	3.45 ± 0.05	4.08 ± 0.06	<0.0001
Amount of nonbeverage foods (g)	819 ± 13	801 ± 12	819 ± 14	0.9
No. of unique nonbeverage foods	10.5 ± 0.2	10.6 ± 0.1	10.6 ± 0.1	0.8
Eating frequency and meal and snack behaviors reported in the 24-h recall				
No. of ingestive episodes	4.74 ± 0.05	4.85 ± 0.05	5.23 ± 0.05	<0.0001
No. of snack episodes	2.05 ± 0.05	2.12 ± 0.04	2.48 ± 0.04	<0.0001
No. of beverage-only ingestive episodes	0.68 ± 0.03	0.86 ± 0.03	1.29 ± 0.03	<0.0001
Subjects reporting an episode with only beverage, no foods (%)	46 ± 1	57 ± 1	71 ± 2	<0.0001
Energy consumed at beverage-only ingestive episodes (kcal)	25 ± 2	72 ± 3	249 ± 10	<0.001
Length of ingestion period (h)	11.7 ± 0.1	12.0 ± 0.1	12.7 ± 0.1	<0.0001
Subjects reporting breakfast (%)	83 ± 1	86 ± 1	85 ± 1	0.1
Food-only energy with main meals (kcal)	1114 ± 18	1176 ± 18	1262 ± 21	<0.0001
Beverage-only energy with main meals (kcal)	49 ± 2	181 ± 3	367 ± 7	<0.0001
24-h Energy from main meals (%)	79.7 ± 0.5	79.5 ± 0.5	74.5 ± 0.6	<0.0001
24-h Beverage energy with main meals (%)[4]	72.8 ± 1.3	70.6 ± 1.0	62.0 ± 0.8	<0.0001
Nonbeverage energy from snacks (kcal)	279 ± 8	270 ± 10	296 ± 13	0.3
Beverage-only energy from snacks (kcal)	26 ± 2	80 ± 3	267 ± 9	<0.0001
Energy density of foods and beverages reported in the 24-h recall (kcal/g)				
Energy density of all nonbeverage foods (kcal/g)[5]	1.83 ± 0.02	1.91 ± 0.02	2.03 ± 0.02	<0.0001
Energy density of all beverages (kcal/g)[6]	0.13 ± 0.01	0.27 ± 0.01	0.39 ± 0.01	<0.0001
24-h Nutrient and alcohol intake				
Total fat (g)	60 ± 1	67 ± 1	79 ± 1	<0.0001
Total fat adjusted for food energy (g)	64 ± 0.7	68 ± 1	74 ± 0.9	<0.0001
Saturated fat (g)	19 ± 0.5	22 ± 0.4	27 ± 0.5	<0.0001
Saturated fat adjusted for food energy (g)	21 ± 0.3	22 ± 0.3	25 ± 0.4	<0.0001
Total sugars (g)	65 ± 1	95 ± 1	148 ± 2	<0.0001
Total sugars adjusted for food energy (g)	68 ± 1	95 ± 1	144 ± 2	<0.0001
Fiber (g)	13.5 ± 0.27	13.7 ± 0.38	14.6 ± 0.33	0.001
Fiber adjusted for food energy (g)	14.0 ± 0.3	13.9 ± 0.3	14.0 ± 0.3	0.8
Sodium (mg)	2679 ± 38	2876 ± 44	3170 ± 46	<0.0001
Sodium adjusted for food energy (mg)	2800 ± 32	2908 ± 31	3016 ± 34	<0.0001
Alcohol (g)	0.52 ± 0.11	3.82 ± 0.33	14.61 ± 0.94	<0.0001
Plain water (g)	1203 ± 38	1030 ± 45	939 ± 48	<0.0001

[1] Estimates are adjusted means ± SEs from multiple linear or logistic regression models with each variable in the table as a continuous or dichotomous dependent. The independent variables included age (continuous), race-ethnicity (non-Hispanic white, non-Hispanic black, Mexican American, or all others), years of education (<12 y, 12 y, some college, or ≥college), family poverty income ratio (<130%, 130–349%, or ≥350%), recalled day of intake (Monday–Thursday or Friday–Sunday), month of Mobile Examination Center exam (November–April or May–October), BMI (in kg/m^2; <25, 25–29.9, or ≥30), any self-reported recreational activity (yes or no), smoking status (never, former, or current smoker), any self-reported chronic disease (yes or no), and survey cycle (2003–2004, 2005–2006, or 2007–2008). For dietary total fat, saturated fat, total sugars, fiber, and sodium, additional models included energy from all foods as an independent variable. *n* = 6081 for all variables except as noted.

[2] Tertile 1 of 24-h energy from beverages (<60 y, <174 kcal; ≥60 y, <112 kcal), tertile 2 of 24-h energy from beverages (<60 y, 174–409 kcal; ≥60 y, 112–257 kcal), and tertile 3 of 24-h energy from beverages (<60 y, >409 kcal; ≥60 y, >257 kcal).

[3] *P* value across ordered tertiles of beverage energy.

[4] *n* = 5919.

[5] *n* = 6072.

[6] *n* = 5942.

beverage consumption (44), one may speculate that whereas one may drive the other, it is also possible that each promotes the other leading to a feed-forward system that results in a higher energy intake. In the former case, better characterization of causality would likely improve intervention strategies, whereas in the latter scenario benefit may be realized by breaking the cycle in either direction.

In the current study, 24-h beverage energy was ∼8-fold and 6-fold higher in the top than in the bottom tertiles in women and men, respectively. Ranawana and Henry (42) and Davy et al (45) have reported sex differences in energy compensation after a semisolid or beverage preload. In these acute trials, the regulation of energy intake was less precise in women than in men. However, our analysis indicates that both men and women in the highest compared with the lowest third of the distribution of 24-h beverage energy had ∼50% greater 24-h total daily energy intake and 12% higher energy intake from nonbeverage foods. Thus, dietary compensation for 24-h beverage energy was weak in men and women.

Notably, respondents who consumed more 24-h energy from beverages reported higher amounts and number of all beverages (except plain water), resulting in >30% of 24-h energy intake from beverages in the highest tertile. Expectedly, plain water intake declined with increasing beverage energy (38); however, the differences in amount of plain water intake among tertiles of beverage energy intake were smaller in magnitude than the magnitude of differences in amounts (g) of beverages or the overall 24-h beverage energy intake across tertiles. It has been suggested that the urge to satisfy thirst may not be a strong driver of beverage intake in free-living, weight-stable adults (18). Thus, it is unlikely that the among-subject differences in 24-h beverage energy and amount in our study were driven by thirst. Instead, these findings may implicate the availability of a wide variety of palatable, energy-yielding beverages and large portions of these beverages in the high energy intake from beverages as reported by others (6, 46).

The study results suggest that higher 24-h beverage energy intakes were associated with a higher frequency of eating and a higher likelihood of ingestive episodes when only beverages were consumed. In fact, the differences in eating frequency between low- and high-beverage-energy reporters appeared to be largely due to the addition of the beverage-only ingestive episodes. In the highest tertile of 24-h beverage energy intake, ∼40% of all beverage energy was consumed as snacks, and most of that was derived from beverage-only snack episodes. In absolute terms, among high-beverage-energy reporters, beverage energy was higher in both main meal and snack ingestive episodes. Moreover, the length of the ingestive period (from the first reported ingestive episode to the last episode of the day) was one full hour longer in the highest third of 24-h beverage energy intake relative to the bottom third.

The role of high-intensity sweeteners (nutritive or nonnutritive low-energy sweeteners), which are consumed largely through beverages, in weight management is controversial (47). When associations are noted, some argue that they play a causal role in weight gain (48, 49), whereas others hold that the relation reflects reverse causality whereby heavier individuals consume products with high-intensity sweeteners as a means to moderate energy intake (47). The current data cannot resolve this issue, but comport with the claim that their use is related to BMI. We observed an inverse association between BMI category and both 24-h energy intake from beverages and the percentage of 24-h energy from beverages. However, in men, a significant positive association of BMI with grams of beverage intake was found. A likely explanation for these opposing trends is displacement of energy-yielding beverages with ones containing high-intensity sweeteners by men with high BMI.

The question posed by our study is related to the association of food form with energy intake, meals, and other ingestive behaviors over the short term (24-h period). Whether compensatory changes in dietary intake occur on subsequent days of consumption cannot be examined in the current study. Cycles of energy intake of 1 d (50, 51), 7 d (52, 53), monthly (54, 55), seasonal (56–58), annual (59), and others have been described, but not clearly established. The different patterns likely reflect predominant environmental influences such as work patterns, pay periods, and food availability.

NHANES dietary data analyzed in this study were collected via the automated multiple pass methodology, which has been shown to improve the accuracy of dietary recalls (60). However, despite these improvements, dietary underreporting remains a problem in self-reported data (61). Thus, it is possible that our absolute estimates of total 24-h beverage energy consumed were lower than true intakes. Proportional intake may also have been underestimated, because sweetened beverages, in particular, may have been underreported because of the possible social undesirability of their consumption and poor recall of consumption frequency and volume (62–64).

Our analytic approach adjusted for possible individual-level factors that may have accounted for differences in food and energy intakes. However, we cannot rule out residual confounding because of unknown or poorly measured covariates. Finally, given the cross-sectional nature of the study, we make no claims about causal associations.

In conclusion, beverage energy intake reported in a 24-h period was directly related to higher energy intake from nonbeverage foods, quality of food selections, eating frequency, and distribution of energy into meal and nonmeal ingestive episodes. The study findings have potential implications for moderating energy intakes in the US population. Counseling to moderate beverage-only ingestive episodes, drinking during main meals relative to snacks, and curtailing the length of the ingestion period may help lower uncompensated beverage energy consumption. These findings may be particularly relevant to younger individuals, to smokers, and to those with low education and income.

We thank Lisa Licitra Kahle, Silver Spring, MD, for expert programming support and David Check, NCI, Bethesda, MD, for graphic support.

The authors' responsibilities were as follows—AKK: conceptualized the study question, designed and conducted the research, wrote the manuscript, and had primary responsibility for the final content; BIG: conducted the research (analytic strategy) and edited the initial and subsequent drafts for important intellectual content; and RDM: conceptualized the study question and contributed to initial and subsequent drafts for important intellectual content. All authors read and approved the final manuscript. None of the authors had a conflict of interest.

REFERENCES

1. Mattes R. Fluid calories and energy balance: the good, the bad, and the uncertain. Physiol Behav 2006;89:66–70.

2. Rolls BJ. Plenary Lecture 1: Dietary strategies for the prevention and treatment of obesity. Proc Nutr Soc 2010;69:70–9.
3. Mattes RD. Dietary compensation by humans for supplemental energy provided as ethanol or carbohydrate in fluids. Physiol Behav 1996;59: 179–87.
4. Beridot-Therond ME, Arts I, Fantino M, De La Gueronniere V. Short-term effects of the flavour of drinks on ingestive behaviours in man. Appetite 1998;31:67–81.
5. DellaValle DM, Roe LS, Rolls BJ. Does the consumption of caloric and non-caloric beverages with a meal affect energy intake? Appetite 2005; 44:187–93.
6. Flood JE, Roe LS, Rolls BJ. The effect of increased beverage portion size on energy intake at a meal. J Am Diet Assoc 2006;106:1984–90.
7. 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;31:1688–95.
8. 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;97:667–75.
9. Cassady BA, Considine RV, Mattes RD. Beverage consumption, appetite, and energy intake: what did you expect? Am J Clin Nutr 2012;95:587–93.
10. Leidy HJ, Apolzan JW, Mattes RD, Campbell WW. Food form and portion size affect postprandial appetite sensations and hormonal responses in healthy, nonobese, older adults. Obesity (Silver Spring) 2010;18:293–9.
11. Martens MJ, Westerterp-Plantenga MS. Mode of consumption plays a role in alleviating hunger and thirst. Obesity (Silver Spring) 2012;20: 517–24.
12. Finlayson G, Bordes I, Griffioen-Roose S, de Graaf C, Blundell JE. Susceptibility to overeating affects the impact of savory or sweet drinks on satiation, reward, and food intake in nonobese women. J Nutr 2012; 142:125–30.
13. Glasbrenner B, Pieramico O, Brecht-Krauss D, Baur M, Malfertheiner P. Gastric emptying of solids and liquids in obesity. Clin Investig 1993; 71:542–6.
14. Hoad CL, Rayment P, Spiller RC, Marciani L, Alonso Bde C, Traynor C, Mela DJ, Peters HP, Gowland PA. In vivo imaging of intragastric gelation and its effect on satiety in humans. J Nutr 2004;134:2293–300.
15. Engle D. Interdependency of food and water intake in humans. Appetite 1988;10:133–141.
16. Phillips PA, Rolls BJ, Ledingham JG, Morton JJ. Body fluid changes, thirst, and drinking in man during free access to water. Physiol Behav 1984;33:357–63.
17. De Castro JM. A microregulatory analysis of spontaneous fluid intake by humans: evidence that the amount of liquid ingested and its timing is mainly governed by feeding. Physiol Behav 1988;43:705–14.
18. McKiernan F, Houchins JA, Mattes RD. Relationships between human thirst, hunger, drinking, and feeding. Physiol Behav 2008;94:700–8.
19. Almiron-Roig E, Flores SY, Drewnowski A. No difference in satiety or in subsequent energy intakes between a beverage and a solid food. Physiol Behav 2004;82:671–7.
20. Wansink B. Environmental factors that increase the food intake and consumption volume of unknowing consumers. Annu Rev Nutr 2004; 24:455–79.
21. De Castro JM. Socio-cultural determinants of meal size and frequency. Br J Nutr 1997;77:S39–55.
22. Harnack L, Stang J, Story M. Soft drink consumption among US children and adolescents: nutritional consequences. J Am Diet Assoc 1999;99:436–41.
23. Storey ML, Forshee RA, Anderson PA. Beverage consumption in the US population. J Am Diet Assoc 2006;106:1992–2000.
24. O'Connor TM, Yang SJ, Nicklas TA. Beverage intake among preschool children and its effect on weight status. Pediatrics 2006;118:e1010–8 (PubMed).
25. O'Neil CE, Nicklas TA, Zanovec M, Fulgoni VL III. Diet quality is positively associated with 100% fruit juice consumption in children and adults in the United States: NHANES 2003-2006. Nutr J 2011;10:17.
26. Breslow RA, Guenther PM, Juan W, Graubard BI. Alcoholic beverage consumption, nutrient intakes, and diet quality in the US adult population, 1999-2006. J Am Diet Assoc 2010;110:551–62.
27. de Castro JM. Accommodation of particular foods or beverages into spontaneously ingested evening meals. Appetite 1994;23:57–66.
28. CDC, National Center for Health Statistics. National Health and Nutrition Examination Survey. Hyattsville, MD: US Department of Health and Human Services. Available from: http://www.cdc.gov/nchs/nhanes/about_nhanes.htm (cited May 2011).
29. CDC, National Center for Health Statistics. National Health and Nutrition Examination Survey 2003-2004. Hyattsville, MD: US Department of Health and Human Services. Available from: http://www.cdc.gov/nchs/nhanes/nhanes2003-2004/nhanes03_04.htm (cited May 2011).
30. CDC, National Center for Health Statistics. National Health and Nutrition Examination Survey 2005-2006. Hyattsville, MD: US Department of Health and Human Services. Available from: http://www.cdc.gov/nchs/nhanes/nhanes2005-2006/nhanes05_06.htm (cited May 2011).
31. CDC, National Center for Health Statistics. National Health and Nutrition Examination Survey 2007-2008. Hyattsville, MD: US Department of Health and Human Services. Available from: http://www.cdc.gov/nchs/nhanes/nhanes2007-2008/nhanes07_08.htm (cited May 2011).
32. CDC, National Center for Health Statistics. NHANES response rates and CPS totals. Hyattsville, MD: US Department of Health and Human Services. Available from: http://www.cdc.gov/nchs/nhanes/response_rates_cps.htm (cited May 2011).
33. US Department of Agriculture, Agricultural Research Service, Beltsville Human Nutrition Research Center, Food Surveys Research Group. What we eat in America, NHANES 2003–2008. Available from: http://www.ars.usda.gov/Services/docs.htm?docid=13793 (cited May 2011).
34. Kant AK, Graubard BI. Contributors of water intake in US children and adolescents: associations with dietary and meal characteristics—National Health and Nutrition Examination Survey 2005-2006. Am J Clin Nutr 2010;92:887–96.
35. Kant AK, Graubard BI. Energy density of diets reported by American adults: association with food group intake, nutrient intake, and body weight. Int J Obes (Lond) 2005;29:950–6.
36. Kant AK, Andon MB, Angelopoulos TJ, Rippe JM. Association of breakfast energy density with diet quality and body mass index in American adults: National Health and Nutrition Examination Surveys, 1999-2004. Am J Clin Nutr 2008;88:1396–404.
37. Kant AK, Graubard BI. Secular trends in patterns of self-reported food consumption of adult Americans: NHANES 1971-1975 to NHANES 1999-2002. Am J Clin Nutr 2006;84:1215–23.
38. Kant AK, Graubard BI, Atchison EA. Intakes of plain water, moisture in foods and beverages, and total water in the adult US population–nutritional, meal pattern, and body weight correlates: National Health and Nutrition Examination Surveys 1999-2006. Am J Clin Nutr 2009; 90:655–63.
39. Graubard BI, Korn EL. Predictive margins for survey data. Biometrics 1999;55:652–9.
40. Korn EL, Graubard BI. Analysis of health surveys. New York, NY: John Wiley & Sons, 1999.
41. Almiron-Roig E, Drewnowski A. Hunger, thirst, and energy intakes following consumption of caloric beverages. Physiol Behav 2003;79: 767–73.
42. Ranawana DV, Henry CJ. Are caloric beverages compensated for in the short-term by young adults? An investigation with particular focus on gender differences. Appetite 2010;55:137–46.
43. Maersk M, Belza A, Holst JJ, Fenger-Grøn M, Pedersen SB, Astrup A, Richelsen B. Satiety scores and satiety hormone response after sucrose-sweetened soft drink compared with isocaloric semi-skimmed milk and with non-caloric soft drink: a controlled trial. Eur J Clin Nutr 2012;66: 523–9.
44. He FJ, Marrero NM, MacGregor GA. Salt intake, hypertension and obesity in children. Hypertension 2008;51:629–34.
45. Davy BM, Van Walleghen EL, Orr JS. Sex differences in acute energy intake regulation. Appetite 2007;49:141–7.
46. Nelson MC, Neumark-Sztainer D, Hannan PJ, Story M. Five-year longitudinal and secular shifts in adolescent beverage intake: findings from Project EAT (Eating Among Teens)-II. J Am Diet Assoc 2009; 109:308–12.
47. Mattes RD, Popkin BM. Nonnutritive sweetener consumption in humans: effects on appetite and food intake and their putative mechanisms. Am J Clin Nutr 2009;89:1–14.
48. Yang Q. Gain weight by "going diet?" Artificial sweeteners and the neurobiology of sugar cravings: Neuroscience 2010. Yale J Biol Med 2010;83:101–8.

49. Fowler SP, Williams K, Resendez RG, Hunt KJ, Hazuda HP, Stern MP. Fueling the obesity epidemic? Artificially sweetened beverage use and long-term weight gain. Obesity (Silver Spring) 2008;16:1894–900.
50. de Castro JM. Circadian rhythms of the spontaneous meal pattern, macronutrient intake, and mood of humans. Physiol Behav 1987;40:437–46.
51. Khare A, Inman JJ. Daily, week-part, and holiday patterns in consumer's caloric intake. J Public Policy Mark 2009;28:234–52.
52. Racette SB, Weiss EP, Schechtman KB, Steger-May K, Villareal DT, Obert KA, Holloszy JO. Influence of weekend lifestyle patterns on body weight. Obesity (Silver Spring) 2008;16:1826–30.
53. de Castro JM. Weekly rhythms of spontaneous nutrient intake and meal pattern of humans. Physiol Behav 1991;50:729–38.
54. de Castro JM, Pearcey SM. Lunar rhythms of the meal and alcohol intake of humans. Physiol Behav 1995;57:439–44.
55. Tarasuk V, Beaton GH. Menstrual-cycle patterns in energy and macronutrient intake. Am J Clin Nutr 1991;53:442–7.
56. Ma Y, Olendzki BC, Li W, Hafner AR, Chiriboga D, Hebert JR, Campbell M, Sarnie M, Ockene IS. Seasonal variation in food intake, physical activity, and body weight in a predominantly overweight population. Eur J Clin Nutr 2006;60:519–28.
57. Corvalán C, Uauy R, Flores R, Kleinbaum D, Martorell R. Reductions in the energy content of meals served in the Chilean National Nursery School Council Program did not consistently decrease obesity among beneficiaries. J Nutr 2008;138:2237–43.
58. Prentice AM, Cole TJ. Seasonal changes in growth and energy status in the third world. Proc Nutr Soc 1994;53:509–19.
59. Yanovski JA, Yanovski SZ, Sovik KN, Nguyen TT, O'Neil PM, Sebring NG. A prospective study of holiday weight gain. N Engl J Med 2000;342:861–7.
60. Moshfegh AJ, Rhodes DG, Baer DJ, Murayi T, Clemens JC, Rumpler WV, Paul DR, Sebastian RS, Kuczynski KJ, Ingwersen LA, et al. The US Department of Agriculture Automated Multiple-Pass Method reduces bias in the collection of energy intakes. Am J Clin Nutr 2008; 88:324–32.
61. Institute of Medicine. Dietary Reference Intakes. Applications in dietary assessment. Washington, DC: National Academy Press, 2000.
62. Heitmann BL, Lissner L, Osler M. Do we eat less fat, or just report so? Int J Obes Relat Metab Disord 2000;24:435–42.
63. Krebs-Smith SM, Graubard BI, Kahle LL, Subar AF, Cleveland LE, Ballard-Barbash R. Low energy reporters vs others: a comparison of reported food intakes. Eur J Clin Nutr 2000;54:281–7.
64. Rumpler WV, Kramer M, Rhodes DG, Moshfegh AJ, Paul DR. Identifying sources of reporting error using measured food intake. Eur J Clin Nutr 2008;62:544–52.