Published in final edited form as:

Appetite. 2018 September 01; 128: 255–262. doi:10.1016/j.appet.2018.06.020.

Complementary and compensatory dietary changes associated with consumption or omission of plain water by US adults

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Abstract

We examined within-person and between-person differences in self-selected diets of free-living individuals when they choose to consume or not to consume plain water. We used 2-days of dietary data from the NHANES 2005–2012 for this study. For within-person analyses, we compared recalls of respondents who reported water in one of the two available recalls ($n = 1875$ men and 1479 women). For between-person analysis, we compared dietary recalls of respondents who reported water in two, one of two, or zero of two recalls ($n = 8632$ men and 8907 women). The outcomes examined included reported intakes of 24-h energy from foods, beverages, and dietary and eating pattern attributes. We used covariate-adjusted regression methods for both types of analyses. For within-person analyses, the regression models included separate person-level fixed effects. Relative to the water day, on the no-water day, amount of beverages and energy contribution of beverages were significantly higher in both men (106 kcal) and women (43 kcal) ($P = 0.002$). However, the water and the no-water days did not differ in 24-h energy intake, or the amount and energy from reported foods ($P > 0.05$). Energy density of foods, servings of fruits or vegetables and eating patterns did not differ between the water and the no-water day in both men and women ($P > 0.05$). For between-person analysis, however, intakes of energy and energy density of foods were higher, but density of sodium, potassium, and magnesium were lower among those who reported no water in both recalls. Overall, beverages partially substituted for plain water on the no-water day but qualitative dietary characteristics and eating patterns, which may relate to habitual food intake and personal preferences, were not appreciably different within individuals.

Keywords

NHANES; Water; Beverages; Foods; Eating patterns; Energy intake; Diet quality

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.appet.2018.06.020>.

Conflicts of interest

None.

1. Introduction

The biological requirement for water, an essential nutrient, can be met by consuming plain water or water containing beverages and foods (Food and Nutrition Board, 2004). In the current food environment of easy access to inexpensive and highly palatable energy containing low- nutrient beverages for hydration, plain water is attractive for contributing no energy (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015; Lafontan, Visscher, Farpour- Lambert, & Yumuk, 2015). Other suggested advantages of plain water intake relative to beverages for hydration include increased satiety (Corney, Sunderland, & James, 2016; Dennis, Flack, & Davy, 2009; Stookey, Constant, Gardner, & Popkin, 2007), and higher energy expenditure due to water induced thermogenesis (Boschmann et al., 2003, 2007; Thornton, 2016; Vij & Joshi, 2013).

Although several popular and professional publications recommend water intake for weight management, a recent review of obesity related myths and presumptions identified beliefs about the role of water in weight management as a presumption that required further investigation (Casazza et al., 2015). In particular, the assumption that addition of water without concurrent change in other eating behaviors may reduce energy intake and promote weight loss requires investigation (Casazza et al., 2015).

The available evidence on the association of water intake with intake of energy and body weight presents a mixed picture. In crosssectional surveys, a comparison of individuals who report plain water in a dietary recall relative to non-reporters found water reporters to have lower energy intake (Popkin, Barclay, & Nielsen, 2005). However, in other analyses, we found water intake and 24-h energy intake or body weight to be unrelated (Kant, Graubard, & Atchison, 2009). Laboratory- based studies with short-term manipulation of water as a preload or as a co-load, reported lower energy intake in the subsequent ad-libitum test meal, but few of these studies provide information about the entire day's intake (Casazza et al., 2015; Corney et al., 2016; Daniels & Popkin, 2010; Dennis et al., 2009; Stookey et al., 2007). In some intervention trials, inclusion of water intake as an adjunct to *hypocaloric* diets was successful in promoting weight loss (Muckelbauer, Sarganas, Grüneis, & Müller-Nordhorn, 2013), but not others (Wong, Ebbeling, Robinson, Feldman, & Ludwig, 2017). Moreover, in trials without a focus on weight management, the findings were generally null (Muckelbauer et al., 2013).

In the body of literature summarized above, no studies shed light on whether self-reported consumption or omission of plain water by free- living individuals is accompanied by compensatory or complementary changes in food and beverage selection and eating patterns. In the current study, we used two days of dietary data in a large, nationally representative sample of free-living US adults to approximate the traditional within-person paradigm of a cross-over trial in which water intake is manipulated. This approach accounts for *unmeasured* individual-level factors such as genetic factors, taste preferences, food and beverage salience, and habitual food intake, and *measured* individual-level factors such as age, race/ethnicity, body weight and geographical location, which may relate to food intake. Although laboratory-based cross-over studies do account for these variables, they also control all aspects of consumption including time and amounts of pre or co-loads of water,

and availability of selected foods and beverages in subsequent meals, and are far removed from the usual work and leisure eating environments of free-living individuals. We have previously used these methods to address questions related to breakfast consumption (Kant & Graubard, 2015a) and alcohol intake (Breslow, Chen, Graubard, Jacobovits, & Kant, 2013).

The two objectives of this study were to examine within-person and between-person differences in reported intakes of energy, sources of energy, and eating patterns in relation to self-reported plain water intake. For within-person analysis, we compared diets on a day when individuals self-selected plain water relative to a day without plain water; for between-person analysis, we compared dietary behaviors of individuals who reported plain water in both, one, or zero dietary recalls.

2. Methods

We used public domain dietary data from the National Health and Nutrition Examination Surveys (NHANES) conducted from 2005–2006 to 2011–2012 for this study. The NHANES is conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention and is an annual survey of a representative sample of noninstitutionalized Americans (Centers for Disease Control and Prevention and National Center for Health Statistics, 2016a), with data release combined for 2 survey years. The study used public domain anonymized data, and was not considered human subjects research by the City University of New York Institutional Review Board. The NHANES use a complex, multistage, probability sampling design that include an at-home interview and a complete medical examination in a specially equipped mobile examination center (MEC) (Centers for Disease Control and Prevention and National Center for Health Statistics). The overall response rates for the MEC examined sample in the surveys we examined were 69% (Centers for Disease Control and Prevention and National Center for Health Statistics).

Dietary Assessment:

The NHANES collected dietary information using two non-consecutive 24-h recalls (Centers for Disease Control and Prevention and National Center for Health Statistics). A trained interviewer used a computer-assisted interview during the MEC visit to administer the first dietary recall. A second recall was obtained, via telephone, 3–10 days after the first recall. The dietary recalls used the USDA's automated multiple pass method, which has been shown to improve the completeness of the recalled information (Moshfegh et al., 2008). Three dimensional food models and other measuring guides facilitated the recall of portion sizes of foods, beverages, and plain drinking water during the in-person MEC recall. A food model booklet of measuring guides was provided to participants for use during the telephone recall. The public domain data include estimates of energy, total water (sum of plain water, and water content of foods and beverages), macronutrients, and micronutrients, computed from all food and beverage items reported in each recall.

For this analysis, we grouped all reported items in each recall as plain water, food, or beverage as described previously (Kant et al., 2009). We used the public domain (NCHS) plain water estimates for grouping subjects into yes/no categories of plain water

consumption. NCHS categorized “plain tap water, water from a drinking fountain, water from a water cooler, bottled water, and spring water” as plain water. Beverages included fruit and vegetable juices and drinks, coffee/tea or alternatives, sweetened or unsweetened carbonated or non-carbonated drinks, milk and other dairy based beverages, smoothies and shakes, alcoholic beverages, meal replacement drinks, and other miscellaneous beverages. For computation of amounts and energy content of beverages, we considered beverages as consumed, and any additions to the beverage, e.g., sugar and cream to coffee and tea, were considered as part of the beverage.

Dietary outcomes examined:

We examined three types of dietary characteristics as outcomes as described below:

Quantitative dietary characteristics: These included amounts (g) of foods, beverages and plain water, and intakes of total 24-h energy (kcal), energy from foods, all beverages, and different beverage types (dairy, juices, alcoholic, sweetened/unsweetened carbonated, and coffee/tea, etc).

Qualitative diet characteristics: We computed energy density of foods and beverages (kcal/g), and intakes of dietary fiber, vitamin C, sodium, potassium, and magnesium per 1000kcal. Beverage energy density computation did not include plain drinking water. We merged the NHANES dietary recall data with the Food Patterns Equivalents Data (FPED), available from the USDA website (US Department of Agriculture, 2016), and estimated tsp of added sugar, and vegetable and fruit serving cup equivalents per 1000 kcal.

Eating patterns: During each recall, respondents selected a name for their eating episode (breakfast, lunch, dinner/supper, snack and their Spanish language equivalents), and a clock time at which the eating episode occurred. Multiple items reported during one clock time and the labeled eating episode were part of that particular eating episode. Given the increasing appreciation of the role of eating patterns in health promotion (St-Onge et al., 2017), we used published methods (Kant & Graubard, 2015a, 2015b), to determine the number of eating episodes from the number of discrete clock times when a food or beverage was mentioned in the recall. Eating episodes where the only reported item was plain water were not considered an eating episode. Reported clock time of the first eating episode and the last eating episode of the day were determined and the interval between the two was considered the length of the 24-h ingestive period. To determine the average length of the interval between eating episodes, we divided the duration of the 24-h ingestive period by the number of reported eating episodes.

Analytic sample:

All respondents aged 20 years with two reliable dietary recalls were eligible for inclusion in the analytic sample (n=18093). We excluded pregnant and lactating women (n=537) and respondents with valid recalls, but no energy intake on either recalled day (n = 17), for a total of 17539 men and women in the final analytic sample. Within this sample, 12324 reported plain water in both recalls, 1862 did not report water in either recall, and 3354

reported plain water in one of two recalls (which comprised the analytic sample for the within-person comparison of water day with no-water day).

Analytic methods:

We examined differences in the socio-demographic and life-style characteristics of respondents in the three categories of plain water reporting in two, one or zero recalls, using the chi-square test of independence. The examined socio-demographic and lifestyle variables included sex, age, race/ethnicity, poverty income ratio, education, body mass index, physical activity, smoking status, alcohol use status, and self-reported chronic disease status. We also compared 2-day average dietary characteristics of reporters of plain water in both, one, or zero recalls, using covariate adjusted regression models.

For within-person comparisons, we compared characteristics of dietary recalls (weekday vs weekend, in-person vs. telephone, and mention of main meals) that included or omitted plain water using chi-square test of independence. We used regression methods to compare within-person differences in dietary outcomes mentioned above in respondents who reported plain water in only one of two recalls. These models included covariates for the day of the first and the second recall (weekday vs. weekend), mode of recall administration (in-person or via telephone) and a separate intercept term, which is a fixed effect, for each individual, that allows for the estimation and inference of within-person differences. These analyses were stratified by sex. Results in Tables 2–4 present adjusted means (i.e., predicted margins) (Graubard & Korn, 1999; Korn & Graubard, 1999) and their 95% CIs for all dietary variables by whether water was reported or omitted in the two recalls. The difference and 95% CI of the difference between the water and the no water day in each dietary outcome are also included. All statistical tests were conducted using Wald's F tests and Tables present p values of test of hypotheses unadjusted for multiple comparisons; however, in the narrative we only mention significant differences based on p values adjusted for multiple comparisons. We used a Bonferroni correction to adjust for multiple tests of hypothesis in each table. Table 2 includes 13 different comparisons for each sex; the multiple comparison corrected p value for statistical significance was < 0.004 ($0.05/12 = 0.004$). Similarly, for Tables 3–5, the multiple comparison corrected p values were, < 0.005 , < 0.01 , and < 0.003 , respectively.

All analyses were conducted using the statistical software package SAS version 9.2, SAS-callable SUDAAN version 11.0.01, and STATA version 13.1 (for regression analyses of within-person comparisons). All analyses accounted for the complex survey design and used 2-day diet weights to adjust for survey non-response and differential probabilities of selection across the sample (Graubard & Korn, 1999; Korn & Graubard, 1999).

3. Results

3.1. Socio-demographic characteristics of respondents grouped by plain water mention in two recalls

More men than women reported no water in either one or both recalls (Supplemental Table 1). Individuals with recalls that omitted plain water on either one or both days were more

likely to be those with lower income and education, current smokers, and low levels of physical activity. Plain water reporting in two recalls differed by race/ethnicity, but body mass index, alcohol drinking status, and self-reported history of chronic disease were unrelated with mention of plain water in the recall.

Within-person comparison of characteristics of recalls that included or omitted mention of plain water.

More of the telephone administered recalls mentioned plain water in both men and women (Table 1). In women, more recalls of weekdays included water, but not in men (Table 1). Mention of breakfast, lunch, or dinner on day with or without water were not different in both men and women.

3.2. Within-person comparison of quantitative dietary characteristics of recalls that mentioned or omitted plain water

24-h energy intake and energy from foods and beverages: On the no water day, total amount of water (g), beverages (g), and their energy contribution were higher in both men and women (Fig. 1, Table 2). However, the amount of foods (g) or their energy contribution were not different between the day with or without mention of plain water in both men and women (Fig. 1, Table 2). Finally, the 24-h energy intake did not differ significantly between the day that included plain water and the day when no water was reported (Fig. 1, Table 2).

Energy contribution of different beverage types: Dairy beverage energy was unrelated to mention of plain water in both men and women (Table 2). In men, energy contribution of fruit and vegetable juices, and in women, energy from coffee and tea was significantly higher on the no-water day. No other differences in energy from various beverage types approached the multiple-comparison adjusted level of significance (p value of < 0.004).

3.3. Within-person comparison of qualitative dietary characteristics between recalls that mentioned or omitted plain water

The examined qualitative dietary characteristics (energy density of foods and beverages); energy-adjusted intake of added sugar, fruit and vegetable servings, fiber, vitamin C, potassium, and sodium did not differ between the water and the no-water day in both sexes (Table 3). Energy-adjusted magnesium intake of women was higher on the water day ($P < 0.004$).

3.4. Within-person comparison of eating patterns between recalls that mentioned or omitted plain water

None of the examined eating behaviors: number of eating episodes, clock time of the first and the last eating episodes of the day, 24-h ingestive period (interval between the first and the last eating episodes of the day), and the interval between eating episodes, differed between the recall that mentioned and the recall that omitted plain water (Table 4).

3.5. Between-person comparison of dietary outcomes among reporters of plain water in 2, 1, or 0 recalls

With adjustment for several potential correlates of plain water intake, 2-day average intakes of energy from foods and beverages, and energy density of foods differed by whether plain water was reported in both, one, or none of the two recalls (Table 5). Overall, intakes of energy, energy density of foods, and added sugar were higher, but servings of fruits and vegetables, and density of fiber, sodium, potassium, magnesium, and vitamin C, were lower among those who reported no plain water in both recalls. Urine osmolality, an indicator of hydration (Shirreffs, 2003), differed among the three groups and was jointly significantly lower in reporters of water in both recalls relative to reporters of plain water in one of two or none of two recalls.

4. Discussion

To our knowledge, this is the first report to examine within-person differences in 24-h dietary and eating behaviors in relation to self-reported plain water intake of free-living adults. Key study findings include: 1) on no-water day, the amount of beverages and their energy contribution were higher, but the reported amount of foods, energy from foods, and 24-h energy intake were not statistically significantly different within persons; 2) there were few qualitative differences in diet consumed on the water vs. the no-water day; 3) eating patterns were similar on the water day and the no-water day; and 4) in between-person comparisons, the dietary profiles of plain water reporters in two recalls were of higher quality relative to comparison groups.

Expectedly, more beverages were reported on the no-water day (429 g higher in men and 206 g higher in women), but this increase did not fully compensate for plain water consumed on the water day (781 g in men and 704 g in women). The higher beverage amount did provide significantly higher beverage energy (additional 106kcal in men and 43 kcal in women) on no-water day. Nevertheless, the overall differences in 24-h energy intake between the water day vs. the no-water day did not reach statistical significance (mean difference was 72 kcal in men and 25 kcal in women), possibly due slightly higher (non-significant) intake of food energy (34 kcals in men and 18 kcals in women) on the water day. These findings suggest that lower energy intake on the water day was largely due to lower beverage energy intake rather than lower food intake.

The results for most examined dietary outcomes differed when we compare dietary outcomes on water day vs. no-water day within individuals (Tables 2–4) or among individuals (Table 5). Relative to reporters of no water in one or both recalls, reporters of water in both recalls had lower mean energy intakes but higher intakes of fruits, vegetables, potassium, magnesium, and vitamin C. This suggests that both quantity and quality of dietary selections of individuals who may drink plain water regularly differ from those of other groups in the population. On the other hand, *addition* of plain water on the water day within persons was not associated with differences in amounts or types of foods selected, possibly reflecting the complex role of habitual ingestive behaviors that determine what, when, and how much is customarily consumed.

This study exploits the availability of two non-consecutive dietary measurements for free-living respondents to approximate the crossover design of short-term nutrition studies. Relative to the usual controlled laboratory-based single meal studies (Casazza et al., 2015), we could examine intake for the entire 24-h period in a large number of subjects in a naturalistic setting. Survey respondents reported the types and amounts of foods and beverages consumed in their usual environmental context. However, there is no repeat measurement of either water condition within persons. For instance, the study is not able to provide any information about whether the observed mean differences in 24-h energy intake between the water and no-water days, although not statistically significant on one day, may over the longer term, contribute to lower energy intake and aid in weight management.

In the NHANES, diet was assessed using state-of-the-art 24-h dietary recall methods (Moshfegh et al., 2008). However, all dietary assessment methods (including recalls) are known to contain measurement errors, including underreporting of energy intake (Dhurandhar et al., 2015; Dietary Reference Intakes, 2000). Of note, the ratio of reported energy intake to computed basal energy requirements, a measure of plausibility of reported energy intakes, was not different between the water and the no-water day in both men and women (Table 2). We speculate that in the within-person design of our study, person-specific systematic errors are likely to be similar for the two days, and on average, would subtract out in the estimation of within-person differences. However, we cannot exclude the possibility that dietary measurement error may have obscured meaningful results in the available data. This observational study provides no information about variation in dietary behaviors due the amount of water consumed on water day. Finally, differences, if any, in the association of dietary behaviors and water consumed before or with meals, were not examined in this study.

Given the observational nature of our study, in an attempt to explore the reliability of self-reported total water intakes available in the NHANES, we examined urine osmolality, a biomarker of total water exposure and hydration status (Shirreffs, 2003), that was measured in the NHANES 2009–2012. Higher osmolality reflects lower total water intake and a more concentrated urine. The trends in urine osmolality do provide some support for the self-reported overall water exposure shown in Table 5. The highest mean osmolality was in the group that reported no plain water in either recall, and the lowest mean osmolality was in the group that reported water in both recalls. Despite day-to-day variation in reported water consumption, these findings suggest that self-reported plain water intake in 2, 1, or 0 recalls was useful to group individuals into categories of total water exposure.

Overall, reporters of plain water in two recalls had higher quality dietary profiles relative to non-reporters of water in one of two or both recalls. The within-person comparisons show that beverages partially substituted for plain water on the no-water day. In contrast, other indices of dietary quantity and quality of foods selected did not differ appreciably between the water and the no-water days, which may reflect the strength of dietary habits. Therefore, plain water consumption may need to be accompanied by changes in amounts and types of foods for any meaningful contributions to weight management.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

We thank Lisa Licitra Kahle for expert SAS and SUDAAN programming support, Fanni Zhang for STATA programming support (both are with IMS, Silver Spring, MD), and David Check for graphic support (NCI, NIH).

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

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Fig. 1.

Within-person comparison of amount of foods and beverages (A), and energy from foods and beverages (B), on a day that mentioned plain water relative to a day without plain water. Footnote: The estimates are adjusted means (i.e., predicted margins) from regression models associated with an indicator for whether it was a recall day with or without water. The multiple linear regression models included g of foods, beverages or plain water (A), or energy contribution of foods and beverages (B), as a continuous dependent variable, and dummy variables for week day of recall (week day vs. weekend), mode of recall

administration (in-person vs. telephone), and a separate dummy variable for each individual to allow individual-intercepts in the study, as independent variables.

Table 1

Within-person comparison of characteristics of dietary recalls that included or omitted plain water (%¹ reporting and 95% confidence intervals), NHANES 2005–2012.

	Men		Women	
	Plain water reported in the 24-h recall	Plain water NOT reported in the 24-h recall	Plain water reported in the 24-h recall	Plain water NOT reported in the 24-h recall
N	1875	1875	1479	1479
In-person recall	41 (37, 44)	59 (56, 63)	41 (37, 44)	59 (56, 63)
Telephone recall	59 (56, 63)	41 (37, 44)	59 (56, 63)	41 (37, 44)
	$P^2 < 0.0001$		$P^2 < 0.0001$	
Recalled a weekday (Monday–Thursday)	59 (56, 63)	56 (53, 59)	62 (59, 65)	54 (51, 58)
Recalled weekend (Friday–Sunday)	40 (37, 44)	44 (41, 47)	38 (34, 41)	46 (42, 49)
	$P^2 = 0.1$		$P^2 = 0.005$	
Recalled breakfast	78 (75, 81)	79 (76, 82)	85 (82, 88)	86 (83, 88)
Not recalled breakfast	22 (19, 25)	21 (18, 24)	15 (12, 18)	14 (12, 17)
	$P^2 = 0.5$		$P^2 = 0.3$	
Recalled Lunch	76 (73, 79)	74 (71, 78)	75 (72, 78)	75 (72, 78)
Not recalled lunch	24 (21, 27)	26 (22, 29)	26 (22, 28)	25 (22, 28)
	$P^2 = 0.1$		$P^2 = 0.9$	
Recalled Dinner	91 (89, 93)	91 (89, 92)	91 (90, 93)	91 (89, 93)
Not recalled Dinner	9 (7, 10)	9 (8, 11)	8 (7, 10)	9 (7, 10)
	$P^3 = 0.4$		$P^3 = 0.8$	

¹May not equal 100 due to rounding.

²P-values associated with the chi-square test of independence for each dietary recall characteristic for each sex.

Table 2

Within-person comparison of quantitative dietary characteristics (adjusted mean and 95% CI^a) in relation to whether or not plain water was mentioned in the recall, NHANES 2005–2012.

	Men		Women		Water day minus no water day, p ² value	Water day minus no water day, p ² value
	Plain water reported in the 24-h recall	Plain water NOT reported in the 24-h recall	Plain water reported in the 24-h recall	Plain water NOT reported in the 24-h recall		
n	1875	1875	1479	1479		
Total water ^{a,3} , g	3019 (2935, 3103)	2629 (2528, 2731)	2416 (2341, 2491)	1903 (1830, 1977)	513 (443, 582)	<0.0001
24-h plain water, g	781 (737, 826)	0	704 (651, 757)	0	1.0 (–36, 38)	P = 0.9
24-h food amount, g	1021 (990, 1051)	1001 (970, 1031)	800 (776, 824)	799 (764, 834)		
24-h beverage amount, g	1739 (1659, 1818)	2168 (2060, 2276)	1292 (1230, 1353)	1497 (1424, 1571)	–206 (–286, –125)	P < 0.0001
24-h energy intake, kcal	2485 (2410, 2559)	2557 (2485, 2629)	1786 (1727, 1846)	1811 (1749, 1874)	–25 (–81, 31)	P = 0.4
24-h food only energy, kcal	1976 (1915, 2037)	1942 (1881, 2003)	1458 (1403, 1512)	1440 (1379, 1500)	18 (–41, 77)	P = 0.5
24-h beverage only energy, kcal	508 (479, 537)	615 (572, 657)	329 (312, 346)	372 (349, 394)	–43 (–69, –16)	P = 0.002
Alcoholic beverage energy, kcal	137 (115, 159)	181 (145, 217)	50 (37, 62)	51 (38, 64)	–1.5 (–15, 13)	P = 0.8
Coffee, Tea beverage energy, kcal	49 (41, 57)	59 (49, 69)	38 (32, 44)	54 (46, 62)	–16 (–23, –8)	<0.0001
Sweetened beverages and juice drinks energy, kcal	191 (174, 208)	221 (200, 242)	124 (115, 134)	136 (123, 149)	–11 (–24, 2.2)	P = 0.1
Fruit and vegetable juices energy, kcal	33 (28, 39)	44 (38, 50)	31 (25, 37)	38 (32, 44)	–6 (–13, 0.2)	P = 0.06
Dairy beverages energy, kcal	81 (73, 90)	92 (79, 104)	62 (53, 71)	69 (55, 82)	–7 (–21, 8)	P = 0.3

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	Men		Women		Water day minus	
	Plain water reported in the 24-h recall	Plain water NOT reported in the 24-h recall	Plain water reported in the 24-h recall	Plain water NOT reported in the 24-h recall	no water day, 2 p value	no water day, 2 p value
EI/BEE ⁴	1.38 (1.34, 1.42)	1.42 (1.38, 1.46)	1.26 (1.22, 1.31)	1.28 (1.24, 1.33)	-0.04 (-0.08, 0.006)	-0.02 (-0.06, 0.02)
	P = 0.1		P = 0.3			

¹Estimates are adjusted means (i.e., predicted margins) and 95% confidence intervals associated with an indicator for whether it was a recall day with or without water. The multiple linear regression models included each dietary characteristic as a continuous dependent variable, and dummy variables for week day vs. weekend) and mode of recall administration (in-person vs. telephone), and a separate dummy variable for each individual in the study to allow individual-intercepts, as independent variables.

²P-values obtained from Wald's F-tests. Actual p values are presented. The multiple comparison adjusted p value for significant differences < 0.004.

³Total water is the sum of water in foods, beverages, and plain water.

⁴EI/BEE is the ratio of reported energy intake to computed basal energy expenditure, used as a measure of plausibility of the self-reported dietary intake data.

Table 3

Within-person comparison of qualitative dietary characteristics (adjusted mean and 95% CI¹) in relation to whether or not plain water was mentioned in the recall, NHANES 2005–2012.

	Men			Women		
	Plain water reported in the 24-h recall	Plain water not reported in the 24-h recall	Water day minus no water day, ² p value	Plain water reported in the 24-h recall	Plain water not reported in the 24-h recall	Water day minus no water day, ² p value
n	1875	1875		1479	1479	
Energy density of foods, kcal/g	2.03 (1.98, 2.07)	2.04 (1.99, 2.10)	-0.01 (-0.07, 0.04) P = 0.6	1.92 (1.86, 1.97)	1.91 (1.86, 1.96)	0.008 (-0.05, 0.07) P = 0.2
Energy density of beverages, kcal/g	0.30 (0.27, 0.29)	0.28 (0.27, 0.30)	0.01 (0.001, 0.02) P = 0.03	0.28 (0.26, 0.29)	0.27 (0.26, 0.28)	0.008 (-0.005, 0.02) P = 0.8
Added sugar, tsp/1000kcal	9.0 (8.4, 9.5)	9.4 (8.9, 9.8)	-0.4 (-0.8, -0.04) P = 0.03	9.0 (8.6, 9.4)	9.6 (9.1, 10.2)	-0.6 (-1.1, -0.1) P = 0.02
Fruit, cup equivalents/1000 kcal	0.4 (0.35, 0.43)	0.4 (0.35, 0.41)	0.009 (-0.02, 0.04) P = 0.6	0.5 (0.43, 0.58)	0.1 (0.45, 0.56)	-0.003 (-0.06, 0.06) P = 0.9
Vegetable, cup equivalents/1000 kcal	0.7 (0.67, 0.78)	0.7 (0.65, 0.74)	0.03 (-0.02, 0.08) P = 0.3	0.8 (0.78, 0.89)	0.8 (0.76, 0.86)	0.02 (-0.04, 0.09) P = 0.5
Fiber, g/1000 kcal	7.3 (7.0, 7.6)	6.9 (6.6, 7.3)	0.36 (0.005, 0.72) P = 0.05	8.2 (7.9, 8.5)	7.9 (7.6, 8.3)	0.26 (-0.09, 0.61) P = 0.1
Vitamin C, mg/1000 kcal	35 (32, 38)	38 (35, 42)	-3.4 (-6.6, -0.2) P = 0.04	43 (38, 48)	46 (41, 50)	-2.4 (-7, 2.2) P = 0.3
Potassium, mg/1000 kcal	1252 (1214, 1289)	1264 (1226, 1303)	-13 (-46, 21) P = 0.4	1339 (1299, 1380)	1374 (1343, 1406)	-35 (-78, 8.1) P = 0.1
Magnesium, mg/1000 kcal	134 (130, 138)	130 (126, 133)	4.9 (1.0, 8.8) P = 0.01	145 (140, 149)	137 (134, 140)	7 (3, 11) P = 0.0004
Sodium, mg/1000 kcal	1665 (1626, 1703)	1614 (1583, 1646)	50 (8, 92) P = 0.02	1727 (1679, 1775)	1654 (1610, 1699)	72 (13, 132) P = 0.02

¹ Estimates are adjusted means (i.e., predicted margins) and 95% confidence intervals associated with an indicator for whether it was a recall day with or without plain water. The multiple linear regression models include each dietary characteristic as a continuous dependent variable, and dummy variables for week day of recall (week day vs. weekend) and mode of recall administration (in-person vs. telephone), and a separate dummy variable for each individual in the study to allow individual-intercepts, as independent variables.

² P-values obtained from Wald's F-tests. Actual p values are presented. The multiple comparison adjusted p value for significant differences < 0.005.

Table 4

Within-person comparison of eating patterns (adjusted mean¹ and 95% CI) in relation to whether or not plain water was mentioned in the recall, NHANES 2005–2012.

	Men			Women		
	Plain water reported in the 24-h recall	Plain water NOT reported in the 24-h recall	Water day minus no water day, p ² value	Plain water reported in the 24-h recall	Plain water NOT reported in the 24-h recall	Water day minus no water day, p ² value
N	1875	1875	1875	1479	1479	1479
Number of eating episodes ³	4.7 (4.61, 4.83)	4.7 (4.6, 4.8)	0.05 (– 0.06, 0.2) P = 0.4	4.7 (4.6, 4.8)	4.7 (4.6, 4.8)	0.03 (– 0.10, 0.2) P = 0.6
Time of day of the first eating episode (HH:MM)	7:59 (7:47, 8:10)	8:06 (7:54, 8:17)	– 7.1 (– 19.9, 5.6) P = 0.3	8:22 (8:09, 8:35)	8:19 (8:08, 8:30)	2.8 (– 8.1, 13.8) P = 0.6
Time of day of the last eating episode (HH:MM)	20:23 (20:14, 20:32)	20:20 (20:11, 20:29)	3.1 (– 7.5, 13.8) P = 0.6	20:12 (20:02, 20:21)	20:08 (20:00, 20:17)	3.3 (– 8.1, 14.7) P = 0.6
Length of the 24-h ingestive period ⁴ , h	12.4 (12.2, 12.7)	12.3 (12.0, 12.5)	0.19 (– 0.08, 0.47) P = 0.2	11.8 (11.6, 12.1)	11.8 (11.6, 12.0)	0.06 (– 0.2, 0.3) P = 0.6
Interval between eating episodes ⁵ , h	2.8 (2.72, 2.85)	2.8 (2.72, 2.83)	0.008 (– 0.06, 0.08) P = 0.8	2.6 (2.6, 2.7)	2.7 (2.60, 2.72)	– 0.03 (– 0.1, 0.04) P = 0.4

¹Estimates are adjusted means (i.e., predicted margins) and 95% confidence intervals associated with an indicator for whether it was a recall day with or without water. The multiple linear regression models include each dietary characteristic as a continuous dependent variable, and dummy variables for week day of recall (week day vs. weekend) and mode of recall administration (in-person vs. telephone), and a separate dummy variable for each individual in the study to allow individual-intercepts, as independent variables.

²P-values obtained from Wald's F-tests. Actual p values are presented. The multiple comparison adjusted p value for significant differences <0.01.

³Subject labeled episodes of consumption of any food or beverage (excluding episodes that mentioned only plain water).

⁴Difference between the reported time of the first and the last eating episodes.

⁵24-h ingestive period/number of eating episodes.

Table 5

Covariate adjusted 2-day average (adjusted mean¹ and 95% CI) intake of energy, nutrients, and eating behaviors by respondents who recalled plain water in both, one, or none of the two recalls: NHANES 2005–2012.

All	Plain water reported			p ² value
	Two 24-h recalls	One of two 24-h recalls	Zero of two 24-h recalls	
n	12324	3354	1861	
Urine osmolality ³ , mOsm/kg	597 (587, 607)	629 (608, 649)	635 (610, 660)	0.002
Total water ⁴ , g	3134 (3077, 3190)	2514 (2459, 2569)	2299 (2234, 2364)	<0.0001
Energy, kcal	2082 (2055, 2108)	2158 (2116, 2200)	2124 (2067, 2181)	0.006
Energy from foods, kcal	1732 (1708, 1756)	1709 (1674, 1744)	1628 (1577, 1680)	0.0008
Energy from beverages, kcal	350 (341, 359)	449 (431, 466)	496 (471, 520)	<0.0001
Energy density of foods, kcal/g (n = 17515)	1.86 (1.84, 1.87)	1.96 (1.93, 1.99)	2.05 (2.02, 2.08)	<0.0001
Energy density of beverages, kcal/g (n = 17426)	0.29 (0.28, 0.29)	0.28 (0.27, 0.29)	0.27 (0.26, 0.28)	0.01
Fiber, g/1000kcal	8.8 (8.7, 9.0)	7.8 (7.6, 8.0)	7.0 (6.8, 7.3)	<0.0001
Added sugar, tsp/1000kcal	7.4 (7.2, 7.6)	9.1 (8.7, 9.4)	10.8 (10.2, 11.3)	<0.0001
Fruit, cup equivalents/1000 kcal	0.6 (0.57, 0.61)	0.5 (0.43, 0.49)	0.4 (0.38, 0.45)	<0.0001
Vegetable, cup equivalents/1000 kcals	0.9 (0.85, 0.89)	0.8 (0.76, 0.82)	0.7 (0.68, 0.76)	<0.0001
Sodium, mg/1000 kcal	1727 (1711, 1742)	1666 (1646, 1687)	1585 (1560, 1610)	<0.0001
Potassium, mg/1000 kcal	1396 (1383, 1409)	1327 (1301, 1354)	1282 (1249, 1315)	<0.0001
Magnesium, mg/1000 kcal	156 (155, 158)	139 (136, 142)	131 (128, 134)	<0.0001
Vitamin C, mg/1000 kcal	47 (45, 48)	41 (38, 44)	42 (39, 45)	0.0001
Number of eating episodes	4.84 (4.80, 4.89)	4.77 (4.71, 4.84)	4.72 (4.62, 4.82)	0.02
Length of the 24-h ingestive period, h	12.1 (12.0, 12.20)	12.1 (12.0, 12.3)	12.2 (12.0, 12.4)	0.5

¹Values are adjusted means (i.e., predicted means) and 95% confidence intervals from regression models with 2-day average of each dietary variable as a continuous dependent variable. The multiple linear regression models included plain water groups (water in 2 recalls, 0 recall, or one of 2 recalls), survey cycle, sex, age, race/ethnicity, poverty income ratio, education, body mass index, chronic disease, month of recall, and level of physical activity, as independent variables. N = 17521 for models with all covariates (unless noted otherwise).

²p-values obtained from Wald's F-tests. Actual p values are presented. The multiple comparison adjusted p value for significant differences < 0.003.

³Urine osmolality was available for only 2009–10 and 2011–12 surveys (n for model with all covariates = 8814). Urine osmolality models included alcohol intake, protein intake, and sodium intake in addition to all variables mentioned above, as independent variables.

⁴Total water included sum of plain water and water content of foods and beverages reported in the 24-h recall.

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