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Abstract

Objective: Differences in bottled v. tap water intake may provide insights into health disparities, like risk of dental caries and inadequate hydration. We examined differences in plain, tap and bottled water consumption among US adults by sociodemographic characteristics.

Design: Cross-sectional analysis. We used 24 h dietary recall data to test differences in percentage consuming the water sources and mean intake between groups using Wald tests and multiple logistic and linear regression models.


Subjects: A nationally representative sample of 20 676 adults aged ≥20 years.

Results: In 2011–2014, 81·4 (se 0·6) % of adults drank plain water (sum of tap and bottled), 55·2 (se 1·4) % drank tap water and 33·4 (se 1·4) % drank bottled water on a given day. Adjusting for covariates, non-Hispanic (NH) Black and Hispanic adults had 0·44 (95 % CI 0·37, 0·53) and 0·55 (95 % CI 0·45, 0·66) times the odds of consuming tap water, and consumed $B = -330$ (se 45) ml and $B = -180$ (se 45) ml less tap water than NH White adults, respectively. NH Black, Hispanic and adults born outside the fifty US states or Washington, DC had 2·20 (95 % CI 1·79, 2·69), 2·37 (95 % CI 1·91, 2·94) and 1·46 (95 % CI 1·19, 1·79) times the odds of consuming bottled water than their NH White and US-born counterparts. In 2007–2010, water filtration was associated with higher odds of drinking plain and tap water.

Conclusions: While most US adults consumed plain water, the source (i.e. tap or bottled) and amount differed by race/Hispanic origin, nativity status and education. Water filters may increase tap water consumption.

Keywords
Plain water intake
NHANES
Disparities in water consumption
Nutrition
Water filters

Provision of safe drinking-water was a critical US public health intervention of the 20th century¹. Mortality rates, particularly child mortality, declined with proper treatment of public water systems. While ongoing challenges persist in the USA, including deteriorating water infrastructure and emerging pathogens, tap water from public water systems remains the healthiest hydration choice for most¹,².

The USA has one of the most comprehensive, reliable and safest water infrastructure systems in the world³, yet sales of bottled water have increased from ~325 billion litres (~350 million US gallons) in 1976 to 48·45 billion litres (12·8 billion US gallons) in 2016⁴,⁵. The Environmental Protection Agency (EPA) regulates US public water systems, which serve ~90 % of the population⁶. By comparison, bottled water is regulated by the Food and Drug Administration and is 240–10 000 times more expensive than tap water⁷. Differences in tap and bottled water consumption have major public health implications for fluoride delivery and exposure to chemical contaminants and pathogens, as studies have found higher proportions of sampled bottled water had fluoride levels below the recommended amount and higher bacterial counts than tap⁸–¹¹.

Perceptions of water sources may affect who drinks tap or bottled water¹². The American Housing Survey found
that foreign-born, Hispanic, non-Hispanic (NH) Black, and adults with lower income and education were more likely to state tap water was unsafe\(^{(13)}\). Previous research found racial disparities in access to community water services such that low-income households experienced more water insecurity and ethnic minorities were more likely to have negative previous experiences with tap water\(^{(14\text{--}16)}\). Therefore, these populations may be consuming less tap and more bottled water.

A few nationally representative studies have examined water intake patterns in the USA\(^{(8,17\text{--}19)}\); however, a gap exists in examining tap vs. bottled water intake by demographic and socio-economic characteristics. It is important to know whether specific populations are more likely to drink tap or bottled water, how much of each source they consume, and whether use of household water filters affects these relationships as water filters may increase trust in tap water, particularly since drinking more bottled water may reflect extra economic and mental stress faced by families spending greater amounts on water and who may perceive tap water to be unclean\(^{(15,16,20)}\). Additionally, these patterns may provide insights into health disparities, like higher prevalence of dental caries, tooth loss and inadequate hydration among NH Black and Hispanic adults\(^{(21,22)}\).

The present study had three objectives: (i) to assess the percentages of US adults who consume total plain, tap and bottled water and examine how these vary by sociodemographic characteristics to assess potential disparities; (ii) to determine how much total plain, tap and bottled water US adults consume on a given day and examine how reported intake varies by race/Hispanic origin, nativity status and socio-economic status; and (iii) to examine how household water treatment use affects these relationships and whether it is associated with differences in likelihood of water source use.

**Methods**

The present study uses four two-year National Health and Nutrition Examination Survey (NHANES) cross-sectional cycles: 2011–2012 and 2013–2014 for the main analysis, and 2007–2008 and 2009–2010 for the sensitivity analysis (discussed later). NHANES provides a representative sample of the non-institutionalized, civilian US population using a complex, stratified, multistage probability design. NHANES combines in-person interviews with physical examinations conducted in mobile examination centres. Details of the survey sampling procedures and methodology are described elsewhere\(^{(23,24)}\). Since 1999, NHANES has been continuously conducted by the National Center for Health Statistics. The Research Ethics Review Board of the National Center for Health Statistics approved the continuous NHANES and all adult participants gave written informed consent. In 2011–2014, NHANES oversampled NH Black, Hispanic and NH Asian persons, among other groups. The examination response rate, which includes the dietary recalls, for adults aged \(\geq 20\) years in 2011–2014 was 64.0\%\(^{(25)}\).

**Measures**

Adults completed an in-person 24 h dietary recall by trained dietary interviewers using the automated multiple-pass method in the mobile examination centre and a second dietary recall by telephone 3–10 d later\(^{(26)}\). This recall method uses standardized probes to improve respondents’ recall of foods and beverages consumed and minimizes bias\(^{(26)}\). During the recall respondents listed all foods and liquids consumed in the previous 24 h period from midnight to midnight. Data from the dietary recall are used to generate estimates of the amount of foods, water and nutrients consumed and to describe dietary behaviours\(^{(19)}\).

To assess population means and differences in overall plain water (sum of tap and bottled water), tap water and non-carbonated, unsweetened bottled water on a given day, we used one 24 h recall to estimate total plain water (millilitres), tap water (millilitres) and bottled water (millilitres) calculated on the Day 1 Total Nutrients file\(^{(24)}\). To assess the percentage of adults using tap, bottled and overall plain water, all three variables were defined as follows: \(>0\text{ ml}=\) drank tap/bottled/plain water; \(0\text{ ml}=\) did not drink tap/bottled/plain water. These categories were also used to distinguish whether an individual drank tap water (\(>0\text{ ml of tap}\)) or not (\(0\text{ ml of tap}\)) and whether an individual drank bottled water (\(>0\text{ ml of bottled}\)) or not (\(0\text{ ml of bottled}\)). The categories of ‘drank tap water’ and ‘drank bottled water’ are not mutually exclusive. For example, adults in the category ‘drank tap water’ may also have drank bottled water, whereas adults in the category ‘did not drink tap water’ consumed \(0\text{ ml of tap}\) but may have drank bottled water.

**Covariates**

For the 2011–2014 NHANES data, race/Hispanic origin was self-reported and made available on the public-use file as NH White, NH Black, Hispanic (Mexican American and other Hispanic) and NH Asian. Adults who identified as other race, including multi-racial, were included in analyses but not shown separately (other ethnicity included NH Asians in 2007–2010). To assess nativity status, participants were asked in what country they were born. Those who answered they were born in the fifty US states or Washington, DC were coded as ‘US-born’ and those who reported being born in other countries or US territories, like Puerto Rico, as ‘born outside fifty US states or Washington, DC’.

We examined income and educational level as markers of socio-economic status. Federal income to poverty ratio (FIPR) is an index based on the ratio of family income to poverty. The US Department of Health and Human Services’ poverty guidelines were used to calculate this index\(^{(27)}\). FIPR was categorized as \(\leq 130\%\), \(131\text{--}350\%\) and \(>350\%\). To assess education, adults were asked ‘What is
the highest grade or level of school you have completed or the highest degree you received? Educational level was categorized as ‘less than high school’ (includes 12th grade with no diploma), ‘high school graduate/GED or equivalent’, ‘some college or associates degree’ and ‘college graduate or above’, where GED is General Educational Development. Age was categorized as 20–39 years, 40–59 years and ≥60 years, and sex as male/female.

**Statistical analysis**

Data analyses were conducted with the statistical software package Stata version 13.1, using survey commands to estimate means and with se estimated by Taylor series linearization. Day 1 dietary sample weights were used to adjust for oversampling, non-response rates, non-coverage and day of week. Differences between categories were tested with Wald F-test statistics adjusted for the survey design and tested for linear trends, when appropriate, by treating categorical ordinal covariates as continuous in linear and logistic regressions.

We used multiple logistic regressions to test for differences in the likelihood to consume any plain, tap and bottled water on a given day by race/Hispanic origin, nativity status and education, adjusting for covariates. We excluded FIPR in the regression models because education and income are strongly correlated and because FIPR had 720 missing observations (see online supplementary material, Supplemental Table 1). Multiple linear regressions were used to test how mean intakes of water (plain, tap and bottled) differed by the sociodemographic characteristics, similar to the logistic regressions.

**Sample**

The analytic sample for 2011–2014 included 9678 adults (unweighted) who completed the dietary recall out of 10,599 adults who participated in any part of the examination (91·3%; see online supplementary material, Supplemental Table 1). Pregnant (n 111) and lactating (n 59) women were excluded. Twelve adults were excluded due to missing nativity status and education, leaving 9666 adults (Supplemental Table 1).

**Sensitivity analysis**

Since water filters may change water consumption behaviours, we examined the role they play as a potential effect modifier or confounder on the association between sociodemographic characteristics and plain, tap and bottled water consumption. In 2007–2010, participants were asked if they used water treatment devices to improve home water safety and quality, including carbon, fibre, reverse osmosis, neutralizers, chemical feed-pumps, disinfection and softeners, and pitcher water filters. We examined the percentage and characteristics of adults using these water treatment devices (see online supplementary material, Supplemental Table 2), and then re-estimated the models in Table 2 with and without water treatment as a covariate (Supplemental Table 3). The sample size for 2007–2010 was 10,998 (Supplemental Table 1) with an examination response rate of 71·4% (21).

**Results**

**Percentage consuming**

In 2011–2014, 81·4 (se 0·6)% of US adults reported they drank any plain water, 55·2 (se 1·4)% consumed any tap water and 33·4 (se 1·4)% consumed any bottled water on a given day (Table 1). Tap and bottled water use was not exclusive, as 13·0 (se 0·9)% of adults who drank tap water also drank bottled water and 21·5 (se 1·2)% of adults who drank bottled water also drank tap water on a given day (all P<0·001).

Differences in plain water use existed by race and Hispanic origin and nativity status (Table 1). In 2011–2014, 80·9 (se 0·9)% of NH White, 78·1 (se 1·1)% of NH Black, 89·3 (se 0·9)% of NH Asians and 84·0 (se 1·2)% of Hispanic adults reported drinking plain water (P<0·001). Of NH White adults, 61·6%, and of NH Asian adults, 61·9%, consumed tap water on a given day, compared with 38·0% of NH Black and 38·7% of Hispanic adults. More than half of Hispanic adults (52·9%) consumed bottled water on a given day compared with 46·0% of NH Black, 37·8% of NH Asian and 26·3% of NH White adults. A significantly higher percentage of adults born outside the fifty US states or DC reported they consumed any plain water as well as any bottled water than US-born adults. A lower percentage of adults born outside the fifty US states or DC consumed tap water on a given day (all P<0·001).

Differences also existed by SES (Table 1). Income (FIPR) and education were positively linearly associated with the percentage of adults who consumed any plain and tap water (all P<0·001), and inversely linearly associated with the percentage of adults who consumed bottled water on a given day (P=0·007 for FIPR; P<0·001 for education). For example, a lower percentage of those making less than 130% FIPR (77·0 (se 1·1)% ) and those with less than a high-school diploma (75·3 (se 1·6)% ) reported consuming any plain water than adults greater than 350% FIPR (85·5 (se 0·8)% ; P<0·001, linear trend) and those with a college diploma or above (87·6 (se 1·0)% ; P<0·001, linear trend), respectively.

The results from the multiple logistic regression models examined the relationship among race/Hispanic origin, nativity status and education on reported drinking of any plain, tap and bottled water on a given day adjusting for these covariates as well as age and sex (Table 2; Fig. 1). Race/Hispanic origin was not associated with increased odds of consuming plain water in adjusted models (Fig. 1a). However, NH Black (OR=0·44; 95% CI 0·37, 0·53) and Hispanic (OR=0·55; 95% CI 0·45, 0·66) adults had significantly lower odds of consuming tap water compared with NH Whites (Fig. 1b). Additionally, NH Black...
(OR = 2.20; 95% CI 1.79, 2.69) and Hispanic (OR = 2.37; 95% CI 1.91, 2.94) adults had more than twice the odds of consuming bottled water than NH Whites (Fig. 1(c)).

Nativity status and education were associated with plain and bottled water consumption, controlling for covariates. Adults born outside the fifty US states or Washington, DC had higher odds of consuming any plain water (OR = 1.67, 95% CI 1.25, 2.21) and bottled water (OR = 1.46, 95% CI 1.19, 1.79) than US-born adults, but were no less likely to consume tap water. Education was significantly associated with plain, tap and bottled water use (Fig. 1(a)-(c)). Being a college graduate or above was associated with 2.63 (95% CI 2.05, 3.38) times the odds of consuming any plain water than adults with less than a high school degree, with similar associations for tap water. Education level was not strongly related to bottled water consumption after adjustment.

**Mean consumption**

In 2011–2014, the mean total plain water intake on a given day for US adults was 1167 (SE 26) ml, with 725 (SE 32) ml (62.2%) from tap water and 441 (SE 23) ml (37.8%) from bottled water (Table 3). Adults who drank any tap water (and potentially some bottled) on a given day consumed more total plain water than adults who did not drink any tap water (1444 (SE 38) ml; 824 (SE 32) ml; P < 0.001) with 131 (SE 11) ml water coming from bottled water. Adults who drank bottled water (and potentially some tap water) consumed 1501 (SE 27) ml of plain water (with 179 (SE 11) ml coming from tap) on a given day, which was higher than adults who did not drink any bottled water (999 (SE 57) ml).

Overall and group-specific differences in total plain, tap and bottled water intake existed between race/Hispanic origin groups (all P < 0.001). Hispanic adults had the highest mean total plain water intake (1281 (SE 48) ml) except for NH Asians (1194 (SE 51) ml), while NH Black (1044 (SE 31) ml) adults had the lowest intake (Table 3). NH White adults had the highest mean tap water intake (813 (SE 38) ml) except for NH Asians (730 (SE 42) ml), while NH Black adults had the lowest intake (450 (SE 32) ml).

| Table 1 Percentage of US adults aged ≥20 years (n 9666) who reported plain water intakes, by sociodemographic characteristics, National Health and Nutrition Examination Survey (NHANES) 2011–2014†‡ |
|---------------------------------|------------------|------------------|------------------|
|                                | Drank plain water§ | Drank tap water§ | Drank bottled water§ |
|                                | %                | %                | %                |
| **Total**                      | 81.4 † †         | 55.2             | 1.4              |
| **Tap water§**                 |                  |                  |                  |
| Yes                            | 100.0            | –                | 13.0             |
| No                             | 59.5             | 1.4              | 58.5             |
| **Bottled water§**             |                  |                  |                  |
| Yes                            | 100.0            | 21.5             | –                |
| No                             | 72.1             | 1.0              | 72.1             |
| **Race/Hispanic origin‡**      |                  |                  |                  |
| NH White                       | 80.9             | 61.6             | 1.3              |
| NH Black                       | 78.1             | 38.0             | 2.1              |
| NH Asian                       | 89.3             | 61.9             | 2.3              |
| Hispanic                       | 84.0             | 38.7             | 2.1              |
| **Nativity status**§           |                  |                  |                  |
| US-born                        | 80.2             | 57.0             | 1.3              |
| Born outside fifty US states or Washington, DC | 87.3 | 46.4 | 2.5 |
| **Federal income to poverty ratio** |                  |                  |                  |
| ≤130%                          |                  |                  |                  |
| 131–350%                       |                  |                  |                  |
| >350%                          |                  |                  |                  |
| **Education**                  |                  |                  |                  |
| Less than high school          | 75.3             | 38.7             | 1.4              |
| High-school graduate/GED or equivalent | 75.9 | 47.9 | 2.2 |
| Some college or associates degree | 82.2 | 55.6 | 1.7 |
| College graduate or above      | 87.6             | 68.5             | 1.7              |

NH, non-Hispanic; GED, General Educational Development.
† Sample sizes and missing values are described in the online supplementary material, Supplemental Table 1.
‡ All estimates are weighted. Data are from NHANES²⁵.
§ Data from a single 24 h dietary recall.
P value by adjusted Wald F test between mean differences of category (joint test).
¶ Includes other race/Hispanic origin, but not shown.
†† P value for test of linear trend across the categories shown based on a linear/logistic regression.
‡‡ Percentage does not sum tap and bottled percentage use because tap and bottled water use are not mutually exclusive.
Table 2 Multiple logistic regression assessing predictors of using plain water sources among US adults aged ≥20 years (n 9666), National Health and Nutrition Examination Survey (NHANES) 2011–2014†‡

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Drank plain water§</th>
<th>Drank tap water§</th>
<th>Drank bottled water§</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR 95 % CI</td>
<td>OR 95 % CI</td>
<td>OR 95 % CI</td>
</tr>
<tr>
<td>Race/Hispanic origin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NH White (ref.)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>NH Black</td>
<td>0.94 (0.79, 1.10)</td>
<td>0.44** (0.37, 0.53)</td>
<td>2.20** (1.79, 2.69)</td>
</tr>
<tr>
<td>NH Asian</td>
<td>1.21 (0.88, 1.67)</td>
<td>1.01 (0.82, 1.26)</td>
<td>1.26 (0.99, 1.61)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>1.21 (0.97, 1.51)</td>
<td>0.55** (0.45, 0.66)</td>
<td>2.37** (1.91, 2.94)</td>
</tr>
<tr>
<td>Nativity status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US-born (ref.)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Born outside fifty US states or Washington, DC</td>
<td>1.67** (1.25, 2.12)</td>
<td>0.88 (0.72, 1.08)</td>
<td>1.46** (1.19, 1.79)</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than high school</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>High-school graduate/GED or equivalent</td>
<td>1.17 (0.94, 1.46)</td>
<td>1.26* (1.06, 1.50)</td>
<td>0.89 (0.75, 1.05)</td>
</tr>
<tr>
<td>Some college or associates degree</td>
<td>1.71** (1.38, 2.12)</td>
<td>1.69** (1.44, 1.98)</td>
<td>0.97 (0.85, 1.11)</td>
</tr>
<tr>
<td>College graduate or above</td>
<td>2.63** (2.05, 3.38)</td>
<td>2.72** (2.26, 3.28)</td>
<td>0.80* (0.66, 0.98)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20–39 years</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>≥60 years</td>
<td>0.97 (0.84, 1.13)</td>
<td>1.17 (1.03, 1.34)</td>
<td>0.78* (0.64, 0.95)</td>
</tr>
<tr>
<td>Sex</td>
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<td></td>
</tr>
<tr>
<td>Female (ref.)</td>
<td>1.39** (1.17, 1.65)</td>
<td>1.03 (0.90, 1.17)</td>
<td>1.28** (1.11, 1.47)</td>
</tr>
</tbody>
</table>

NH, non-Hispanic; GED, General Educational Development; ref., reference category.
*P < 0.05, ** P < 0.01.
†All estimates are weighted.
‡Sample sizes and missing values are described in the online supplementary material, Supplemental Table 1. Data are from NHANES(23).
§Data from a single 24 h dietary recall.
∥All covariates listed are adjusted for in the models.

Fig. 1 Adjusted odds ratios (●), with their 95% confidence intervals represented by horizontal bars, from multiple logistic regression models in Table 2 assessing the predictors of US adults aged ≥20 years (n 9666) consuming (a) plain water, (b) tap water and (c) bottled water, National Health and Nutrition Examination Survey (NHANES) 2011–2014. Models adjusted for all variables shown as well as sex and age (NH, non-Hispanic; ref., reference category; GED, General Educational Development)
Hispanic adults had the highest bottled water intake (731 (SE 39) ml), while NH Whites had the lowest (345 (SE 19) ml).

US-born adults reported lower total plain water intake than adults born outside the fifty US states or DC (1147 (SE 28) vs. 1261 (SE 39) ml, $P<0.01$), higher tap (755 (SE 35) vs. 579 (SE 38) ml, $P<0.001$) and lower bottled water intake (393 (SE 19) vs. 682 (SE 41) ml, $P<0.001$). Adults with higher income (FIPIR) consumed more total plain water, more of their plain water from tap and less bottled water than adults with lower income ($P<0.001$, linear trends). Education was associated with plain water intake patterns, as total plain and tap water intake was highest among college graduates and bottled water intake was higher among adults with less education ($P<0.001$, linear trends).

We examined how these sociodemographic characteristics were associated with total plain, tap and bottled water intake adjusted for all variables in the models (Table 4). Similar to bivariate analyses, in regression models NH Black adults consumed less total plain water ($B = -118$ (SE 46) ml), less tap water ($B = -330$ (SE 45) ml) and more bottled water ($B = 212$ (SE 40) ml) than NH Whites after adjustment (Table 4). Hispanic adults consumed less tap ($B = -180$ (SE 64) ml) and more bottled water ($B = 243$ (SE 42) ml) than NH Whites. No differences were found for nativity status on total plain or tap water; however, adults born outside the fifty US states or DC consumed significantly more bottled water ($B = 188$ (SE 41) ml) than US-born. Total plain and tap water were higher with more education, but there were no differences in bottled water intake by education after adjustment.

### Sensitivity analysis

In 2007–2010, 33.1 (SE 1.7) % of adults reported using home water treatment devices (see online supplementary material, Supplemental Table 2). These adults were more likely to drink plain and tap water, but less likely to drink bottled water on a given day. Additional differences in water treatment usage were seen by race/Hispanic origin, FIPIR and education (all $P<0.001$).

We re-estimated the multiple logistic regressions presented in Table 2 unadjusted and adjusted for filter use (see online supplementary material, Supplemental Table 3). Interactions...
between water treatment and key sociodemographic variables were not significant (results not shown); therefore, we included filter use as a covariate to address confounding. The models unadjusted for water treatment from 2007–2010 are mostly consistent with results in Table 2.

Adjusting for sociodemographic characteristics, adults who did not use water treatment had 0·60 (95 % CI 0·51, 0·71) and 0·55 (95 % CI 0·47, 0·64) times the odds of consuming any plain and tap water compared with adults who reported water treatment, respectively; they were more likely to drink bottled water (OR = 1·21; 95 % CI 1·01, 1·44; Supplemental Table 3). Controlling for water treatment, the results changed slightly but remained mostly consistent.

Discussion

In 2011–2014, 81·4 % of adults consumed any plain water on a given day, 55·2 % consumed tap water and 33·4 % consumed bottled water. Overall, the results suggest that while the majority of US adults consumed plain water, we found major differences in the source of plain water (i.e. tap v. bottled) by race/Hispanic origin and nativity status. While overall differences in plain water intake between NH Black and NH White adults were relatively small at 118 ml (or ~4 US fluid ounces), which on a given day may not translate into substantial hydration improvements, the differences in tap and bottled water intake were up to 330 ml (or ~11 US fluid ounces) which may have compounding benefits or consequences in terms of fluoride delivery or other exposures. For NH Black, Hispanic and non-US-born adults, the majority of plain water intake came from bottled water, whereas for NH White, NH Asian and US-born adults the majority of plain water came from tap water. Our results were consistent with a previous study showing that NH Blacks and Hispanics had lower odds of tap water use among children(177).

The results of our study may help explain health disparities in inadequate hydration and dental caries among non-Hispanic Black and Hispanic adults(21,22).

Many factors influence the decision to drink tap or bottled water, including access, convenience, cost, education, location, environmental beliefs, marketing, previous experiences, and perception of water source quality and safety(13,28–31). Written reports of water quality violations, required by the EPA Safe Drinking Water Act, from public water systems to users may induce households to seek alternatives, whereas bottled water companies are not held to this same EPA standard(32). Access to water that meets water quality standards often falls along race/ethnicity and socio-economic boundaries, which may affect consumption of tap v. bottled water, leading to restriction of intake or consumption of other beverages(27,13,20,28,33). For example, tap water from wells is not regulated by the EPA Safe Drinking Water Act, yet is more frequently used on Tribal lands and in rural parts of the USA such that well testing is not conducted systematically in the same way as on municipal water systems(32,34,35).
While Hispanic and non-US-born adults consumed more plain water than other groups, they consumed the majority of their plain water from bottled water, which is more expensive\(^6\). One potential explanation for these findings relates to perception of tap water safety. The American Housing Survey found that foreign-born adults from Latin American countries had the lowest perception of tap water safety (70-9%) and that US-born Hispanic (85-3%) and NH Blacks (89-4%) had lower perception of tap water safety than NH Whites (94-8%)\(^{13}\).

Our study found that adults with lower FIPR and educational attainment consumed less plain and tap water than their higher-income and higher-education peers, but that in regression analyses lower education was not as strongly associated with bottled water intake. While bottled water is more expensive than tap water\(^6\), previous research found that taxes on bottled water reduced consumption.\(^{16} \) One potential explanation for these findings relates to perception of tap water safety. The present study found differences in plain, tap and bottled water consumption by race/Hispanic origin, nativity status and socio-economic status. While most research has quantified the amount of plain water US adults consume\(^9,18,19\), we also estimated the percentage of adults who drink or do not drink plain water, which provides information on the proportion of consumers in the population. The multiple plain water intake outcomes provide better understanding of who chooses tap or bottled water and the potential dental, hydration and other health implications\(^{21,22}\). Finally, the present report provides one of the first nationally representative water intake estimates for adults born outside the fifty US states or Washington, DC and for NH Asians.

**Conclusions**

The present study found differences in plain, tap and bottled water consumption by race/Hispanic origin, nativity status and socio-economic status. While most people drank plain water, where they obtained their plain water differed, which has implications for fluoride delivery, risk of dental caries and potential water-related exposures to contaminants. Water filters were associated with higher likelihood of drinking plain and tap water and thus may encourage water intake and hydration. Future research should further elucidate these relationships by the specific tap water sources available and by geographic regions in the USA to understand structural differences that may exist to help explain people’s options for drinking different water sources.

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Supplementary material

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References