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Trends in purchases and intake of foods and beverages containing caloric and low-calorie sweeteners over the last decade in the U.S

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Abstract

Background—Current food databases might not capture rapidly occurring changes in the food supply, such as the increased use of caloric (CS) and low-calorie sweeteners (LCS) in products.

Objective—We explored trends in purchases and intake of foods and beverages containing LCS, CS or both sweeteners over the last decade in the U.S., as well as household and SES predictors of these trends.

Methods—We analyzed household purchases from Homescan 2000–10 (n=140,352 households; 408,458 individuals); and dietary intake from NHANES 2003–10 (n=34,391 individuals). We estimated per-capita purchases and intake (g or mL/d) and percent of consumers of foods and beverages containing LCS, CS, or both LCS+CS. We estimated change in purchases associated with SES and household composition using random-effects longitudinal models.

Results—From 2000–10, percent of households purchasing CS products decreased, whereas for LCS and LCS+CS products increased among all types of households and particularly among those with children. African-American, Hispanic, and households with children had a higher % CS beverage purchases (+9%; +4%; +3% respectively, P<0.001) and lower % LCS beverage purchases (−12%; −5%; −2% respectively, P<0.001).

Conclusions—During a period of declining purchases and consumption of CS products, we have documented an increasing trend in products that contain LCS and a previously unexplored trend in products with both LCS and CS, especially important among households with children.

Keywords

purchases; intake; beverages; trends; low-calorie sweeteners; caloric-sweeteners

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CONFLICTS OF INTEREST STATEMENT

CP, SWN and BMP have no conflicts of interest of any type with respect to this manuscript. The authors alone are responsible for the content and writing of the paper.

Author contributions: CP, SWN and BMP had full access to all study data, take full responsibility for the integrity of the data and the accuracy of the analysis, and had final approval of the submitted and published versions. Study concept and design, critical revision of the manuscript for important intellectual content, obtained funding, and study supervision: CP, SWN, BMP
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INTRODUCTION

The consumption of food and beverages containing added caloric sweeteners (CS) have been systematically linked with weight gain among adults and children (1–6). At the same time, many still question if low calorie sweeteners (LCS) are a good option for weight and diabetes control (7, 8). Overall, the majority of food and beverage products consumed in the U.S. contain CS (9). However, consumption of LCS in foods and beverages has increased rapidly over the past 30 years (9–13), a trend that will continue rising after the implementation of national policies and industry efforts that encourage manufacturers to reformulate and reduce the energy density of food products (14). In this context, nutrition research needs far more comprehensive nutrient databases capable of capturing newly introduced or reformulated products in the U.S. marketplace (15). Since LCS use is approved by the Food and Drug Administration, producers and manufacturers do not provide information about LCS content on labels, so obtaining accurate and direct measures of the LCS concentration in the food supply is problematic. On the other hand, the USDA food composition tables are not updated frequently enough to capture the rapidly occurring changes in the food supply (14). In each two-year wave, the National Health and Nutrition Examination Surveys (NHANES) food databases can only capture consumption of about 7,600 unique foods, out of over 85,000 products with unique formulations that U.S. consumers currently purchase (12). As a consequence of the lack of a standardized way of quantifying the exact amount of LCS in products, most research is focused on consumption of LCS beverages (16–19). Very few studies have explored consumption of LCS in foods (10, 11) and none have been able to identify products that contain both LCS and CS.

This study explores trends in purchases and intake of foods and beverages that contain LCS, CS and both sweeteners over the last decade. We analyze prospective measures of purchases by households included in the Nielsen Homescan Longitudinal dataset from 2000–10 (20). Homescan captures unique food products that have barcodes or Universal Product Codes (UPC) assigned to track retail sales and purchases of U.S. brands and private label packaged food products for more than 400,000 UPCs that are sold every year in the U.S. Products containing LCS and CS were identified by searching on the ingredient list from the nutrition facts panel of each uniquely barcoded product, which also contains updated and complete measures of the nutritional content of the purchased products (21). We estimated per-capita purchases (g or mL/d) and percent of households purchasing foods and beverages containing LCS, CS or both LCS and CS. In addition, we examined the demographic characteristics of households with different patterns of sweetener use. Finally, we used individual-level dietary intake in NHANES 2003–10 to estimate trends in intake per capita and percent consumers of foods and beverages containing LCS or CS.

METHODS

Sample

This study uses data on food purchases from the Nielsen Homescan (The Nielsen Co.) from 2000–2010; and data on food consumption from the U.S. Department of Agriculture (USDA) National Health and Nutrition Examination Survey (NHANES) from 2003–2010 (both described below). We included these two U.S. nationally representative datasets to investigate consumption of sweeteners from different perspectives, from sales to actual intake of products that contain sweeteners.

Primary Measure

Identification and classification of foods and beverages with sweeteners—

Low calorie sweeteners (LCS) could be derived from natural (i.e., sugar alcohols, stevia) or

artificial (i.e., aspartame, saccharine) sources. For the purpose of this research, LCS are defined as food additives that provide <3.8 kcal/g and/or are used in very low quantities so that the caloric amount they provide is negligible. All other sweeteners that provide ≥3.8 kcal/g are considered as caloric sweeteners (CS) as this cut-point reflects the caloric value of a gram of carbohydrate. Because the exact amounts of low-calorie sweeteners (LCS) in particular food products are not readily accessible, we studied LCS and CS consumption using information of purchases and intake of foods and beverages containing these sweeteners. To separate specific products by sweetener type in each dataset, we screened all groups of foods and beverages that were found in previous research to contain added sweeteners (9), which include dairy, grains, desserts, dressings, processed fruits, snacks, discretionary sweeteners, soft drinks, juice/fruit drinks, coffee/tea and milk beverages.

Study design and population

1) Food purchase data: The Nielsen Homescan Consumer Panel—We selected households with adults and children from the Nielsen Homescan (The Nielsen Co.) (20) from 2000–2010 (n=140,352 unique households comprised of 408,458 individuals), an ongoing nationally representative longitudinal survey of 35,000 to 60,000 households per year that contains information on consumer purchases of consumer packaged food items at the Universal Product Code (UPC) level. Participating households are provided with home scanners with which they record yearly food purchases from grocery, drug, mass-merchandise, club, supercenter and convenience stores. Households also report socio-demographic (SES) and household information including gender and age of each family member, income, education and race/ethnicity of the main head of the household. Households included in Homescan are sampled and weighted to be nationally representative. The Homescan dataset has been used frequently by researchers to analyze food demand, consumption and sale strategies (12, 22, 23).

Each uniquely barcoded product captured in Homescan has been linked with Nutrition Facts Panel (NFP) data and ingredient information using the commercial Gladson Nutrition Database (21). Gladson contains national brands and private label items at the UPC level and these data are updated weekly as new products enter the market. Further details regarding matching these commercial datasets at the UPC level, and other methodological facts are available in the following sources (9, 12, 14). To ensure comparability across products, we applied weighted factors to those items sold as concentrates (e.g., beverage powders) to reflect the volume of the product in the “ready to drink/eat” form.

We classified products containing sweeteners in Homescan 2000–2010. For each food/beverage group, we conducted keyword searches by looking at the ingredient lists provided for each UPC purchased by participating households. A detailed list of key terms is available elsewhere(9). Briefly, the main sweeteners identified as CS included fruit juice concentrate (not reconstituted), cane sugar, beet sugar, sucrose, corn syrup, high fructose corn syrup, agave-based sweeteners, honey, molasses, maple, sorghum/malt/maltose, rice syrup, fructose, lactose, inverted sugars; terms to identify LCS included artificial sweetener, aspartame, saccharin, sucralose, cyclamate, acesulfame K, stevia, sugar alcohols (i.e. xylitol, etc.) and brand name versions of each sweetener. Foods and beverages were then classified as containing CS only; LCS only; or both LCS+CS.

Classically, consumers are defined as persons who reported any consumption greater than 0 g or mL on any given day, usually over a 24-h period (13, 24, 25). However, for each household Homescan captures purchases over an entire year. To define a consumer in a meaningful way and exclude unusual or one-time purchases, we divided the total purchases per year by pre-defined portions: 100 mL for beverages and 50 g for foods. For the purpose

of this research, a household was considered a consumer in Homescan if it had purchases of at least 52 portions per year, or one portion per week.

2) Dietary intake data: The National Health and Nutrition Examination Surveys (NHANES)—We selected adults and children (n=34,391) who participated in one of the four waves of the U.S. Department of Agriculture (USDA) National Health and Nutrition Examination Survey (NHANES) from 2003–2010: NHANES 2003–04 (n=8,272), NHANES 2005–06 (n=8,549), NHANES 2007–08 (n=8,528) and NHANES 2009–10 (n=9,042). These nationally representative surveys are based on self-weighting, multistage and stratified probability samples of non-institutionalized U.S. households. Dietary intake data is collected using two non-consecutive 24-h recalls. The NHANES surveys implemented a fully automated, computer-assisted multiple-pass dietary recall methodology that involves a 5-step process to reduce underreporting of diet. Dietary intake data is linked to the USDA food composition tables, which provide nutrient information and food descriptions for each food item consumed by the participants. Socio-demographic information, such as age, gender, race/ethnicity and income is also collected for each participant. Further details of each of these surveys are available elsewhere (22, 23, 26–29).

We classified foods and beverages containing sweeteners in NHANES 2003–2010. Consistent with previous work (11), we conducted keyword searches by looking at the food description of each food-code that represents a specific food or beverage consumed. We classified items as LCS-products if their food description included the following terms: “with low/no calorie sweetener”, “sugar-free” and “dietetic/low sugar”. Items that included terms such as “sugar”, “sweetened” or didn’t specify the type of sweetener but are typically sweetened (i.e. soft-drink, cola-type) were considered CS-products. Foods and beverages were classified as LCS-foods; LCS-beverages; CS-foods and CS-beverages. Products that contain both LCS and CS cannot be separated in NHANES.

Consumers in NHANES were defined as those who consumed at least one pre-defined portion over the 24-h recalled (100 mL for beverages and 50 g for foods). Together with dietary intake, information on where the foods or beverages were consumed is provided by each individual. Information on location of consumption was used to estimate intake from store-bought foods in addition to total intake.

Statistical Analysis

All analyses were performed using Stata 12 (StataCorp, Stata Statistical Software, Release 12, 2011). Survey commands were used to account for survey design and weighting to generate nationally representative results. In both datasets, race/ethnicity was used to classify participants as Hispanic, non-Hispanic White, non-Hispanic African-American and Others. Age was used to generate age groups: 2–6 y-old; 7–12 y-old; 13–18 y-old; 19–39 y-old; 40–59 y-old and >60 y-old. The ratio of family income to poverty threshold, calculated from self-reported household income, was used to categorize income according to the percent of the poverty level: “Lower income, <185%”, “Middle income, ≥185-<400%” and “Higher income, ≥400%”.

In Homescan, we used estimates of total purchases per year to estimate total volume purchased per day (mL/day for beverages; gr/day for foods) by a household. Then, the total purchases of each household were divided by the number of people in the household to get a per capita estimate of purchases. We also estimated the percent of households purchasing foods and beverages by sweetener type. Then, we estimated trends in per-capita and percent of consumers using measures of intake per day (mL/day for beverages; gr/day for foods) in NHANES. Since Homescan includes measures of store purchases, some of the estimates from NHANES are reported as total intake and also as consumption from store and away-

from-home products. Estimates of trends in per capita and percent of consumers were obtained using multivariable simple linear and logistic regression models to adjust for household size, race and income (Homescan) and age, gender, race and income (NHANES).

We also investigated SES and household predictors of purchases of products with CS and LCS in Homescan. We estimated change in percent of purchases of each type of food or beverage associated with SES and household variables using average marginal effects from random-effects longitudinal regression models. To control for differences in total spending across households with different grocery expenditures and sizes, the outcomes for these models were defined as the percent of volume purchased (mL or g) from each type of product respect to the total purchases of that category (i.e., volume from LCS beverages divided by total volume from all beverages). As exposures, we modeled changes with time, presence of different family members by age and gender, presence of children, race/ ethnicity, income, and the following interactions: race/ethnicity and presence of children; race/ethnicity and income. For NHANES, we calculated per capita daily intake and the difference in percent intake of CS and LCS products by race/ethnic group. Estimates are presented as means (95% CI) or β coefficients (96% CI). Statistically significant linear trends were tested using adjusted Wald test. Statistically significant differences were tested using Student's *t* test. A two sided *P* value of 0.001 was set to denote statistical significance for Homescan and 0.05 for NHANES due to the sample sizes available.

RESULTS

Both the Homescan and the NHANES samples had a higher proportion of adults, females and non-Hispanic Whites (Table 1). In Homescan, there was a higher proportion of 40–59-y-olds and middle income individuals whereas in NHANES there was a higher proportion of 19–39-y-olds and higher income individuals.

Sources of LCS and CS in the US

In the most recent period (2007–10), beverages were the main sources of LCS in terms of volume compared to foods (Figure 1a–b). Volume (mL/d) of LCS beverages represented 32% of all beverages among adults and 19% among children. Purchases of beverages containing LCS only represented around 26% of all beverage purchases whereas those containing both LCS and CS represented around 15%. Results for both foods and beverages are shown (Tables 1S–4S), but we focus on presentation of the beverage results.

Trends in purchases and intake of LCS and CS products

While the percent of households that purchase beverages containing CS decreased slightly, purchases of beverages with LCS only and LCS+CS increased from 2000 to 2010 significantly among households with and without children (Figures 2a–b, Table 1S). Per capita volume (mL/day) purchased from CS beverages decreased significantly over this period (Figures 2a–b, Table 1S). Per capita volume purchased from LCS beverages increased from 2000 to 2006 and then decreased from 2006 to 2010, for LCS+CS beverages increased gradually from 2000 to 2010. Although the percentage point changes are smaller, the trends for beverages and foods were similar (Table 1S).

Percent of consumers and per capita intake of beverages containing LCS increased significantly whereas intake of CS beverages decreased significantly among children/ adolescents (store and total) and adults (total) from 2003–2010 (Figures 3a–b, Table 2S).

Household and SES predictors of purchases of LCS and CS products

Using random-effects longitudinal models, we investigated household and SES factors associated with changes in purchases of beverages and foods with LCS, CS and both LCS +CS in Homescan 2000–10 (Table 2, Tables 3S–4S). Percent of purchases of CS beverages was significantly higher among households with children, particularly in households with at least one an adolescent male; among households with young and middle age adults; among African-American and Hispanic compared to White households and among lower income households. Percent of purchases of LCS beverages was significantly lower among households with children and African-American and Hispanic compared to White households, and significantly higher among higher income households. Percent of purchases of LCS+CS beverages was slightly higher among households with adult females, among White households compared to the other ethnic groups and among higher income households. Similar results were observed between different races within households that had or not children; and within households of different income categories (Table 3S). Changes in foods containing sweeteners were smaller but consistent with the changes in beverage purchases associated with race and presence of children in the household (Table 4S).

In NHANES, intake per capita (total and from stores) and the difference in percent intake of LCS beverages was significantly higher in White children and adults compared to the other races (Table 3). Intake per capita (total and store) of CS beverages was significantly higher among White and African-American adults compared to the other races; but not different between White, African-American and Hispanic children. In addition, the difference in percent intake of CS beverages was significantly higher among African-American children and adults.

DISCUSSION

Using measures of purchases and intakes from nationally representative samples of U.S. households, we have investigated recent trends in purchases and consumption of products containing LCS, CS or both sweeteners. Ingredient information from each barcoded product consumed by U.S. households was used to create a novel system of identification of sweeteners in the food supply. We showed a previously unexplored trend in consumption of products containing both LCS and CS. Over the last decade, although purchases and intakes of CS foods and beverages continued to decline, they remained high, whereas purchases and intakes of products containing LCS or both LCS+CS rose among all types of households.

In terms of volume, beverages were the main source of LCS in the food supply, accounting for up to a third of the beverages that are currently consumed and purchased in the U.S. Previous research investigated the use of CS and LCS in consumer packaged goods in the U.S. (9). Around two thirds of all uniquely formulated products consumed in the U.S. contained CS, whereas a smaller percent of products contained either LCS only or both LCS +CS, which are mainly beverages. We found that an increasing percent of households purchased beverages with LCS only or LCS+CS. The trend in LCS+CS beverages increased more markedly among household with children and even exceeded the trend in LCS beverages after 2006. Still, purchases of CS beverages were higher than LCS or LCS+CS in 2010. In NHANES, the percent of consumers (adults and children) increased for LCS products but decreased for CS products from 2003–2010. Per capita purchases in Homescan decreased for CS beverages but increased for LCS and LCS+CS beverages. Trends in per capita intake decreased for CS beverages but increased for LCS beverages only among children. Recent reports using national surveys have shown similar trends in percent of adults and children consuming beverages or foods containing LCS and CS (11, 13, 30–33).

We also investigated household and SES factors associated with changes in purchases of beverages and foods with LCS, CS and both LCS+CS. Among African-American, Hispanic and households with children, we found a higher percent of CS purchases but lower percent of LCS beverage purchases. Higher income was associated with lower CS but higher percent of LCS beverage purchases. Changes in purchases of LCS+CS were very small, and only associated with presence of adult females and higher income households. In terms of intake, Whites consumed overall more LCS products than other race groups (total and consumption from stores). Consistent with our results, previous works reported a higher prevalence and per capita consumption of LCS foods and beverages among Whites and higher income individuals (11, 13, 34, 35); but a higher prevalence and per capita consumption of CS beverages among children, males, African-Americans, Hispanics and lower income individuals (11, 24, 34–37). Although we found significant increases in products containing LCS and LCS+CS among households with children; households with children had a higher percent of purchases of CS beverages but lower percent of purchases of LCS and LCS+CS beverages. This might be due to the fact that the actual amount of purchases per capita from LCS and LCS+CS products is still lower than purchases of CS beverages.

Over the period studied, purchases from Homescan and intake from NHANES trended similarly. However, these trends are might not be exactly comparable in absolute terms. Homescan collects all grocery purchases that happened over an entire year; whereas NHANES collects dietary intake reported for the day before the interview, so our definition of consumers reflects the different timing captured by each dataset. In Homescan, we considered consumers as households that purchased at least one standard portion per week; whereas in NHANES a consumer was considered as a respondent with at least one standard portion over the previous 24 hours. Therefore, prevalences of consumption from Homescan are much larger than in NHANES. Interestingly, the trend in percent of households purchasing CS beverages declined very slightly from 2000 to 2010, whereas in NHANES the percent of consumers of CS beverages decreased significantly from 2003 to 2010. These contradicting trends might reflect the different timing captured by each dataset but they could also reflect a potential underreporting in dietary intake data of unhealthier products such as CS beverages. Another source of variation comes from the different identification of products containing sweeteners. To our understanding, the use of ingredients lists to classify products (Homescan) is a more accurate approach than defining them according to their food description (NHANES). Moreover, identification of products that contain both LCS+CS is not currently possible in NHANES.

Food purchasing and expenditure surveys such as Homescan have previously been used to measure household food availability, and although these datasets do not provide measures of individuals' actual intake, they are useful to characterize the wide variability in food consumption patterns at the population level (22, 38–40). Since Homescan data is self-reported and the recording time-consuming, several reports have investigated the validity of Homescan against retailer's transaction data and diary survey data (41–43). There is potential for recording errors in Homescan (i.e. missing trips, missing purchases), and although the overall accuracy of the data is consistent with other commonly used economic datasets, this might constitute another source of differences between NHANES and Homescan. Another challenge of using Homescan is that estimates of per capita purchases might not be comparable with per capita intake from NHANES. For example, in a given household all purchases of LCS beverages might be consumed by a single member of the household, rather the being shared among all household members. Then, per capita estimates represent the amount available from all purchases to each member of the household. Another limitation affecting Homescan is that away-from-home intake (i.e. restaurants, school) is not available. In the last period (NHANES 2009–10), non-store sources of intake of LCS and CS foods and beverages accounted for a range of 0 to 30% of total intake (Table

2S). Estimates of store purchases collected by Homescan do not account for sharing, wastage and storage of products, constituting another source of variation between datasets. Finally, although estimates of store purchases are weighted to be nationally representative, questions still remain about potential selection bias in response rates, participation and attrition, resulting in larger samples of middle age/older and middle income households (44).

In the context of the growing interest in the role of CS and LCS in the obesity epidemic (45) and the importance of these factors on weight gain and incident obesity (1, 3, 4, 8, 46), we have reported new trends in purchases and intake of foods and beverages that contain CS, LCS and both LCS and CS over the last decade. Although products containing LCS are lower in calories and sugar than their regular counterparts, the effect of LCS on toxicity, glucose metabolism, satiety, sweetness preference and overall dietary quality is unclear (19, 47–56). Products containing CS are higher in empty calories and CS beverages have been specifically linked to obesity because they have lower satiety rate compared to solid sweetened foods (57). Although the prevalence of consumption of =500 ml per day of CS beverages is still high among in children, adolescent and younger adults (58), recent randomized controlled trials in these age groups have found decreased weight gain, fat accumulation (7, 59) and higher weight loss (60) when CS beverages were replaced with beverages containing LCS. The debate regarding the role of sweeteners in the obesity epidemic still continue despite the fact that most intervention strategies and nutrition policy recommendations in the U.S. are currently focused on caloric beverages (61).

In conclusion, consumption of CS products declined over the past decade, but remained high, especially in households with children, and in African American, Hispanic and lower income households. However, we have shown an increased trend in purchases and intake of foods and beverages that contain LCS. For the first time, we showed an important but previously unexplored trend in purchases of products that contain both LCS and CS, which has been heretofore impossible to document in the NHANES surveys. As new beverages and food choices become available in the food supply, a better understanding of the role of these new varieties of products on energy balance and dietary quality is warranted.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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BIBLIOGRAPHY

1. Malik VS, Schulze MB, Hu FB. Intake of sugar-sweetened beverages and weight gain: a systematic review. Am J Clin Nutr. 2006; 84:274–288. [PubMed: 16895873]
2. Dhingra R, Sullivan L, Jacques PF, et al. Soft drink consumption and risk of developing cardiometabolic risk factors and the metabolic syndrome in middle-aged adults in the community. Circulation. 2007; 116:480–8. [PubMed: 17646581]
3. Lesser LI, Ebbeling CB, Goozner M, Wypij D, Ludwig DS. Relationship between funding source and conclusion among nutrition-related scientific articles. PLoS Med. 2007; 4:e5. [PubMed: 17214504]

4. 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. [PubMed: 17329656]
5. Lutsey PL, Steffen LM, Stevens J. Dietary intake and the development of the metabolic syndrome: the Atherosclerosis Risk in Communities study. Circulation. 2008; 117:754–61. [PubMed: 18212291]
6. de Koning L, Malik VS, Kellogg MD, Rimm EB, Willett WC, Hu FB. Sweetened Beverage Consumption, Incident Coronary Heart Disease and Biomarkers of Risk in Men. Circulation. 2012
7. Ebbeling CB, Feldman HA, Chomitz VR, et al. A randomized trial of sugar-sweetened beverages and adolescent body weight. N Engl J Med. 2012; 367:1407–16. [PubMed: 22998339]
8. Morenga LT, Mallard S, Mann J. Dietary sugars and body weight: systematic review and meta-analyses of randomised controlled trials and cohort studies. BMJ. 2013:346.
9. Ng SW, Slining MM, Popkin BM. Use of Caloric and Noncaloric Sweeteners in US Consumer Packaged Foods, 2005–2009. J Acad Nutr Diet. 2012; 112:1828–1834 e6. [PubMed: 23102182]
10. 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. [PubMed: 19056571]
11. Sylvetsky AC, Welsh JA, Brown RJ, Vos MB. Low-calorie sweetener consumption is increasing in the United States. Am J Clin Nutr. 2012; 96:640–6. [PubMed: 22854409]
12. Ng SW, Popkin BM. Monitoring foods and nutrients sold and consumed in the United States: Dynamics and Challenges. J Acad Nutr Diet. 2012; 112:41–45. [PubMed: 22389873]
13. Fakhouri TH, Kit BK, Ogden CL. Consumption of diet drinks in the United States, 20092010. NCHS Data Brief. 2012:1–8.
14. Slining MM, Ng SW, Popkin BM. Food companies' calorie-reduction pledges to improve U.S. diet. Am J Prev Med. 2013; 44:174–84. [PubMed: 23332336]
15. Gortmaker SL, Story M, Powell LM, Krebs-Smith SM. Building infrastructure to document the U.S. food stream. Am J Prev Med. 2013; 44:192–3. [PubMed: 23332339]
16. Schulze MB, Manson JE, Ludwig DS, et al. Sugar-sweetened beverages, weight gain, and incidence of type 2 diabetes in young and middle-aged women. JAMA. 2004; 292:927–34. [PubMed: 15328324]
17. 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. [PubMed: 18535548]
18. de Koning L, Malik VS, Rimm EB, Willett WC, Hu FB. Sugar-sweetened and artificially sweetened beverage consumption and risk of type 2 diabetes in men. Am J Clin Nutr. 2011; 93:1321–7. [PubMed: 21430119]
19. Duffey KJ, Steffen LM, Van Horn L, Jacobs DR Jr, Popkin BM. Dietary patterns matter: diet beverages and cardiometabolic risks in the longitudinal Coronary Artery Risk Development in Young Adults (CARDIA) Study. Am J Clin Nutr. 2012
20. The Nielsen Co. [Accessed Novemeber 1, 2012.] Nielsen Consumer Panel and Retail Measurement. http://www.nielsen.com/us/en/measurement/retail-measurement.html
21. Gladson. [Accessed November 1, 2012.] Gladson Nutrition Database. http://www.gladson.com/our-services/nutrition-database
22. Harris, JM. Using Nielsen Homescan Data and Complex Design Techniques to Analyze Convenience Food Expenditures. American Agricultural Economics Association (New Name 2008: Agricultural and Applied Economics Association); 2005.
23. Harris, JM.; Blisard, N. Characteristics of the Nielsen Homescan Data. US Department of Agriculture Economic Research Service; 2005.
24. Ogden CL, Kit BK, Carroll MD, Park S. Consumption of sugar drinks in the United States, 2005–2008. NCHS Data Brief. 2011:1–8.
25. Bremer AA, Byrd RS, Auinger P. Racial trends in sugar-sweetened beverage consumption among US adolescents: 1988–2004. Int J Adolesc Med Health. 2011; 23:279–86. [PubMed: 22191196]
26. U.S. Department of Agriculture ARS, Beltsville Human Nutrition Research Center, Food Surveys Research Group (Beltsville, MD)., U.S. Department of Health and Human Services CfDCaP,

National Center for Health Statistics (Hyattsville, MD). What We Eat in America, NHANES 2003–2004. 2003. Available from: http://www.cdc.gov/nchs/about/major/nhanes/nhanes2003-2004/dr1tot_c.xpt

27. U.S. Department of Agriculture ARS, Beltsville Human Nutrition Research Center, Food Surveys Research Group (Beltsville M, U.S. Department of Health and Human Services CfDCaP, National Center for Health Statistics (Hyattsville, MD). [accessed 09/11/11]. 2008.] What We Eat in America, NHANES 2007–2008. Available from: http://www.cdc.gov/nchs/about/major/nhanes/nhanes2007-2008/dr1tot_c.xpt
28. U.S. Department of Agriculture ARS, Beltsville Human Nutrition Research Center, Food Surveys Research Group (Beltsville, MD), U.S. Department of Health and Human Services CfDCaP, National Center for Health Statistics (Hyattsville, MD). What We Eat in America, NHANES 2005–2006. 2005. Available from: http://www.cdc.gov/nchs/about/major/nhanes/nhanes2005-2006/dr1tot_c.xpt
29. U.S. Department of Agriculture ARS, Beltsville Human Nutrition Research Center, Food Surveys Research Group (Beltsville M, U.S. Department of Health and Human Services CfDCaP, National Center for Health Statistics (Hyattsville, MD). [[accessed 01/11/12]. 2010.] What We Eat in America, NHANES 2009-2010. Available from: http://www.cdc.gov/nchs/about/major/nhanes/nhanes2009-2010/dr1tot_c.xpt
30. Lasater G, Piernas C, Popkin BM. Beverage patterns and trends among school-aged children in the US, 1989–2008. Nutr J. 2011; 10:103. [PubMed: 21962086]
31. Storey M. The shifting beverage landscape. Physiol Behav. 2010; 100:10–4. [PubMed: 20188750]
32. Popkin BM. Patterns of beverage use across the lifecycle. Physiol Behav. 2010; 100:4–9. [PubMed: 20045423]
33. Welsh JA, Sharma AJ, Grellinger L, Vos MB. Consumption of added sugars is decreasing in the United States. Am J Clin Nutr. 2011; 94:726–34. [PubMed: 21753067]
34. Bleich SN, Wang YC, Wang Y, Gortmaker SL. Increasing consumption of sugar-sweetened beverages among US adults: 1988–1994 to 1999–2004. Am J Clin Nutr. 2009; 89:372–81. [PubMed: 19056548]
35. Wang YC, Bleich SN, Gortmaker SL. Increasing caloric contribution from sugar-sweetened beverages and 100% fruit juices among US children and adolescents, 1988–2004. Pediatrics. 2008; 121:e1604–14. [PubMed: 18519465]
36. Park S, Blanck HM, Sherry B, Brener N, O'Toole T. Factors associated with sugar-sweetened beverage intake among United States high school students. J Nutr. 2012; 142:306–12. [PubMed: 22223568]
37. Han E, Powell LM. Consumption Patterns of Sugar-Sweetened Beverages in the United States. Journal of the Academy of Nutrition and Dietetics. 2013; 113:43–53. [PubMed: 23260723]
38. Naska A, Paterakis S, Eeckman H, Remaut AM, Trygg K. Methodology for rendering household budget and individual nutrition surveys comparable, at the level of the dietary information collected. Public Health Nutr. 2001; 4:1153–8. [PubMed: 11924940]
39. Naska A, Vasdekis VG, Trichopoulou A. A preliminary assessment of the use of household budget survey data for the prediction of individual food consumption. Public Health Nutr. 2001; 4:1159–65. [PubMed: 11924941]
40. Fan JX, Brown BB, Kowaleski-Jones L, Smith KR. Household food expenditure patterns: a cluster analysis. Monthly Lab Rev. 2007; 130:38.
41. Einav, L.; Leibtag, E.; Nevo, A. Not-so-classical measurement errors: a validation study of Homescan. National Bureau of Economic Research Cambridge; Mass., USA: 2008.
42. Einav, L.; Leibtag, E.; Nevo, A. On the accuracy of Nielsen Homescan data. Washington D.C: U.S. Department of Agriculture, Economic Research Service; 2008.
43. Zhen C, Taylor JL, Muth MK, Leibtag E. Understanding differences in self-reported expenditures between household scanner data and diary survey data: A comparison of homescan and consumer expenditure survey. Applied Economic Perspectives and Policy. 2009; 31:470.
44. Ma Y, Ren R, Han EQ, et al. Inhibition of the Wnt-beta-catenin and Notch signaling pathways sensitizes osteosarcoma cells to chemotherapy. Biochem Biophys Res Commun. 2013

45. Fitch C, Keim KS. Position of the Academy of Nutrition and Dietetics: Use of Nutritive and Nonnutritive Sweeteners. Journal of the Academy of Nutrition and Dietetics. 2012; 112:739–758. [PubMed: 22709780]
46. Ebbeling CB, Feldman HA, Chomitz VR, et al. A Randomized Trial of Sugar-Sweetened Beverages and Adolescent Body Weight. New England Journal of Medicine. 2012
47. Bellisle F, Drewnowski A, Anderson GH, Westerterp-Plantenga M, Martin CK. Sweetness, satiation, and satiety. J Nutr. 142:1149S–54S. [PubMed: 22573779]
48. Brown RJ, Walter M, Rother KI. Ingestion of diet soda before a glucose load augments glucagon-like peptide-1 secretion. Diabetes care. 2009; 32:2184. [PubMed: 19808921]
49. Gardener H, Rundek T, Markert M, Wright CB, Elkind MS, Sacco RL. Diet soft drink consumption is associated with an increased risk of vascular events in the Northern Manhattan Study. J Gen Intern Med. 2012; 27:1120–6. [PubMed: 22282311]
50. Pepino MY, Bourne C. Non-nutritive sweeteners, energy balance, and glucose homeostasis. Curr Opin Clin Nutr Metab Care. 2011; 14:391–5. [PubMed: 21505330]
51. Tordoff MG. How do non-nutritive sweeteners increase food intake? Appetite. 1988; 11 (Suppl 1): 5–11. [PubMed: 3056267]
52. Tordoff MG, Alleva AM. Effect of drinking soda sweetened with aspartame or high-fructose corn syrup on food intake and body weight. Am J Clin Nutr. 1990; 51:963–9. [PubMed: 2349932]
53. Ford HE, Peters V, Martin NM, et al. Effects of oral ingestion of sucralose on gut hormone response and appetite in healthy normal-weight subjects. Eur J Clin Nutr. 2011; 65:508–13. [PubMed: 21245879]
54. Schernhammer ES, Bertrand KA, Birmann BM, Sampson L, Willett WW, Feskanich D. Consumption of artificial sweetener- and sugar-containing soda and risk of lymphoma and leukemia in men and women. Am J Clin Nutr. 2012
55. Englund-Ogge L, Brantsaeter AL, Haugen M, et al. Association between intake of artificially sweetened and sugar-sweetened beverages and preterm delivery: a large prospective cohort study. Am J Clin Nutr. 2012; 96:552–9. [PubMed: 22854404]
56. Piernas C, Tate Deborah, Wang Xiaoshan, Popkin Barry. Does diet beverage intake affect dietary consumption patterns? Results from the Choose Healthy Options Consciously Everyday (CHOICE) randomized clinical trial. American Journal of Clinical Nutrition. 2013; 97:1–8. [PubMed: 23221575]
57. Mattes R. Fluid calories and energy balance: the good, the bad, and the uncertain. Physiol Behav. 2006; 89:66–70. [PubMed: 16516935]
58. Han E, Powell LM. Consumption patterns of sugar-sweetened beverages in the United States. J Acad Nutr Diet. 2013; 113:43–53. [PubMed: 23260723]
59. de Ruyter JC, Olthof MR, Seidell JC, Katan MB. A trial of sugar-free or sugar-sweetened beverages and body weight in children. N Engl J Med. 2012; 367:1397–406. [PubMed: 22998340]
60. Tate DF, Turner-McGrievy G, Lyons E, et al. Replacing caloric beverages with water or diet beverages for weight loss in adults: main results of the Choose Healthy Options Consciously Everyday (CHOICE) randomized clinical trial. Am J Clin Nutr. 2012; 95:555–63. [PubMed: 22301929]
61. Elbel B, Cantor J, Mijanovich T. Potential effect of the New York City policy regarding sugared beverages. N Engl J Med. 2012; 367:680–1. [PubMed: 22823559]

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'WHAT IS ALREADY KNOWN ABOUT THIS SUBJECT'

- Caloric sweetener (CS) intake in beverages and food has been linked with weight gain.
- Over the last 30 years, there have been important changes in consumption of caloric- and low-calorie sweetened foods and beverages among children and adults in the U.S.
- However, current food databases might not capture rapidly occurring changes in the U.S. food supply, such as the increased use of caloric (CS) combined with low-calorie sweeteners (LCS) in newly introduced or reformulated food products.

'WHAT THIS STUDY ADDS'

- We analyzed the Homescan commercial dataset (foods as purchased) and NHANES surveys of dietary intake (foods as consumed) to explore recent time trends in foods and beverages containing LCS, CS or both sweeteners in the U.S.
- In terms of purchases (Homescan 2000–10), although CS food and beverages continue declining, they remained high. We showed an important but previously unexplored trend in purchases of products that contain both LCS and CS, especially among households with children.
- In terms of intake (NHANES 2003–10), children (2–18 y-old) increased their consumption of LCS beverages and decreased intake of CS beverages.
- We found heterogeneity of consumption of CS and LCS foods and beverages across key SES subpopulations in both datasets.

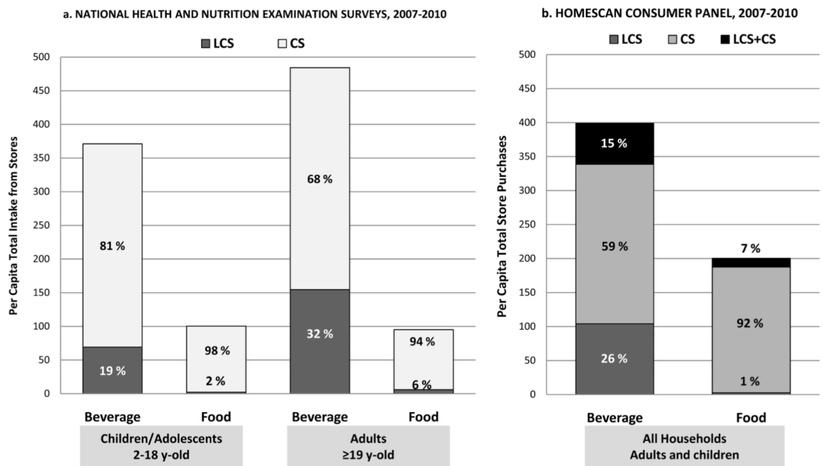

Figure 1.

a–b. Sources of low-calorie and caloric sweeteners in the US, 2007–2010*

* Means per capita for beverages (mL/d) and foods (g/d). LCS, low-caloric sweetened beverages or foods; CS, caloric-sweetened beverages or foods.

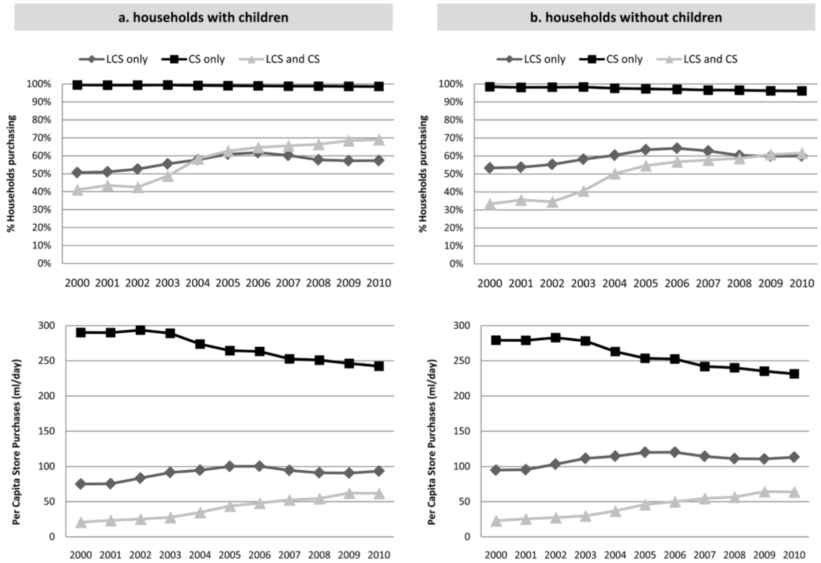

Figure 2.

a–b. Trends in percent households purchasing and per capita purchases of beverages by sweetener type, Homescan 2000–2010*

* Means per capita for beverages (mL/d). LCS, low-caloric sweetened beverages; CS, caloric-sweetened beverages. Multivariable linear (per capita estimates) and logistic (percent of households purchasing) regression models were used to adjust for household size, race and income. All linear trends shown were statistically significant, Wald tests, $P<0.001$.

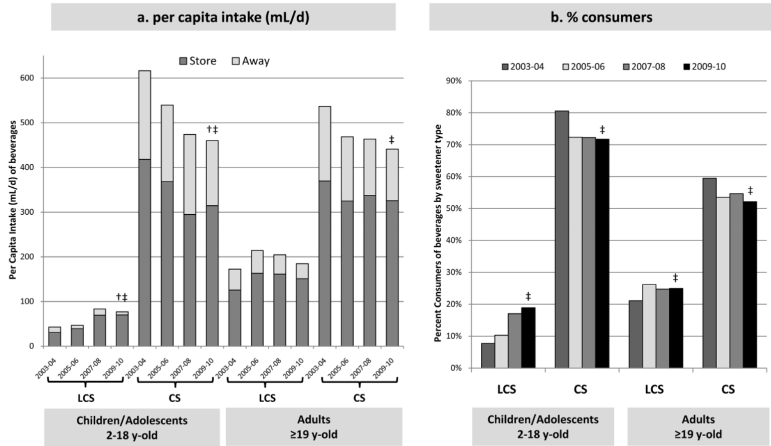

Figure 3.

a–b. Trends in consumption per capita and percent of consumers of beverages, NHANES 2003–2010*

* Trends in per capita intake of beverages (mL/d) by source of food (store vs. away-from-home); and % consumers from all sources. LCS, low-caloric sweetened beverages; CS, caloric-sweetened beverages. Multivariable linear (per capita estimates) and logistic (percent of households purchasing) regression models were used to adjust for age, gender, race and income.

† Statistically significant linear trend, Wald test, $P<0.05$

‡ Total beverages (store and away-from-home): statistically significant linear trend, Wald test, $P<0.05$

Table 1

Demographic characteristics of the populations of HOMESCAN (household and per capita purchase data) and NHANES (per capita dietary intake data)*

	HOMESCAN† 2000–2010	NHANES 2003–2010
Total population		
Individuals	408,458	34,391
Households	140,352	-
Children (2–18-y-old) [n (%)]	99,833 (20.4)	13,421 (24.3)
Adults (>19-y-old) [n (%)]	308,625 (79.6)	20,970 (75.7)
***Gender* [n (%)]**		
Male	195,007 (48.4)	16,956 (48.6)
Female	213,451 (51.6)	17,435 (51.4)
***Race-Ethnicity* [n (%)] ‡**		
White	318,822 (73.4)	14,234 (68.0)
African American	39,005 (11.8)	8,055 (12.2)
Hispanic	32,128 (10.8)	7,949 (9.6)
Other	18,503 (4.0)	4,153 (10.1)
***Age Groups* [n (%)]**		
Children 2–6y	27,471 (6.4)	4,041 (7.0)
Children 7–12y	33,985 (7.0)	4,335 (8.4)
Children 13–18y	38,377 (7.1)	5,045 (8.9)
Adults 19–39y	93,797 (29.7)	7,782 (29.5)
Adults 40–59y	141,253 (31.3)	6,284 (28.2)
Adults >60y	73,575 (18.6)	6,904 (18.0)
***Income* [n (%)] §**		
Lower income (< 185%))	87,666 (26.3)	15,800 (32.6)
Middle income (≥185% to <400%))	189,167 (39.9)	9,352 (30.4)
Higher income (≥400%)	131,625 (33.8)	9,239 (37.0)

*Sample size (%). Percentage of the population estimated with weights to adjust for unequal probability of sampling.

†For Homescan, the average age and income from 2000–10 were used to create the categories.

‡Race/ethnicity was self-reported by the head of the household in Homescan or by each participant in the NHANES surveys.

§Ratio of family income to poverty threshold (calculated from self-reported household income), was used to categorize income according to the percent of the poverty level.

Table 2

Change in percent volume (mL/day) purchased from each type of beverage using estimated average marginal effects from random-effects longitudinal regression models, among U.S. households from the Homescan Longitudinal dataset, 2000–2010*.

BEVERAGES	LCS only†				CS only†				LCS and CS			
Predictors	**B**	**[95%CI]**		**P value‡**	**B**	**[95%CI]**		**P value‡**	**β**	**[95%CI]**		**P value‡**
Gender-age categories												
Female												
2–6 y-old	−0.5	−0.8	−0.2	0.002	1.4	1.1	1.8	0.000	−0.3	−0.5	0.0	0.026
7–12 y-old	−0.4	−0.7	−0.2	0.001	0.4	0.1	0.7	0.015	0.3	0.1	0.5	0.002
13–18 y-old	−0.7	−1.0	−0.5	0.000	0.3	−0.1	0.6	0.110	0.2	0.0	0.3	0.134
Male												
2–6 y-old	−0.7	−1.0	−0.4	0.000	1.5	1.1	1.9	0.000	−0.2	−0.5	0.0	0.042
7–12 y-old	−0.7	−1.0	−0.5	0.000	0.8	0.5	1.1	0.000	0.1	−0.1	0.3	0.185
13–18 y-old	−1.6	−1.8	−1.3	0.000	2.0	1.7	2.4	0.000	0.0	−0.2	0.2	0.830
Female												
19–39 y-old	−0.4	−0.6	−0.2	0.000	−0.1	−0.4	0.1	0.318	0.3	0.2	0.4	0.000
40–59 y-old	1.1	0.9	1.3	0.000	−2.2	−2.5	−2.0	0.000	0.6	0.5	0.8	0.000
>60 y-old	1.1	0.8	1.3	0.000	−1.7	−2.0	−1.4	0.000	0.4	0.2	0.5	0.000
Male												
19–39 y-old	−1.8	−2.0	−1.6	0.000	2.6	2.4	2.8	0.000	−0.4	−0.5	−0.3	0.000
40–59 y-old	0.0	−0.2	0.2	0.839	1.3	1.1	1.5	0.000	−0.5	−0.6	−0.3	0.000
>60 y-old	1.0	0.7	1.2	0.000	0.7	0.4	1.0	0.000	−0.6	−0.8	−0.5	0.000
Presence of children												
Presence vs. Absence	−1.8	−2.1	−1.6	0.000	3.0	2.6	3.3	0.000	−0.4	−0.7	−0.2	0.000
Race/ethnicity												
African-American vs. White	−12.0	−12.5	−11.6	0.000	9.3	8.8	9.8	0.000	−0.6	−0.8	−0.3	0.000
Hispanic vs. White	−5.3	−5.8	−4.8	0.000	3.9	3.3	4.5	0.000	−1.0	−1.3	−0.6	0.000
Other vs. White	−5.9	−6.6	−5.3	0.000	5.8	5.0	6.6	0.000	−2.1	−2.5	−1.7	0.000
Income												
Middle vs. Low Income	1.2	1.0	1.3	0.000	−2.0	−2.2	−1.8	0.000	0.4	0.3	0.6	0.000

BEVERAGES	LCS only†				CS only†				LCS and CS			
Predictors	B	[95%CI]		P value‡	B	[95%CI]		P value‡	β	[95%CI]		P value‡
High vs. Low Income	2.7	2.5	2.9	0.000	−4.6	−4.8	−4.3	0.000	0.9	0.8	1.1	0.000

*Coefficients can be interpreted as the change in the percent of grocery expenditure (volume purchased, mL/d) on each type of beverage respect to the total purchases of beverages. Changes with presence of different family members by age and gender, presence of children, race/ethnicity and income are shown. Results for other predictors are shown in Table 3S.

†LCS, low-caloric sweetened beverages or foods; CS, caloric-sweetened beverages or foods.

‡Significance level: P<0.001

Table 3

Race/ethnic differences in consumption of foods and beverages by sweetener type, NHANES 2003–2010*.

	CHILDREN (2–18 years old)				ADULTS (≥19 years old)			
	Beverages (mL/d)		*Foods (g/d)*		*Beverages (mL/d)*		*Foods (g/d)*	
Per Capita Intake ‡	***LCS*** †	***CS*** †	***LCS*** †	***CS*** †	***LCS*** †	***CS*** †	***LCS*** †	***CS*** †
Reported intake from stores								
White	64.4	364.6 *b*	2.8 *a*	111.2	178.3	348.9 *ab*	7.2	95.6
African American	39.9	324.1 *ab*	1.6 *a*	98.0 *a*	77.6 *a*	382.6 *b*	3.2 *a*	86.5
Mexican American	31.0 *a*	337.0 *ab*	2.8 *a*	88.7 *a*	82.5 *a*	311.3 *a*	3.7 *a*	72.5 *a*
Other	31.4 *a*	309.8 *a*	2.3 *a*	88.5 *a*	89.5 *a*	237.2	4.5 *a*	66.3 *a*
Total reported intake								
White	76.5	549.9 *b*	3.4	147.2	226.1	489.3 *ab*	7.4	125.0
African American	46.7	473.7 *a*	2.0 *a*	134.2	96.9 *a*	532.9 *b*	3.6 *a*	114.1
Mexican American	37.1 *a*	502.8 *ab*	3.1 *a*	119.0 *a*	113.3 *a*	451.9 *a*	3.9 *a*	92.7 *a*
Other	39.8 *a*	461.0 *a*	2.4 *a*	117.0 *a*	141.6 *a*	334.3	4.7 *a*	89.6 *a*
	Beverages (mL/d)		*Foods (g/d)*		*Beverages (mL/d)*		*Foods (g/d)*	
Difference in Percent Intake ‡	***LCS*** †	***CS*** †	***LCS*** †	***CS*** †	***LCS*** †	***CS*** †	***LCS*** †	***CS*** †
Reported intake from stores								
African American vs. White	−1.9 %	8.0 %	−0.2 % *c*	−2.6 %	−5.2 %	11.0 %	−0.5 %	−2.3 %
Mexican American vs. White	−3.3 %	1.7 % *c*	0.0 % *c*	−6.1 %	−5.2 %	1.8 % *c*	−0.4 %	−6.1 %
Other vs. White	−3.1 %	0.3 % *c*	−0.1 % *c*	−6.3 %	−4.6 %	−1.0 % *c*	−0.4 %	−6.9 %
Total reported intake								
African American vs. White	−1.1 %	4.0 %	−0.1 % *c*	−1.8 %	−4.4 %	10.2 %	−0.4 %	−0.7 %
Mexican American vs. White	−2.0 %	1.8 % *c*	−0.1 % *c*	−4.2 %	−3.9 %	3.4 %	−0.3 %	−3.8 %
Other vs. White	−1.6 %	−1.1 % *c*	−0.1 % *c*	−4.2 %	−3.2 %	−1.7 % *c*	−0.3 %	−4.4 %

*Means per capita of beverages (mL/d) and foods (g/d) and difference in percent intake of beverages (mL/d) and foods (g/d)

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†LCS, low-caloric sweetened beverages or foods; CS, caloric-sweetened beverages or foods.

‡Multivariable regression models were used to adjust for age, gender, year and income.

a,b,c Estimates in the same column (i.e. LCS beverages) sharing a letter are not significantly different at the 5% level, Bonferroni-adjusted Student's test.

c Not significantly different between race/ethnic groups at the 5% level, Student's test.