U.S. HOUSEHOLD PURCHASES OF NO- AND LOW-SUGAR PRODUCTS FROM KEY FOOD GROUP SOURCES OF ADDED SUGAR, 2002-2014

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ABSTRACT

Elyse S. Powell: U.S. household purchases of no- and low-sugar products from key food group sources of sugar, 2002-2014
(Under the direction of Linda Adair)

Despite recent declines in added sugar intake, population sugar consumption remains above recommended levels. More than two thirds of added sugars consumed in the U.S. comes from stores, and more than 75% of added sugars consumed comes from the top eight food and beverage group sources. As such, widespread public and private efforts to promote purchases of no- and low- sugar alternatives to these foods and beverages are seen as promising strategies to reduce population sugar consumption.

However, trends in household no- and low-sugar products purchases in these eight key food groups have not been assessed over this time period. Further, there are concerns that ongoing efforts to promote no- and low- sugar products will not equitably reach minority and low-income populations, and may unintentionally increase consumption of low-calorie sweeteners. We currently do not know whether there are racial/ethnic and income differences in purchases of these products. We additionally do not know what proportion of no- and low-sugar product purchases contain low-calorie sweeteners.

One reason for the scarcity of research on no- and low-sugar purchases is that there is no comprehensive, consistent definition of low-sugar used in the U.S.. The FDA does not currently define low-sugar. Previous research has alternatively used definitions that focus on

calories per labelled servings, which are not consistent across brands and products, or on low-calorie sweetener consumption, which does not capture all low-sugar products.

This research addressed these gaps using the 2002-2014 Nielsen Homescan Consumer Panel. Homescan captures year-long household purchases of packaged foods by providing households with a barcode scanner. Scanned barcodes are then linked to product specific nutrient information, including total sugar content, package volume or weight, and ingredients lists. This product specific information facilitates our classification of no- and low-sugar products in eight key food and beverage groups. We then used Homescan's nationally representative sample of household purchases to examine trends in no- and low-sugar product purchases from 2002 through 2014 in these eight food groups. We also examined cross-sectional differences in no- and low-sugar product purchases by household race/ethnicity and income for each year from 2002 through 2014. Finally, we examined trends in the proportion of no- and low-sugar purchases that contain different types of sweeteners.

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LIST OF ABBREVIATIONS

CDC	Centers for Disease Control and Prevention
CS	Caloric sweetener
FDA	Food and Drug Administration
FJC	Fruit Juice Concentrate
FPL	Federal poverty limit
FSA	Food Standards Agency
LCS	Low-calorie sweetener
NH	non-Hispanic
RTD	Ready to drink
RTE	Ready to eat
SSB	Sugar-sweetened beverage
U.K.	United Kingdom
U.S.	United States

CHAPTER 1. INTRODUCTION

Background

Over the past 15 years, there has been rising concern about excess sugar consumption, as growing evidence links this modifiable behavior to obesity, diabetes and cardiovascular disease. [1–5] In an effort to reduce population sugar consumption, there have been numerous public and private efforts during this period to create and promote no- and low-sugar alternatives to foods and beverages that contribute the most sugar to the U.S. diet.[6,7] These efforts have included reformulation efforts, consumer education, and marketing campaigns. [5,8–11]

However, studies have not examined whether purchases of no- and low-sugar products in key food groups sources of added sugar has increased over this time period. One reason for this gap is that there is not a consistent, nutritionally meaningful definition of low-sugar used in the U.S..[12] A central barrier to applying such a definition is that the food composition tables of publicly available datasets do not capture sufficient detail to accurately assess the sugar content of specific products. [13–15] Capturing this information using self-report dietary assessment methods is also limited by consumers' knowledge of the sugar content of the products they consume, and their ability to recall this information.

It is further unclear whether there are differences by race/ethnicity or income in purchases of no- or low-sugar products. Many of the efforts used over the past 15 years to promote no- and low-sugar alternatives may not equitably reach racial/ethnic minority and low-income populations. [16–23] A previous criticism of national level efforts has been that they fail to reach these subgroups, who have disproportionately higher rates of obesity and diabetes. [24,25]

There is widespread concern that efforts to promote no- and low-sugar products may have the unintended consequence of increasing low-calorie sweetener (LCS) consumption. Previous research has found that children and adults have increased their LCS consumption since 2000. [26,27] However, not all no- and low-sugar products contain LCS; such products may contain caloric sweeteners (CS) or may be unsweetened. There is ongoing debate as to whether LCS containing products should be promoted as part of a sugar reduction strategy; findings linking LCS to health outcomes have been discrepant. [28–35] Researchers and public health organizations widely agree that unsweetened products are the preferred option to promote. [36] However, there is a gap in understanding what percent of no- and low-sugar products purchased contain LCS or are unsweetened, and whether that has changed over the past 15 years.

These studies aimed to address these research gaps using the Nielsen Homescan Consumer Panel, a national sample of household packaged food purchasing. Examining products in the top eight food and beverage group sources of added sugar, we used the product specific nutrient information to classify products as no- or low-sugar. We applied the U.K. Food Standard Agency's (FSA) definition of low-sugar, a consistent, comprehensive cut point that has been previously used in the U.K. We utilized Homescan's product specific ingredients list to then identify products that contain CS, LCS, both or none. We then examined purchases from these eight food and beverage groups in a nationally representative sample of U.S. households to determine 1) trends in household no-and low-sugar purchases, 2) the proportion of no- and low-sugar purchases that contain different types of sweeteners, 3) differences in no- and low-sugar purchases by household race/ethnicity and household income and 4) differences in no- and low-sugar purchases that contain different types of sweeteners by household race/ethnicity and income. Homescan's objective measure of purchases, using a barcode scanner, and year-long collection of data may help us better capture trends in purchases of these episodically consumed foods and beverages.

Research Aims

The overarching goal of this research project was to examine nationally representative trends in household no- and low-sugar product purchases from eight key food and beverage group sources of added sugars. We further aimed to examined household race/ethnic and income differences in purchases of these products.

Aim 1: Examine nationally representative trends in household no- and low-sugar product purchases from 2002-2014

> We examined purchases in a nationally representative sample of U.S. households to determine U.S. trends in purchases of no- and low-sugar beverages and low-sugar foods. We further identified trends in the proportion of no- and low-sugar product purchases containing different types of sweeteners. We hypothesized that purchases

of no- and low-sugar products from our examined food and beverage groups increased from 2002 to 2014.

Aim 2- Examine household race/ethnic and income differences in no- and low-sugar product purchases

We determined whether there are race/ethnic or income disparities in no and low-sugar product purchases. We further examined race/ethnic or income differences in the proportion of no- and low-sugar products that contain different types of sweeteners. We hypothesized that NH black, Hispanic, and low-income households would have lower purchases of no- and low-sugar foods and beverages, and that these households would also have lower purchases of LCS containing no- and low-sugar products.

CHAPTER 2: LITERATURE REVIEW

The "sugar backlash" and efforts to promote low-sugar products

Over the past 15 years, there has been growing concern about sugar consumption by consumers and researchers alike, amidst rising evidence linking excess sugar consumption to obesity, diabetes, and other diet-related chronic diseases. [1–5] This rising concern, dubbed the 'sugar backlash', has led to various public and private efforts to promote low-sugar alternatives to many food and beverages. [5]

Industry efforts over this time period have included voluntary initiatives by national food manufacturers to create and promote healthier packaged foods, including lower sugar products. The Healthy Weight Commitment Foundation, which is comprised of 16 of the largest food manufacturers, removed over 1.5 trillion calories from packaged foods from 2005-2015; this was achieved in part through lowering the sugar in some products. [10] Additionally, Walmart reduced sugars in the foods they manufacture by 10% from 2007 through 2010. [11] Public-private partnerships have implemented front of pack labels and in store promotions for products that meet various nutrition guidelines. [37–39] One example of this is the Guiding Stars program, which was found to increase purchases of products including ready-to-eat (RTE) cereals that had fewer total sugars. [38,39]

There have also been numerous public efforts to promote lower sugar alternatives. Recommendations from public health organizations to reduce sugar intake have included suggestions to replace key foods and beverage sources with lower sugar alternatives.[36,40,41] Public education and marketing campaigns include federal campaigns such as the CDC's "Rethink your Drink", as well as state and local campaigns including "Are you pouring on the pounds?" and "Sugar pack" from New York and Los Angeles. [8,40,42] The potential for expanding U.S. policies replicating local and international sugar sweetened beverage (SSB) taxes, such as those in Berkley and Mexico, have prompted food manufacturers to create and market more lower sugar alternatives. [43–47]

The top eight food and beverage sources of sugar contribute more than 75% of added sugars consumed by the U.S. population ≥6y. [6] Therefore, there has been particular emphasis on creating and promoting low-sugar products in these food and beverage categories as a strategy to reduce population sugar consumption.[7,46,48,49] We focused our analysis on purchases in these eight food and beverage groups: soft drinks and energy drinks; fruit drinks, sports drinks, and flavored waters; ready-to-drink (RTD) teas; grain-based desserts; candy; flavored yogurt; dairy-based desserts; and RTE cereals. A similar approach has been taken with sodium, where monitoring of key food group contributors has been used to assess public and private sodium reduction efforts. [50–52] We examined sugar-free beverages separately from low-sugar beverages, because there has been extensive focus on sugar-free beverages in the literature and among public health efforts.[1,36,41,53–56]

The U.S. lacks a consistent, comprehensive definition of low-sugar

Despite widespread efforts to promote low-sugar alternatives over the past 15 years, national trends in low-sugar purchases over this time period have not been quantified. A primary reason for this gap is that there is not a consistent, comprehensive definition of low-sugar used in the U.S.. The Food and Drug Agency (FDA), which sets specific cut points for labels such as ‘low calorie’, ‘low cholesterol’ and ‘low sodium’, only defines ‘reduced/less sugar’ compared to ‘an appropriate reference food’; it does not define ‘low sugar’.[12] Products labelled as ‘reduced sugar’ are not necessarily low in sugar.[57] Further, the food manufacturers set the ‘appropriate reference product’, and so the ‘reduced sugar’ definition is not consistent across brands or products. [12,57] Finally, new low-sugar products may not have an ‘appropriate reference product’.

A limited number of studies have examined trends in consumption of ‘diet’ beverages utilizing NHANES data. [58–60] These studies, which defined diet beverages as those with <40 kcal per labelled serving, found that the percent of children and adults consuming diet beverages has increased from 2001 to 2014. Mesirow et al found that the amount of diet beverages consumed also increased among U.S. children 2-18y.[60] However, low-calorie is not equivalent to low-sugar; for example, certain dairy based beverages may not be low in calories but may be low in sugar. For the same reason, this definition could not be used to identify low-sugar foods. Further, labelled servings are not standardized, making this an inconsistent definition across products and brands.

The United Kingdom’s (U.K.’s) Food Standard Agency (FSA) has established cut points to define low-sugar foods and beverages, based on the grams of total sugar per 100g or

100mL of product, respectively.[61] These cut points have been used in the U.K. both for product claims as well as a traffic light front of pack labelling system. A meaningful cut point that can be consistently applied across products, like the one established by the FSA, is needed to determine national trends in low-sugar product purchases. Dunford et al. applied the FSA's definition of low-sugar to the 2017 Label Insight dataset, a national dataset of Nutrition Facts Panels from barcoded packaged foods and drinks available in stores.[62] They found that 48% of uniquely barcoded foods and 14% of uniquely barcoded beverages met the FSA's criteria for low-sugar. [62] This definition could be further used to determine whether the number of products meeting this criteria have changed, to quantify purchases of low-sugar products, and to examine changes in low-sugar purchases over time.

The role of low-calorie sweeteners

A central concern about public and private efforts to promote low-sugar alternatives to sugary products is that these efforts will increase consumption of LCS. [36,63–65] There is extensive debate about whether LCS sweetened products are an acceptable low-sugar alternative. [66–70] While proponents argue that LCS sweetened products allow people to satisfy sweet cravings with products that are lower in sugar and energy, there have been long standing concerns that they may maintain sweet preference and trigger compensatory mechanisms. [67,70–72] Research linking LCS consumption to health outcomes has generated discrepant findings. [28,29] Some prospective studies have found that consumption of LCS beverages is associated with a reduced risk of obesity and type 2 diabetes.[30,31] Several RCTs examining LCS beverages have also found a reduction in sugar intake and weight loss. [32,33]

Conversely, several cross-sectional and cohort studies have found increased risk of obesity and type 2 diabetes associated with LCS consumption. [29,34,35]

In 2005-09, 15% of U.S. household food and beverage purchases from stores contained LCS.[73] Purchases and consumption of LCS beverages has increased among U.S. children and adults since 2000.[27,74,75] The percent of adults consuming any type of LCS rose from 8.7% in 1999-2000 to 41.4% in 2009-12. [75,76] Consumption of LCS beverages rose from 172.4 ml/day to 184.5 ml/day from 2003 to 2010. [27] Over this time period children and adults did not significantly increase their consumption of LCS containing foods. [26,27] However, not all LCS products are low-sugar, and not all low-sugar products contain LCS. While these changes occurred over the same time that there was an effort to promote low-sugar alternatives, it is not clear what percent of low-sugar purchases contained LCS. Examining what proportion of low-sugar purchases contain LCS, and how that has changed over the past 15 years, can help us better understand whether shifting purchases towards low-sugar alternatives may increase consumption of LCS.

Are there sociodemographic or socioeconomic disparities in purchases of low-sugar products?

Race/ethnic and income disparities in sugar consumption are well documented. [77–80] Low-income children and adults have higher added sugar consumption, and are more likely to be in the highest tertile of added sugar consumption in the U.S. [2,6,81] Non-Hispanic black adults also have higher added sugar consumption compared to non-Hispanic white adults. [2,6,80] These groups also have higher consumption of sugar-sweetened beverages. [77–80] Chronic diseases associated with excessive sugar consumption, including obesity and type 2 diabetes, are more prevalent amount low-income, non-Hispanic black and Hispanic adults. [82–84]

A central goal of national-level efforts is to reduce sugar consumption across the U.S. population.[41,48,85] However many the efforts implemented, including reformulating products, marketing efforts, and educational efforts, may not equitably impact low-income and NH black and Hispanic households. [5,8–11,16–23] Reformulation efforts aim to reduce the sugar content of products.[48,85] The information needed to determine whether a product is low-sugar is available on the nutrition facts panel, however only about 30% of consumers regularly consult the nutrition facts panel, and these consumers are more likely to be higher income and higher educated. [22,86,87] Nutritional literacy and health education also predict food label use, both factors that Hess et al. found to be lower in low-income and less educated adults. [22] While marketing efforts may promote low-sugar alternatives, studies have found that outdoor and television advertisements targeted to non-Hispanic blacks and Hispanics are less likely to promote healthy products. [16,88–90]

We do not know whether there are race/ethnic or income disparities in no- and low-sugar product purchases. Fewer NH black and low-income children and adults purchase and consume LCS. [27,74,75] Piernas et al found that in 2003-10 NH white adults consumed 226 mL/day of beverages containing LCS, while NH black and Hispanic adults consumed 97 mL/day and 113mL/day, respectively.[91] Similar differences were found for children. However, as mentioned previously, containing LCS is not equivalent to no- or low-sugar. A comprehensive definition of low-sugar can identify whether there are disparities in this broader category of purchases, as well as examine whether these groups purchase a higher proportion of low-sugar products that are calorically sweetened or unsweetened.

Opportunities in using the Homescan Consumer Panel Dataset to study no- and low-sugar products

The Homescan Consumer Panel dataset (Homescan) will uniquely allow us to accurately classify no- and low-sugar products using the FSA's gram cut points for low-sugar, as well as use an objective measure for examining no- and low-sugar purchases from stores. Many scholars have noted that publicly available datasets do not collect sufficient information to accurately monitor sugar content in products.[13–15,36] Publicly available databases use aggregates, estimates, and 'standard recipes' to determine the sugar content of food items, making it difficult to accurately identify whether a product is 'low sugar' using a gram cut point. Sugar content can vary widely for the same type of product across brands. [92] Further, self-report dietary assessment methods are limited by recall errors, consumer knowledge of the contents of the food they consume, underreporting, and difficulty estimating portion size. [93–95]

Homescan is a national study of household packaged food purchases from stores. Participating households are provided with a barcode scanner, which they use to scan all packaged foods and beverages purchased from any type of store that are brought into the home. Each scanned barcoded item has been linked to a product specific nutrition facts panel, which includes grams of total sugars, and ingredients list. This allows us to classify products as no-sugar or low-sugar using the FSA's cut points. We can also accurately identify products according to presence of sweetener using the ingredients list. Households that participate in Homescan must participate for a minimum of 10 months, thus Homescan may better capture usual purchasing patterns than short term dietary assessment methods like 24-hour recalls.[96–98] This is useful when examining no- and low-sugar foods and beverages, which are likely to be episodically consumed. While the potential for underreporting still exists, the objective scanning of barcodes may also reduce measurement error caused by relying on recall or consumer knowledge of the contents and portion sizes of the products. [99]

CHAPTER 3. TRENDS IN LOW-SUGAR PACKAGED FOOD AND BEVERAGE PURCHASES FROM KEY FOOD GROUP SOURCES OF ADDED SUGARS, 2002-2014

Overview

Background: Over the past 15 years, rising concern surrounding sugar consumption in the United States (U.S.) has led to public and industry efforts to promote low-sugar alternatives to many foods and beverages. However, trends in household low-sugar products purchases during this period have not been assessed.

Objective: To identify nationally representative trends in U.S. household purchases of packaged low-sugar alternatives from all types of stores, 2002-2014.

Methods: This study used the 2002–2014 Nielsen Homescan Consumer Panel of household packaged food and beverage purchasing. The selection of low-sugar products for this analysis was guided by the identification of the eight top sources of added sugars in the diet. The low-sugar versions of these products are the focus of study in 152,987 households. The percent of barcoded beverages classified as no-sugar (0g sugar), low-sugar (sugar >0g-2.5g/100mL) and foods classified as low-sugar (sugar <5g/100g) was counted in each year. Survey weighted nationally representative means were determined for household purchases of no- and low-sugar beverages as a percent of total purchases from examined beverage groups (% mL), for low-sugar food purchases as a percent of total purchases from examined food groups (% g), and for the percent of no- and low-sugar purchases that contained caloric sweeteners and/or low-calorie sweeteners.

Results: More than two thirds of U.S. households purchased no- or low-sugar products from our examined food and beverage groups. Sugar-free beverage purchases from examined beverage groups rose from 2002 (25%±0.2% mL) through 2007 (31%±0.2% mL, $p<.001$), and then stabilized through 2014 (29%±0.2% mL, $p<.001$). Household low-sugar food purchases from selected food groups did not change significantly from 2002 (5%±0.1% g) to 2014 (4%±0.1% g). Household low-sugar beverage purchases also did not change over the study period.

Conclusions: Despite multi-sectoral efforts, sugar-free beverage purchases did not substantially change after 2008, and low-sugar food and beverage purchases did not change from 2002-2014.

Introduction

Despite recent declines in added sugar consumption, population intake remains above recommended levels. [24,36,41,100] More than two thirds of added sugars in the U.S. diet are purchased from stores, while the remainder comes from restaurants, schools, and other away-from-home locations.[6] The top eight sources of added sugar, including sugar-sweetened beverages, fruit drinks, ready-to-drink (RTD) teas, grain-based desserts, candy, flavored yogurt, dairy-based desserts, and ready-to-eat (RTE) cereals, contribute more than 75% of added sugars consumed by the U.S. population aged ≥ 6 y. [6] Therefore, efforts to shift household store purchases towards sugar-free and low-sugar alternatives in these eight food and beverage categories are seen by several public health organizations as promising strategies to reduce population sugar consumption. [41,48,85,101] These efforts include educational campaigns, changes in marketing strategies, and industry pledges to reduce the sugar and calories in the products they manufacture. [8,42,85,102,103] Reformulating products that are main contributors of added sugars have been identified by public and private organizations as a priority. [7]

However, whether actual consumer purchases of no- and low-sugar products in these eight key food groups has increased is unknown. While studies have documented increases in the consumption and purchases of low-calorie sweeteners (LCS), little attention has been paid to purchases of a broader range of low-sugar products. [26,27] Not all low-sugar products in the packaged food supply contain LCS. In 2005-09, 25% of uniquely formulated packaged foods purchased did not contain sugars or low-calorie sweeteners. [73] Similarly, products that contain LCS are not necessarily low in sugar, as products containing LCS can also contain caloric sweeteners, or be high in natural sugars. Household purchases of products containing both LCS and caloric sweeteners rose from 2000 to 2010. [27] A more comprehensive approach to studying low-sugar products is needed. Understanding trends in no- and low-sugar product purchases over the past 15 years can inform evaluations of manufacturers' efforts to create low-sugar products. Furthermore, such knowledge can establish baseline trends to better evaluate future public and private efforts.

While not all no- and low-sugar products contain LCS, a central concern about efforts to promote lower sugar alternatives is that they will unintentionally increase consumption of LCS. [36,63–65] There is extensive debate about whether LCS sweetened products are an acceptable alternative to promote. [66–70] The proportion of no- and low-sugar purchases that contain LCS, CS, both or are unsweetened is unknown. Examining what proportion of no- and low-sugar purchases contain different types of sweeteners, and how that has changed over time, can help future evaluations better understand whether shifting purchases towards no- and low-sugar alternatives may increase LCS purchases.

A main reason for this research gap is the lack of a comprehensive definition of low-sugar products. In the U.S., the FDA does not define low-sugar, instead defining 'reduced sugar' compared to 'an appropriate reference product'. However, 'reduced sugar' products are not necessarily low in sugar. [57] Further, food manufacturers determine the 'appropriate reference product', and so the 'reduced sugar' definition is not consistent across brands or products. [12,57] Finally, many new low-sugar products may not be labelled as 'reduced sugar' because they do not have an 'appropriate reference product'. A consistent and nutritionally meaningful cut point for low-sugar, such as the one established in the U.K. for front-of-package labelling, is needed [61]

To address these research gaps, we applied a consistent, nutritionally relevant definition of low-sugar to the Nielsen Homescan dataset, a national study of packaged food purchases. Our study focuses on low-sugar products in eight food and beverage categories identified previously as top contributors of added sugar to the U.S. diet. [6] We examined sugar-free and low-sugar beverages separately because education efforts and research has focused on sugar-free beverages. We examined available products and determined: 1) the proportion of barcoded items categorized as no-sugar beverages, low-sugar beverages and low-sugar foods and 2) the proportion of no- and low-sugar products that contain different types of sweeteners. Then we examined purchases in a nationally representative sample of

U.S. households to determine U.S. trends from 2002 through 2014 in 1) purchases of no- and low-sugar beverages and low-sugar foods and 2) the proportion of no- and low-sugar product purchases containing different types of sweeteners.

Methods

Study design and population

This study used data from the 2002-2014 Nielsen Homescan Panel (Homescan), a longitudinal study of packaged food and beverage purchases by U.S. households. [104] Households were provided with a barcode scanner and instructed to scan all items after each shopping trip. Households scanned products purchased from all store types, including supermarkets and grocery, warehouse-club, mass-merchandise, convenience, and drug stores.

Households were sampled from 76 markets, comprised of 52 metropolitan and 24 non-metropolitan geographical areas. To be included, households must report for ≥10 months in a year (mean 4.3y). Homescan used an open cohort design; new households were enrolled to replace households that dropped out and rebalance the panel to match demographic and geographic targets. Household composition (age and gender of family members) and sociodemographics (race/ethnicity, income, and head of household's education) were self-reported annually. [105]

Household level purchases were analyzed by year. Year-level household observations were excluded if they contained >1 quarter of unreliable reporting (2.4% excluded). A household's quarter was deemed unreliable if it included ≥4 weeks of inconsistent reporting as judged by dollar value of purchases (<$45/month for a single person household, <$135/month for a multiple person household). [105] The final analytical sample included

655,948 household-year observations, from 152,987 unique households. This secondary analysis was exempt from IRB approval.

Nutrition information & food and beverage groups

For every food or beverage scanned, the product's barcode, product weight (g) or volume (mL), and product specific attributes were recorded. Each barcode was linked to a corresponding Nutrition Facts Panel, which includes calorie and nutrient content, and an ingredients list. The methods for this process have been described elsewhere. [14,106]

We limited our analysis to products in eight key food and beverage groups that represent the top sources of added sugars in the U.S. diet [6] These eight groups are: soft drinks and energy drinks; fruit drinks, sports drinks and flavored waters; ready-to drink teas; grain-based desserts; candy; flavored yogurts; dairy-based desserts; and ready-to-eat cereals**.** Barcoded products were categorized into these groups as part of a food grouping system which has been previously published. [105,107] Powders and concentrates were excluded because we cannot confirm whether these products remain sugar-free or low-sugar when consumed, as sugar may be added during preparation.

Classifying sugar-free and low-sugar products

Beverages were classified as sugar-free or low-sugar and foods were classified as low-sugar at the product level, using the barcode-linked nutrition fact panel data. Since the FDA does not currently define low-sugar, we used the U.K.'s Food Standards Agency criteria for low-sugar. We examined sugar-free beverages separately from low-sugar beverages because policy and education efforts have focused on sugar-free beverages, in part due to recommendations to avoid sugars from beverages based on evidence that they are less satiating than foods and that intake of sugar sweetened beverages is associated with weight gain and obesity. [1,36,41,53–56] Low-sugar foods were defined as those with ≤5 g of sugar per 100 g of product. [12,61] Sugar-free beverages were defined as those with 0g of sugar and low-sugar beverage were classified as those containing >0g to 2.5g of sugar per 100mL of product. Nutrition Fact Panel rounding rules allow products with <0.5 g of sugar per serving to be reported as 0 g, thus these beverages were classified as sugar-free.

We used SAS (SAS version 9.3, SAS Institute Inc., Cary, NC) for data management. A detailed table of products classified as low-sugar or sugar-free by group is provided in **Table 1.**

Classifying products by the presence of sweeteners

All products were classified according to whether they contained caloric sweeteners, LCS, both, or no sweeteners (**Table 1).** Caloric sweeteners were defined as those that provide ≥3.8 kcal per gram, the caloric value of sucrose. [108] Fruit juice concentrate was considered a caloric sweetener, unless the ingredient list also included water. [65] This reflects the FDA's inclusion of fruit juice concentrate as an added sugar, but exclusion of fruit juice concentrate that has been diluted to single-strength juice. LCS were defined as those with <3.8 kcal/g or those that are used in such small quantities that they provide negligible calories. [27,73] These sweeteners could be derived from artificial (i.e., aspartame, saccharine) or natural (i.e., stevia) sources. A keyword search was performed on the ingredient lists of the products examined. A complete list of keywords used to identify sweeteners has been previously published. [65]

Statistical Analysis

Proportion of products that meet low-sugar or sugar-free criteria

The number of uniquely barcoded products in our eight examined food and beverage groups were counted for each year from 2002 to 2014. Products have unique barcodes because they are different products, or because they are the same product with different package sizes (12-ounce can vs 20-ounce bottle), different flavors (tea-peach vs tea-original) or have seasonal or promotional packaging (i.e., candy with promotional movie character).

Annually, for each beverage group, the percent of barcoded items categorized as low-sugar or sugar-free was calculated as the number of low-sugar or sugar-free barcoded products divided by the total number of barcoded beverages. For each food group the percent of barcoded items categorized as low-sugar was calculated. We then determined, for each food and beverage group, the percent of barcoded low-sugar or sugar-free products that contained caloric sweeteners, LCS, both or none. A two-sample test of proportions was used to test differences from 2002; $p<.001$ was considered significant to account for multiple comparisons and the large sample size. [27,109–111]

Household purchases of low-sugar and sugar-free products

Data analysis was conducted using survey commands in Stata 14 (Stata Corp, College Station, TX) to account for survey design, and projection weights were used to create nationally representative estimates. Projection weights were created using iterative proportional fitting. The Current Population Survey's (CPS) count of households for each year were used as control totals to create nationally representative estimates based on the

CPS distribution of household size, head of household age, presence of children, and the joint distribution of race (white, black, and Other), Hispanic origin, and household income. [112]

Our goal was to estimate nationally representative trends in the percent of households that purchased low-sugar foods, low-sugar beverages, and sugar-free beverages were examined. While consumers are often defined as individuals who report >0 g consumed over a 24h period, Homescan captures packaged food and beverage purchases for a household over an entire year. To meaningfully examine the proportion of households that purchased low-sugar products, households that purchased an average of ≥1 serving per week for a year were classified as a purchaser for that year. A serving was defined as 50 g for foods and 100 mL for beverages. [27] Survey weighted proportions were determined for each year, and survey-weighted logistic regression models with clustering at the household were used to test time trends in prevalence of purchasers.

We then examined household-level purchases of no- and low-sugar products in our eight food and beverage groups. To control for differences in total purchase amounts and household size across households, no- and low-sugar product purchases were examined as a percent of total purchases (mL or g) from our eight food and beverage groups. Household level purchases of low-sugar foods, sugar-free beverages, low-sugar beverages were measured separately. Low-sugar and sugar-free beverage purchases were defined as the mL of low-sugar or sugar-free beverages purchased, respectively divided by the total mL from the 3 examined beverage groups purchased in a year. Low-sugar food purchases were defined as the grams of low-sugar foods purchased divided by the total grams from the 5 examined food groups purchased in that year. We then determined the proportion of low-sugar beverage, sugar-free beverage and low-sugar food purchases containing CS, LCS, both or neither in each year. Survey weighted means of low-sugar beverage purchases, sugar-free beverage purchases, low-sugar food purchases, and the proportion of low-sugar purchases containing each type of sweetener were determined for each year. Survey-weighted linear regression models with clustering at the household were used to test time trends in amounts purchased, and significance was calculated using Wald's *F* test. For all analyses, $p<0.001$ was considered significant to account for multiple comparisons and to account for the large sample size.

Results

The Homescan study population has a higher proportion of non-Hispanic white and high-income households than the general U.S. population.[112] All results for household-level purchases are weighted to generate nationally representative estimates. Sociodemographic characteristics of the study sample are presented in **Supplemental Table 1.**

Proportion of barcoded products in selected food groups that were categorized as no- or low-sugar

In our examined key food and beverage groups, the percent of uniquely barcoded products categorized as low-sugar or sugar-free rose slightly from 2002 to 2014 (+3%, $p<.001$), from 11% to 14% (**Table 2).** While the number of low-sugar and sugar-free beverages and low-sugar foods increased over the survey period, there was also an increase in the total number of products in our examined food and beverage groups. (**Table 2)**

The proportion of barcoded beverages categorized as sugar-free rose from 22% in 2002 to 28% in 2014. (**Table 2**) The proportion of soft drinks and energy drinks (+8%, p<.001), and fruit drinks, sports drinks, and flavored waters (+6% p<.001) that were categorized as sugar-free increased from 2002-2014. Only 6% of barcoded beverages examined were classified as low-sugar in 2014; this did not significantly change from 2002.

We found that 4% of barcoded foods were low-sugar in 2014 and there was limited change from 2002 (-1%, p<.001). (**Table 2)** In 2014 the candy group had the largest absolute number of low-sugar products, however ready-to-eat cereal and flavored yogurts had the highest proportion of products that were categorized as low-sugar.

Percent of low-sugar and sugar-free products that contain different types of sweeteners

In 2002, among the top beverage sources of added sugar, 80% of barcoded sugar-free beverages contained only LCS. However, from 2002 through 2014, the percent of sugar-free beverages containing only LCS decreased (-6% p<.001) (**Figure 1a)**. 81% of barcoded low-sugar beverages in our examined beverage groups contained CS-only and 11% contained LCS-only in 2002. In 2014, 15% of low-sugar beverages contained CS-only 16% contained LCS-only, and 68% contained both CS and LCS.

From 2002 to 2014, there were not significant changes in the percent of low-sugar foods in top food sources of added sugar that contained caloric sweeteners or LCS (**Figure 1b)**

Trends in household sugar-free and low-sugar purchases

In 2014, 69±0.1% of households purchased sugar-free beverages and 49±.1% purchased low-sugar foods. This proportion changed little across the survey period. (**Figure**

2) The percent of households that purchased low-sugar beverages declined from 48±0.4% to 24±0.3% in 2008, and then increased to 37±0.3% in 2014.

For the 3 top beverage sources of sugar, mean household-level purchases of sugar-free beverages increased from 25±0.2 % in 2002 to 31±0.2 % in 2007 ($p<.001$), and then declined slightly to 29±0.2% from 2007 to 2014. (**Figure 3a)** Trends in volume of sugar-free beverage purchases per capita per day increased from 2002 to 2006, but also declined slightly in the second half of the study period. (**Supplemental Figure 1)** In 2014, 72±0.3% of sugar-free beverage purchases were sugar-free soft drinks and energy drinks**.** Low-sugar beverage purchases declined slightly from 2002-2014 (-2%, $p<.001$), and remained under 7% of beverage purchases from our examined beverage groups throughout the study period.

In 2014, low-sugar foods were 5±0.1 % of purchases in our examined food groups. Low-sugar food purchases did not substantially change from 2002 to 2014. (**Figure 3b)** Ready to eat cereals were the largest contributor to low-sugar food purchases (32±0.3% of low-sugar food purchases in 2014).

The proportion of low-sugar and sugar-free purchases that contain different types of sweeteners

From 2002 through 2014, LCS sweetened sugar-free beverages in the examined beverage groups accounted for more than three quarters of U.S. household sugar-free beverage purchases. (**Table 3)** However, purchases of LCS sweetened sugar-free beverages declined slightly in this time period. Declines in the percent of sugar-free soft drink and sugar-free ready to drink tea purchases containing LCS-only declined from 2002 (90±0.2% and 72±1.2%, respectively) to 2014 (89±0.2% and 67±0.6%, $p<.001$ for both) were partially offset by increases in the percent of sugar-free fruit drink, sports drinks and flavored water purchases containing LCS-only (23±0.7% to 55±0.5%, p<.001). There was also an increase in the proportion of sugar-free beverage purchases that were unsweetened between 2002 and 2014. There was a significant decline in purchases of CS sweetened low-sugar beverages from 2002 (89±.3%) to 2014 (24±.4%, p<.001). Low-sugar beverage purchases containing CS+LCS increased from 8±.3% in 2002 to 61±.1% in 2014 (p<.001).

While household-level purchases of low-sugar foods remained steady from 2000-2014, the mean percent of low-sugar food purchases that contained only caloric sweeteners declined, and the percent of low-sugar food purchases containing both caloric sweeteners and LCS increased. **(Table 3)** This trend is partially attributable to an increase in purchases of flavored yogurts sweetened with both types of sweeteners (3±0.3% to 59±0.6% from 2000-2014).

Discussion

Our study is novel in its examination of nationally representative trends in household store purchases of low- and no-sugar products in eight key food and beverage sources of added sugar. We found that more than two thirds of U.S. households purchased low-sugar foods and no- and low-sugar beverages in our eight examined groups. Mean household purchases of sugar-free beverages, as a percent of beverage purchases from our examined groups, increased from 2002 to 2008, and then did not substantially change from 2008 to 2014. Household purchases of low-sugar beverages remained under than 7%. More than three quarters of sugar-free beverage purchases in our examined beverage groups were sweetened with LCS. The percent contribution of low-sugar foods to household purchases of top food sources of sugar remained at approximately 5% over the study period. However, we observed a decrease in purchases of low-sugar foods sweetened with only caloric sweeteners and an increase of low-sugar foods sweetened with both low-calorie and caloric sweeteners.

Our finding that there was an overall increase in sugar-free beverage purchases from 2002 to 2014 is consistent with studies of LCS-sweetened beverage purchases and consumption, which our results indicate account for more than three quarters of sugar-free beverages purchased. [26,27] The increase in sugar-free beverage purchases occurred over the same period as the decline in consumption of sugar sweetened beverages and overall added sugars for the first time in decades. [24,113–115]

We did not observe any substantial change in sugar-free beverage purchases during the second half of the study period. Industry reports show a reduction in beverage sales volume for no- calorie carbonated soft drinks in 2014 and 2015. [103] Our results are similar in showing a decline in absolute mL purchased per capita per day; thus the slight decline we observed in the *proportion* of beverage purchases that are low-sugar is not explained by rising total beverage purchases in our examined beverage groups. This decline may be attributable to observed increases in the consumption of water and other beverages not included in our examined groups. [60,103] In 2014, the American Beverage Association, the Coca-Cola Company, Pepsi-Co and the Dr. Pepper-Snapple group pledged to reduce beverage calories in the U.S. diet by 20% by 2025. [103] Further monitoring is needed to determine whether there will be renewed increases in sugar-free beverage purchases, or whether trends towards other beverages such as water will continue.

In our examined beverage groups, there were a limited number of uniquely barcoded low-sugar beverages. Low-sugar beverage purchases declined slightly from 2002-14, but overall remained low. This matches an industry study which found low-calorie beverages only contributed 1.5% of the volume of household purchases, while no-calorie beverages made up 50.5% of beverage sales volume. This report defined low-calorie beverages as those with 5-40 calories per 8 oz (2.1-17 calories/100mL); dairy beverages were excluded in their analysis. Consumption studies separately examining low-sugar or low-calorie beverages are limited. Maurissa et al., found that the percent of U.S. children reported consuming low-calorie beverages increased from 1% to 11% from 2001-2010, while the percent consuming no-calorie beverages did not change. Mean total daily ounces of low-calorie beverages consumed also increased. However, this study defined low-calorie beverages as those with >5-<40 calories per labeled serving. Labelled servings are not standardized across beverages, and USDA food codes used in this study lack product specific nutrient information. A consistent definition of low-sugar beverages is needed to generalize findings. We found that while LCS sweetened beverages accounted for the majority of sugar-free beverage purchases, there was a decline in the percent of sugar-free beverage purchases that were sweetened with LCS and an increase in the proportion that were unsweetened. This is consistent with Piernas et al., who observed declines from 2005 to 2010 in LCS beverages purchased by U.S. households; however, this study did not examine unsweetened products. [27]. This trend may reflect increasing public skepticism about the healthfulness of LCS noted by other researchers. [66–68] However, we also observed an increase in LCS-sweetened fruit drinks, sports drinks and flavored waters. Thus our results captured a broader shift in purchases away from sugar-free soft drinks, and towards sugar-free products that are marketed as healthier, independent of ingredients. [116]

U.S. household purchases of low-sugar foods remained low from 2002-14, representing 5% of food purchases from our examined groups. Our U.S. findings are consistent with global reports that reduced sugar foods remain a niche category within the food industry. [5] There may be lower consumer awareness about the amounts of added sugar in foods than in beverages, and hence less awareness about the need for low-sugar foods. Public efforts to reduce added sugar consumption have focused on sugary beverages, including sugar-sweetened beverage taxes, proposed large portion soda bans, and public marketing campaigns against their consumption. [8,45,117–119] Additionally, while the U.S. does not permit 'low-sugar' to be used on labels, 'reduced sugar' or other positive nutrient claims may be used on products that may not meet our low-sugar criteria. [57,86,116,120,121] We examined low-sugar foods from groups that were top sources of sugar in the U.S. diet. Further research is needed to determine whether households purchase low-sugar foods from other food groups, such as granola and energy bars. The new U.S. nutrition facts panel includes a line for added sugars and is supposed to be implemented in 2018. [122] If implemented, this may change low-sugar food purchasing by encouraging manufacturers to create more low-sugar products, or encouraging consumers to select more low-sugar foods. [102] Our study provides a baseline from which to monitor trends in low-sugar food purchases. Future research will be needed to determine the impact of the new nutrition facts panel on low-sugar product purchases.

Although low-sugar food purchases remained stable, we observed shifts in the sweeteners used in the low-sugar foods purchased. Our study found a decline in sugar-sweetened low-sugar foods, which is consistent with trends observed across total food purchases. [65] The trend we observed towards LCS+CS sweetened foods as a percent of low-sugar food purchases (+9% grams purchased) was larger than the trends in previous studies across LCS sweetened foods as a percent of all foods purchased (+3% grams purchased). [27] This could be for a number of reasons. Further research is needed to better understand the extent to which changes in low-sugar products and changes in household preferences are driving the observed trends.

The proportion of barcoded beverages that were categorized as sugar-free increased from 2002-2014. These changes occurred over a time period when food and beverage manufacturers announced initiatives to improve the healthfulness of the products they manufacture, including by reducing calories from sugar. (3–5) As part of the previously mentioned commitment, PepsiCo pledged that at least two-thirds of the beverages in its portfolio will contain fewer than 100 calories per 12 ounces, with an increased focus on zero calorie products. [103] The proportion of low-sugar barcoded beverages in our examined food groups did not significantly change. Continued monitoring and evaluation are needed to determine whether the number of low- and no-sugar beverages will grow, or whether growth occurs in beverages higher in sugar.

The proportion of barcoded foods in our examined groups classified as low-sugar remained stable from 2002 through 2014. Developing low-sugar foods may be a slower process, as there is also greater complexity involved in reformulating foods. In foods, sugar serves many purposes, including providing structure and texture as well as enhancing shelf life. [49] A stated goal of the addition of added sugars to the nutrition facts panel is to encourage food manufacturers to reformulate their products. Further monitoring is needed to determine if the number of low-sugar food products increases in future years. Whether there are changes in the number of low-sugar barcoded products in other food groups also merits further study.

A limitation of our study is our focus on low- and no-sugar products in food and beverage groups that are the top sources of sugar in the U.S. diet. This focus misses potential changes in low and no-sugar purchases from other food and beverage groups. However, a strength of this approach is that focusing on these groups ensure that the products examined are low-sugar alternatives to products traditionally high in sugar. These groups are also key targets of reformulation. [7] We only examined products with barcodes that were purchased and brought into the home; the dataset does not capture foods purchased away from home (e.g. at school, restaurants), or purchased and consumed before returning home, and non-packaged foods (e.g. loose produce). Further there is uncertainty about whether purchases are consumed. The aim of this study was to assess foods and beverages purchases from stores. Results should not be interpreted as total diet; certain beverage or food groups that are more frequently consumed away from home may be underrepresented, while products that are perishable or more frequently wasted may be overrepresented. Our categorization of low-sugar products used nutrition facts panel information. Because the FDA allows up to a 20% discrepancy between nutrient amounts reported on the nutrition facts panel and true nutrient content, and rounding rules allow products with <0.5g of sugar per serving to report 0g of total sugars, misclassification of low-sugar products was possible. Additionally, there is currently no universally accepted definition of a low-sugar product, and total sugars were used to define low-sugar products, because added sugar content is not currently required on nutrition labels. However, using total sugars has been found to be reasonable for nutrient profiling. [123] Furthermore our data only captures household level purchasing; intra-household distribution of the foods is not known. While validation studies of the Homescan dataset have found that it is comparable to other commonly used economic datasets, misreporting and selection bias due to study burden are possible. [99,124,125]

Despite these limitations, our study also has several important strengths. Homescan captures barcoded products, which were linked to product-specific sugar content. This makes it possible to accurately classify low- and no-sugar products. In contrast, publicly available datasets lack brand specific and product-specific information, instead relying on aggregated estimates to determine the sugar content of each food item, making it difficult to accurately identify whether a product is 'low-sugar.' [14,15] Further, our dataset's product specific ingredients list makes it possible to accurately identify the presence and type of sweetener in low-sugar products. This allows us to examine low-sugar product and the sweeteners they contain without relying on consumer knowledge and recall of this information. Additionally, low- and no- sugar products are likely to be episodically consumed; capturing purchases year-round may therefore better capture usual intake compared to a single 24-hour recall.

In conclusion, we provide novel, nationally representative estimates of low-sugar product purchases. We examine purchases over a time period of critical change, including reductions in added sugar consumption, increasing public focus on sugar, and multiple food manufacturers' pledges to improve the healthfulness of the products they produce. Numerous efforts have been taken to reduce the sugar in household purchases by reformulating products, or by shifting household purchases towards lower sugar options. Our findings that there has not been a substantial change in sugar-free beverages purchased from 2008 through 2014, and continued low purchasing of low-sugar foods and beverages indicate that further efforts are needed to translate public efforts into changes in household purchases in the groups that we examined. Our findings also establish baseline trends for evaluating the impact of future efforts, including the new American Beverage Association pledge and the implementation of the inclusion of added sugar in the nutrition facts panel, on low-sugar product purchases.

Tables and Figures

Table 3.1. Classification of barcoded packaged foods and beverages as sugar-free and low-sugar, by presence of sweetener[1]

Food Group	Sweetener type	Food and beverages included		
		Sugar-free beverages (total sugar 0g/100g)	Low-sugar beverages	Not Low-sugar beverages
Soft drinks and energy drinks	CS only	Sparkling water	None identified	Soft drinks, energy drinks, kombucha, tonic waters,
	LCS only	Diet soft drinks, diet energy drinks, sparkling water, diet tonic water	Diet soft drinks, diet energy drinks, sparkling flavored water	Soft drinks, energy drinks, sparkling water with juice, sparkling juice drinks
	CS + LCS	Diet energy drinks	Diet soft drinks, diet energy drinks, sparkling flavored water	Soft drinks, energy drinks, sparkling juice drinks
	Unsweetened	Sparkling water, seltzer, club soda	Sparkling flavored water	Sparkling water with fruit juice
Fruit drinks[2], sports drinks, and flavored waters[3]	CS only	None identified	Flavored water, maple water	Sports drinks, fruit drinks, vegetable drinks, combined fruit/vegetable drinks, flavored water, tonic water
	LCS only	Diet sports drinks, flavored water, coconut water	Flavored water	Fruit drinks, vegetable drinks, flavored water
	CS + LCS	Flavored water	Low-calorie sports drinks, aloe water, flavored water, diet energy drinks	Sports drinks, flavored water, energy drinks, smoothie mixes, fruit drinks, combined fruit/vegetable drinks,
	Unsweetened	Flavored water, unflavored mineral water, aloe vera juice	Coconut milk, Kraut juice	Fruit drinks, combined fruit/vegetable drinks
Ready-to-drink teas	CS only	Unflavored tea	Kombucha, flavored tea, unflavored tea	Sweet tea, half tea/half lemonade (or other fruit flavors), flavored tea
	LCS only	Flavored tea, unflavored tea, half tea/half lemonade (or other fruit flavors)	Half tea/half lemonade, flavored tea	Half tea/half lemonade (or other fruit flavors), flavored tea, tea with caffeine
	CS + LCS	Unflavored tea, flavored tea, half tea/half lemonade (or other fruit flavors)	Kombucha, unflavored tea, flavored tea	Sweet tea, flavored tea, tea with caffeine, flavored tea, half tea/half lemonade, (or other fruit flavors)
	Unsweetened	Unflavored tea, flavored tea	None identified	Kombucha, tea flavored with fruit juice

Food Group	Sweetener type	Food and beverages included: Low-sugar foods (total sugar ≤5g/100g)	Food and beverages included: Not Low-sugar foods
Candy	CS only	Mints	Chocolate bars and pieces, hard candy, gummy candy, chocolate coated candies (e.g. peanut butter cups, candy bars).
	LCS only	Mints; chocolate bars, hard candy, gummy candy, and licorice	Chocolate bars
	CS + LCS	Chocolate bars, chocolate pieces, mints	Caramel, toffee, gummy candy, licorice, hard candy
	Unsweetened	None identified	None identified
Grain-based desserts	CS only	Croissants, puff pastry cups, crumpet, mousse cake	Cakes, pies, cookies, rolls, toaster pastries, doughnuts, strudels
	LCS only	Cookies, cakes, cupcake, brownie, muffins	None identified
	CS + LCS	Muffin tops, carrot cake, cookies, cakes, pies	Muffin tops, scones, cookies, cakes, pies
	Unsweetened	Cookies, crumpets	Mochi, fig 'cake'
Dairy-based desserts	CS only	None identified	Ice cream, ice cream cake, frozen yogurt, cheesecake, pudding, custard
	LCS only	Ice cream, pudding, rice pudding, cheesecake	Ice cream
	CS + LCS	Pudding	Ice cream, frozen yogurt, dairy free frozen desserts, sherbet, ice cream cake
	Unsweetened	None identified	None identified
Flavored yogurt[4]	CS only	Regular[5] yogurts	Greek yogurt, regular yogurt, non-dairy yogurt substitute (soy, coconut, almond)
	LCS only	Greek yogurt, regular yogurt	Regular yogurt
	CS + LCS	Greek yogurt, regular yogurt, non-dairy yogurt substitute	Regular yogurt, Greek yogurt, non-dairy yogurt substitute (coconut, almond)

Food Group	Sweetener type	Food and beverages included	
	Unsweetened	Kefir, non-dairy yogurt substitute, Greek yogurt	Goat milk yogurt, sheep milk yogurt, non-dairy yogurt substitute (soy)
Ready-to-Eat Cereal	CS only	Oat rings, whole grain flakes, crispy rice cereal	Flakes, clusters, loops, frosted cereals, granola, cereal with candy pieces (e.g. marshmallows)
	LCS only	Corn bran, wheat fiber cereal	None identified
	CS + LCS	None identified	Shredded wheat, granola, whole grain corn cereal, O’s, flakes
	Unsweetened	Shredded wheat, puffed rice, puffed corn	Seed, grain and fruit cereal; muesli, granola, multigrain squares

[1] Beverage and food types may appear in multiple categories. This is because similar products from different brands or different flavors may have different amounts of sugar. For example, brand A fruit drink may contain LCS and have 0g of sugar, while brand B fruit drink may have 14g of sugar and contain CS.
[2] Fruit drinks are defined as beverages primarily composed of sugar or sweetener (as 1st or 2nd ingredients) with fruit juice or fruit juice concentrate as a lesser ingredient.
[3] Flavored waters are defined as beverages that contain flavors but no fruit juice or fruit juice concentrate.
[4] Flavored yogurts are defined as yogurts that contain some type of flavoring; plain unflavored yogurt is not included.
[5] Regular, as opposed to Greek style yogurt
CS= caloric sweetener, LCS= low-calorie sweetener
Data from the 2002-2014 Nielsen Homescan longitudinal panel of household purchases of consumer packaged foods. *Source: University of North Carolina calculation based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol for the 2002-2014 periods across the U.S. market. © The Nielsen Company, 2015.*

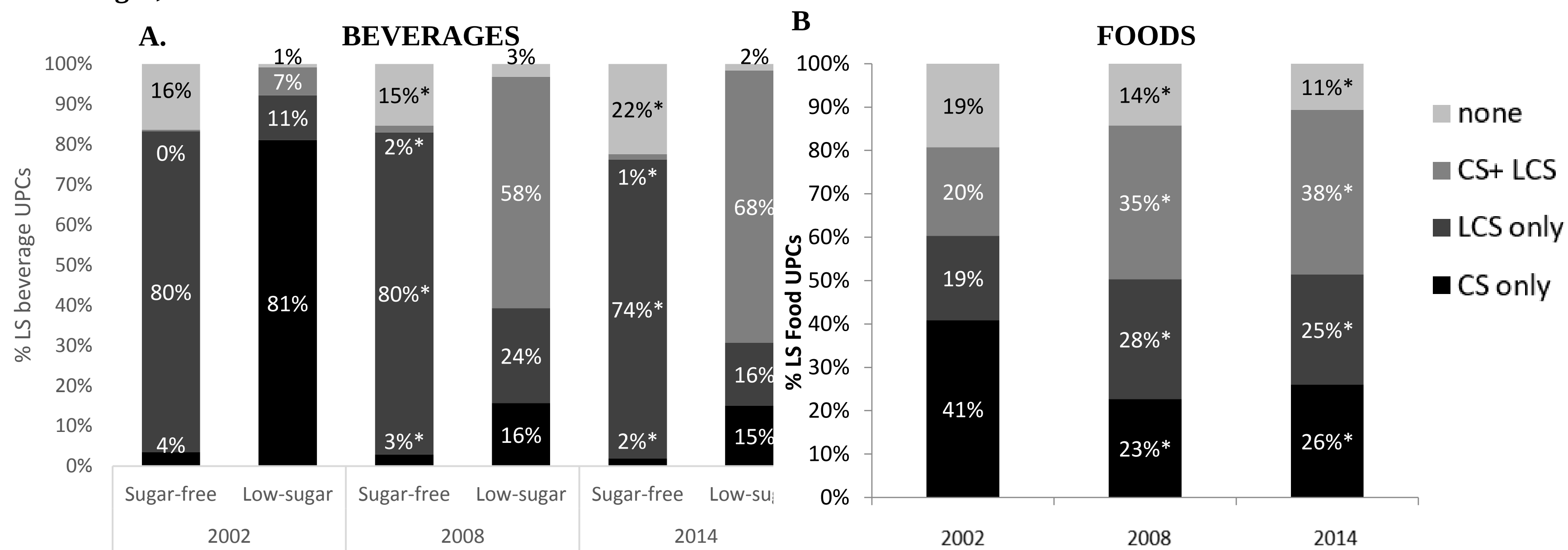
Table 3.2: Number and proportion of products categorized as sugar-free and low-sugar, by food and beverage group, Homescan 2002-2014[1]

	2002					2008					2014				
Product Group	Sugar-free		Low-Sugar		non-LS	Sugar-free		Low-Sugar		non-LS	Sugar-free		Low-Sugar		non-LS
	n	%	n	%	n	n	%	n	%	n	n	%	n	%	n
Soft drinks and energy drinks	1828	29%	121	2%	4393	2424	34%*	62	1%	4579	2894	37%*	440	6%	4518
Fruit drinks, sports drinks, and flavored waters	143	5%	121	4%	2474	350	10%*	177	5%	2996	401	11%*	251	7%	2919
Ready-to- drink tea	75	18%	28	7%	308	242	25%*	41	4%	696	328	24%*	103	8%	935
Beverage group total[3]	**2046**	**22%**	**270**	**3%**	**7175**	**3016**	**26%***	**280**	**2%**	**8271**	**3623**	**28%***	**794**	**6%**	**8372**
Grain-based desserts			173	2%	7656			277	3%*	10124			321	3%*	11334
Candy			513	7%	6576			777	7%	10463			608	5%*	11662
Flavored yogurt			53	4%	1166			111	5%	1987			175	6%	2884
Dairy-based desserts			131	3%	3619			169	3%	4861			198	4%	5276
Ready-to-eat cereal			280	10%	2396			278	7%*	3949			255	7%	3568
Food group total[4]			**1150**	**5%**	**21413**			**1612**	**5%**	**31384**			**1557**	**4%***	**34724**
Total[5]			**3466**	**11%**	**28588**			**4908**	**11%**	**39935**			**5974**	**14%***	**43096**

[1] Number and proportion of products with unique barcodes classified as low-sugar. Foods with sugar ≤5g/100g and beverages with sugar 0g/100g were defined as low-sugar. Products have unique barcodes because they are different products, or because they are the same product with different package sizes, different flavors, or have seasonal or promotional packaging.
[2] By product group, the number of uniquely barcoded low-sugar products was divided by the total number of barcoded products.
[3] Total of selected beverage groups. Beverage groups selected are top beverage sources of added sugar.

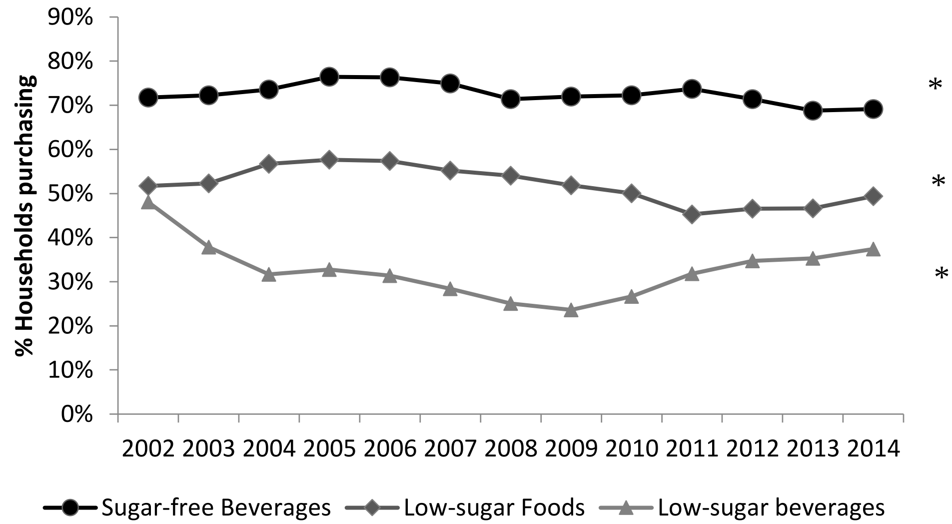
[4] Total of selected food groups. Food groups selected are top food sources of added sugar.
[5] Total of all selected food and beverage groups.
LS= low-sugar
*Significant compared to the same category in 2002, two sample test of proportions. $P<.001$
Data from the 2002-2014 Nielsen Homescan longitudinal panel of household purchases of consumer packaged foods.
Source: University of North Carolina calculation based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol for the 2002-2014 periods across the U.S. market. © The Nielsen Company, 2015.

Figure 3.1. Proportion of no- and low-sugar products that contain different types of sweeteners in key food and beverage sources of sugar, Homescan 2002-20141



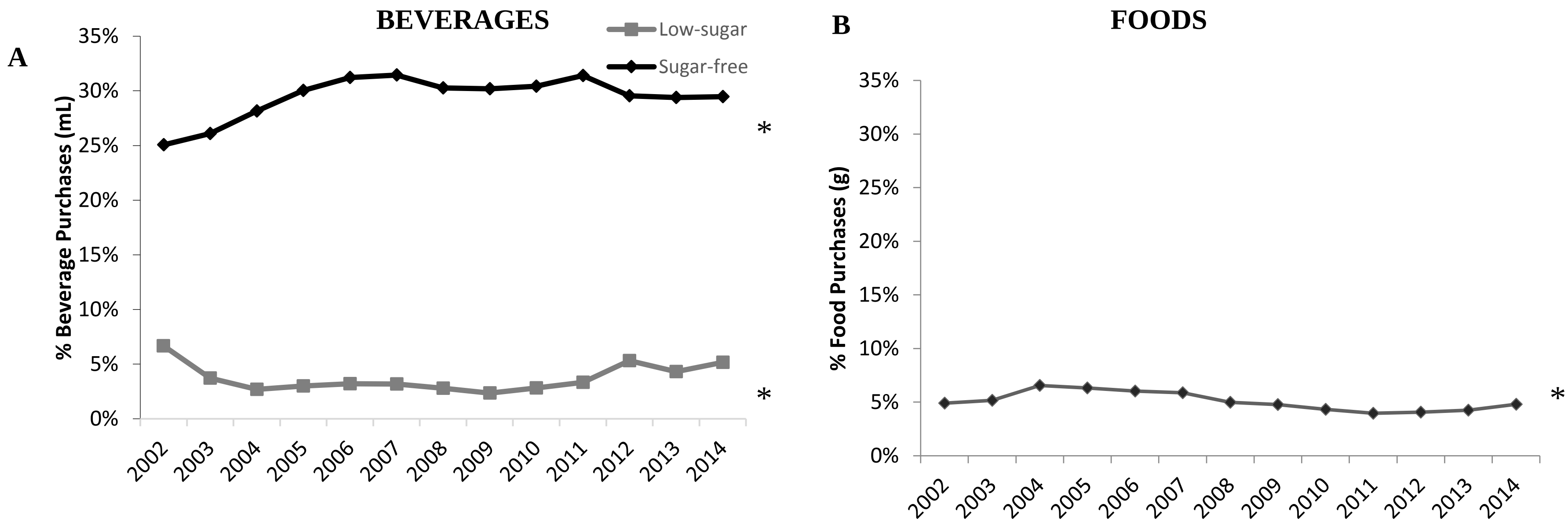
[1]The percent of uniquely barcoded (A) no- and low-sugar beverages and (B) low-sugar foods that contain caloric sweeteners (CS), low-calorie sweeteners (LCS), both, or none (unsweetened). Barcoded low-sugar products from our 8 examined food and beverage categories were placed into mutually exclusive categories by sweetener presence. The number of barcoded products in each sweetener category was divided by the total number of barcoded (a) no- or low-sugar beverages and (b) low-sugar foods in that year. Low-calorie sweeteners were defined as those with < 3.8kcal/g, or that were used in such small quantities they contributed negligible calories. No-sugar beverages and low-sugar beverages were defined as all beverages with 0g and >0-2.5g of sugar, respectively, in examined groups (soft drinks and energy drinks; fruit drinks, sports drinks, and flavored waters; and ready-to-drink teas). Low sugar foods were defined as all foods with ≤5g/100g of sugar in examined groups (grain-based desserts, dairy-based desserts, candy, flavored yogurts, and ready-to-eat cereal.)
* Significant compared to the same category in 2002, two sample test of proportions, $P<0.001$
Data from the 2002-2014 Nielsen Homescan longitudinal panel of household purchases of consumer packaged foods.
Source: University of North Carolina calculation based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol for the 2002-2014 periods across the U.S. market. © The Nielsen Company, 2015.

Figure 3.2. Weighted percent of U.S. households that purchased no-sugar beverages, low-sugar beverages and low-sugar foods, Homescan 2002-2014[1]



[1]Unadjusted proportions of households that purchased ≥1 serving/week of no-sugar beverages, low- sugar beverages, and low-sugar foods (% households) were calculated for each year and weighted to be nationally representative. One serving was defined as 50g for food and 100mL for beverages. No-sugar beverages and low-sugar beverages were defined as all beverages with 0g and >0-2.5g of sugar, respectively, in examined groups (soft drinks and energy drinks; fruit drinks and flavored waters; and ready-to-drink teas). Low-sugar foods were defined as all foods with ≤5g/100g of sugar in examined groups (grain-based desserts, dairy-based desserts, candy, flavored yogurts, and ready-to-eat cereal).
* Significant linear trend, determined using survey-weighted logistic regression. *P*<0.001 to account for sample size
Data from the 2002-2014 Nielsen Homescan longitudinal panel of household purchases of consumer packaged foods.
Source: University of North Carolina calculation based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol for the 2002-2014 periods across the U.S. market. © The Nielsen Company, 2015.

Figure 3.3. Weighted mean household no- and low-sugar beverage and low-sugar food purchases from top food and beverage group sources of added sugars, Homescan 2002-2014.[1]



[1]Weighted unadjusted mean household purchases of (A) No- and low-sugar beverages (% mL) and (B) low-sugar foods (% grams) from examined beverage and food groups. Means were weighted to be nationally representative. No- and low-sugar beverage purchases (mL) were examined as a percent of all beverage purchases (mL) from examined beverage groups (soft drinks and energy drinks; fruit drinks, sports drinks, and flavored waters; and ready-to-drink teas) in each year. Low-sugar food purchases (g) were examined as a percent of all food purchases (g) from examined food groups (Grain-based desserts, dairy-based desserts, candy, flavored yogurts, and ready-to-eat cereal) in each year. No-sugar and low-sugar beverages were defined as all beverages with 0g and >0-2.5g of sugar in examined groups, respectively, and low-sugar foods were defined as all foods with ≤5g/100g of sugar in examined groups.

* Significant linear trend, determined using survey-weighted linear regression. *P*<0.001 to account for sample size

Data from the 2002-2014 Nielsen Homescan longitudinal panel of household purchases of consumer packaged foods.

Source: University of North Carolina calculation based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol for the 2002-2014 periods across the U.S. market. © The Nielsen Company, 2015.

Table 3.3: Weighted mean percent of sugar-free and low-sugar purchases that contain low-calorie sweetener (LCS), caloric sweetener (CS), both or none, by food and beverage group Homescan 2002-2014[1]

	2002				2014			
	CS	LCS	CS+LCS	None	CS	LCS	CS+LCS	None
	Mean(SE)							
Sugar-free Soft drinks and energy drinks	7(.2)	90(.2)	0(.0)	3(.1)	2(.1)*	89(.2)*	0(.0)	9(.2)*
Sugar-free Fruit drinks, sports drinks, and flavored waters	8(.4)	23(.7)	1(.2)	68(.7)	3(.2)*	55(.5)*	11(.3)*	31(.5)*
Sugar-free Ready to drink tea	8(.7)	72(1.2)	6(.8)	15(.9)	5(.3)*	67(.6)*	5(.3)*	24(.5)*
Sugar-free Beverage group total[2]	**7%**	**81%**	**0%**	**11%**	**3%**	**78%**	**3%**	**16%**
LS Soft drinks and energy drinks	98(0.1)	2(0.1)	0(0.1)	0(0)	29(0.5)*	11(0.4)*	59(0.6)*	1(0.1)*
LS Fruit drinks, sports drinks, and flavored waters	59(1)	2(0.3)	39(1)	0(0.1)	17(0.5)*	13(0.5)*	69(0.7)*	1(0.3)
LS Ready to drink tea	48(2.5)	19(1.8)	32(2.6)	0(0)	8(1)*	48(1.3)*	44(1.3)*	0 (0)
LS Beverage group total[2]	**89(.3)**	**2(.1)**	**8(.3)**	**0(0)**	**24(.4)***	**14(.3)***	**61(.1)***	**1(.1)***
LS Grain-based desserts	58(.7)	7(.4)	35(.7)	0(.1)	48(.9)*	13(.6)*	32(.7)*	7(.4) *
LS Candy	30(.6)	40(.6)	30(.6)	0(.1)	39(.5)*	30(.4)*	30(.4)*	1(.1)*
LS Flavored yogurt	17(.6)	75(.6)	3(.3)	5(.3)	4(.3)*	37(.6)*	59(.6)*	0(.0)*
LS Dairy-based desserts	25(.8)	3(.2)	72(.8)	0(.0)	5(.2)*	8(.3)*	83(.4)*	5(.2)*
LS Ready-to-eat cereal	73(.4)	4(.2)	1(.1)	22(.4)	82(.3)*	3(.2)*	0(.0)*	15(.3)*
LS food group total[3]	**50%**	**22%**	**19%**	**9%**	**41%**	**22%**	**38%**	**7%**

[1] Weighted unadjusted mean percent of no- and low-sugar product purchases in each category that contain low-calorie sweetener (LCS), caloric sweetener (CS), both or none (unsweetened). Means are weighted to be nationally representative. Percentages were calculated as the grams of household purchases from no- or low-sugar products containing each type of sweetener divided by total grams of no- or low-sugar product purchased, respectively, from that food or beverage group. Values are expressed as mean (SE).
[3] Total of selected beverage groups. Beverage groups selected are top beverage sources of added sugar.
[4] Total of selected food groups. Food groups selected are top food sources of added sugar.
* Significant compared to the same category in 2002, student's *t* test. (*P*<0.001 to account for sample size).

Data from the 2002-2014 Nielsen Homescan longitudinal panel of household purchases of consumer packaged goods.
Source: University of North Carolina calculation based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol for the 2002-2014 periods across the U.S. market. © The Nielsen Company, 2015.

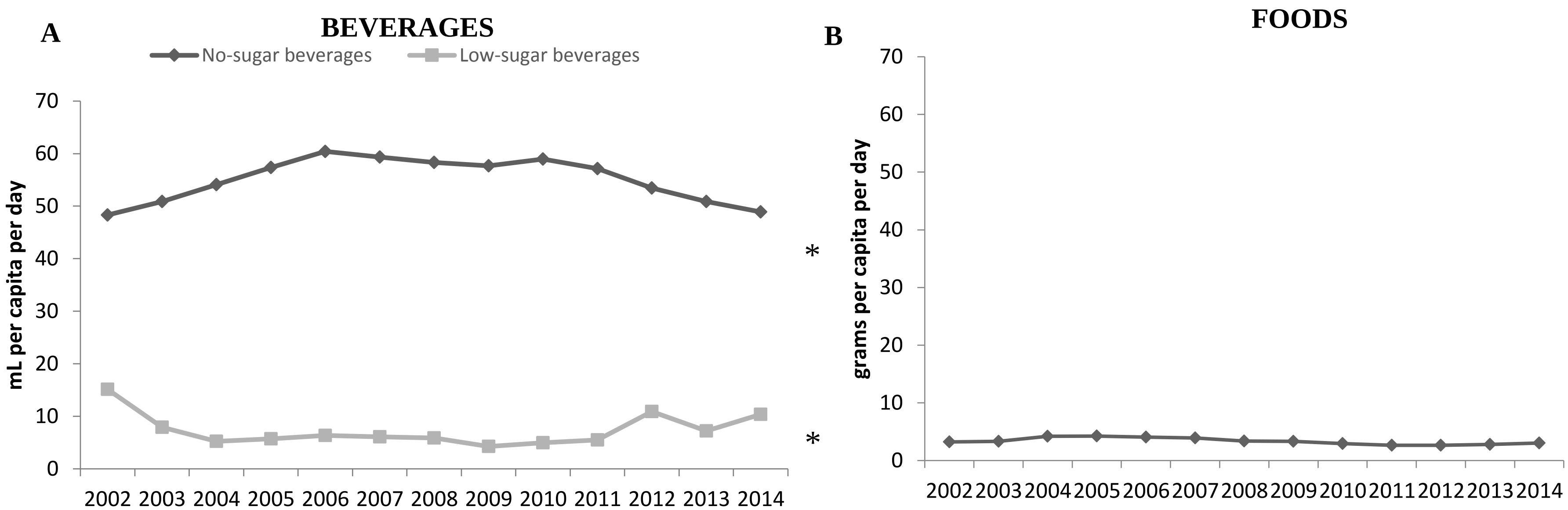
Table 3.4: Sociodemographic characteristics of U.S. households participating in the 2002-2014 Homescan Panel[1]

	2002		2004		2006		2008		2010		2012		2014		Total	
Household characteristics	**n**	**%[2]**														
Race/ethnicity[3]																
Non-Hispanic white	28,769	73%	28,624	72%	45,306	71%	45,523	71%	44,987	69%	44,268	68%	44,862	68%	529,373	70%
Non-Hispanic black	3,587	12%	3,461	12%	4,840	12%	5,003	12%	5,059	12%	5,356	13%	5,738	13%	61,522	12%
Hispanic	2,191	10%	2,312	11%	3,010	11%	2,872	12%	2,962	12%	2,933	13%	3,150	13%	36,199	12%
Non-Hispanic Other	1,287	5%	1,362	5%	2,227	6%	2,335	6%	2,595	6%	2,769	6%	2,922	7%	28,854	6%
Income[4]																
<185% FPL	6,082	26%	6,792	27%	10,573	27%	10,428	27%	10,572	29%	12,091	30%	12,128	28%	127,976	28%
185%-<400% FPL	16,131	35%	14,768	33%	21,955	32%	24,178	35%	24,950	37%	23,035	35%	24,999	36%	280,431	35%
≥400% FPL	13,621	39%	14,199	40%	22,855	41%	21,127	38%	20,081	34%	20,200	36%	19,545	36%	247,541	38%
Head of Household Education[5]																
Less than high school diploma	913	11%	761	8%	963	8%	861	7%	743	6%	757	7%	743	7%		2%
Graduated high school	7,445	19%	7,257	18%	10,302	17%	10,137	16%	9,650	15%	9,049	14%	10,602	16%	119,442	16%
Some College	11,547	31%	11,307	31%	17,471	30%	16,757	28%	16,297	28%	16,160	28%	16,397	28%	198,269	29%
Graduate College	10,746	31%	11,046	32%	18,144	34%	18,933	36%	19,544	37%	19,855	38%	19,018	35%	221,193	35%
Post College graduate	5,261	16%	5,456	16%	8,598	17%	9,129	18%	9,447	18%	9,566	19%	9,972	19%	107,315	18%
Household Composition																
Single adult, no children[6]	9,485	26%	9,761	26%	13,476	26%	14,363	27%	14,432	26%	13,846	27%	14,285	27%	168,022	27%
Single adult, with children	1,125	4%	946	3%	1,485	3%	1,307	2%	1,136	3%	908	2%	1,069	2%	14,871	3%

Multiple adults, no children	15,744	41%	16,449	41%	25,845	41%	26,744	41%	27,750	43%	28,493	43%	28,975	43%	319,239	42%
Multiple adults, with children	9,480	30%	8,603	30%	14,577	30%	13,319	29%	12,285	28%	12,079	28%	12,343	27%	153,816	29%

[1] Data from the 2002-2014 Nielsen Homescan longitudinal panel of household purchases of consumer packaged goods.
[2] Percentages of households weighted to be nationally representative
[3] Race/ethnicity self-reported by head of household
[4] Income calculated as a percent of the Federal Poverty Limit (% FPL)
[5] Highest level of education self-reported by male or female head of household
Data from the 2002-2014 Nielsen Homescan longitudinal panel of household purchases of consumer packaged goods.
Source: University of North Carolina calculation based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol for the 2002-2014 periods across the U.S. market. © The Nielsen Company, 2015.

Figure 3.4: Weighted mean no- and low-sugar beverage and low- sugar food purchases per capita per day, Homescan 2002-2014[1]



[1] Unadjusted weighted means of U.S. household (A) Sugar-free and low-sugar beverage purchases (mL per capita per day) and (B) low-sugar food (g per capita per day) purchases. Sugar-free beverages were defined as all beverages with 0g of sugar, and low-sugar beverages were defined as those with sugar >0g – 2.5g/100mL, in examined groups (soft drinks and energy drinks; fruit drinks and flavored waters; and ready-to-drink teas). Low-sugar foods were defined as all foods with ≤5g/100g of sugar in examined groups (grain-based desserts, dairy-based desserts, candy, flavored yogurts, and ready-to-eat cereal.) Weighted to be nationally representative.
* Significant linear trend, determined using survey-weighted linear regression. *P*<0.001 to account for sample size
Data from the 2002-2014 Nielsen Homescan longitudinal panel of household purchases of consumer packaged goods.
Source: University of North Carolina calculation based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol for the 2002-2014 periods across the U.S. market. © The Nielsen Company, 2015.

Table 3.5: Number of barcoded products, classified by low-sugar and by presence of sweetener, Homescan 2002 and 2014[1]

	2002								2014							
	LS				non-LS				LS				non-LS			
	CS only	LCS only	CS+LCS	none	CS only	LCS only	CS+LCS	none	CS only	LCS only	CS+LCS	none	CS only	LCS only	CS+LCS	none
Soft drinks and energy drinks	52	1481	4	291	4415	29	45	25	57	2198	20	616	3989	91	757	113
Fruit drinks, sports drinks, and flavored waters	21	82	5	35	2458	6	126	5	7	308	7	77	2245	34	846	44
tea	6	41	9	19	318	8	7	3	3	184	22	119	753	33	242	10
Beverage group total[2]	79	1604	18	345	7191	43	178	33	67	2690	49	812	6987	158	1845	167
Grain-based desserts	62	23	84	4	7440	2	205	9	70	23	133	94	10845	0	454	34
candy	116	161	231	5	6229	4	339	4	148	203	242	13	10600	7	1033	16
Flavored yogurt	4	46	2	1	833	72	258	3	14	48	96	17	2269	47	562	6
Dairy-based desserts	53	11	67	0	3605	3	10	1	26	43	129	0	5177	6	89	3
Cereal, RTE	139	1	2	138	2314	--	71	11	133	19	2	101	3475	0	56	36
Food group total[3]	374	242	386	148	20421	81	883	28	391	336	602	225	32366	60	2194	95

[1]Uniquely barcoded low-sugar products from 8 food and beverage categories were classified as low-sugar, and separately placed into mutually exclusive categories by presence of sweetener; caloric sweeteners (CS), low-calorie sweeteners (LCS), both, or none (unsweetened). Low-sugar beverages were defined as all beverages with 0g of sugar in examined groups (soft drinks and energy drinks; fruit drinks and flavored waters; and ready-to-drink teas). Low-sugar foods were defined as all foods with ≤5g/100g of sugar in examined groups (grain-based desserts, dairy-based desserts, candy, flavored yogurts, and ready-to-eat cereal.)

[2] Total of selected beverage groups. Beverage groups selected are top beverage sources of added sugar.

[3] Total of selected food groups. Food groups selected are top food sources of added sugar.

Data from the 2002-2014 Nielsen Homescan longitudinal panel of household purchases of consumer packaged goods.

-- no products were identified.

Source: University of North Carolina calculation based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol for the 2002-2014 periods across the U.S. market. © The Nielsen Company, 2015.

CHAPTER 4. RACE/ETHNIC AND INCOME DISPARITIES IN U.S. HOUSEHOLD LOW-SUGAR FOOD AND BEVERAGE PURCHASES FROM 2002- 2014

Overview

Background: Public and private efforts to reduce added sugar consumption have aimed to increase store purchases of low-sugar products, however race/ethnic and income differences in low-sugar product purchases have not been examined

Objective: We examined differences in nationally representative estimates of U.S. household packaged no- and low-sugar product purchases in selected food groups by household race/ethnicity and income from 2002-2014.

Methods: This study used the 2002-2014 Nielsen Homescan Consumer Panel to examine low-sugar packaged food and beverage purchases. We examined household (n=152,987) no- and low-sugar product purchases from eight food and beverage groups identified as top sources of added sugar. To define low-sugar products, the U.K. Food Standard Agency cut points were used; purchases of low-sugar foods (sugar <5g/100g), low-sugar beverages (sugar >0g-2.5g/100ml) and sugar-free beverages (sugar 0g) were examined separately. By household race/ethnicity (Non-Hispanic (NH) white, NH black, Hispanic) and income [low-income (<185% federal poverty limit (FPL)), middle-income (185-<400% FPL), and high-income (≥400% FPL)], we examined survey-weighted nationally representative percent of households that purchased low-sugar products. We also examined mean no- and low-sugar beverage purchases and low-sugar food purchases as a percent of total purchases from our examined beverage and food

groups, respectively. We also examined survey-weighted nationally representative means in the percent of low-sugar beverage purchases and low-sugar food purchases that contained caloric sweeteners (CS), low-calorie sweeteners (LCS), both, or neither. For the above cross-sectional analyses, students *t* tests were used to test for within year differences between race/ethnic and income groups in 2002 and 2014. Differences between race/ethnic and income groups in the change in low-sugar beverage and low-sugar food purchases from 2002-14 were tested using ordinary least squares linear regression.

Results: Across study years, a lower percent of NH black, Hispanic and low-income households purchased sugar-free beverages than NH white and high-income households, respectively. In 2014, mean sugar-free beverage purchases from our examined beverage groups were lower for Hispanic (17±.4% $p<.001$) and NH black (23±.7% $p<.001$) households than for NH white households (34+0.2%). There were not consistent differences in low-sugar beverage purchases across subgroups. There was a small difference in low-sugar food purchases between NH white (5±.06%) and NH black (3±.09% $p<.001$), and between higher income (6±.1%) and lower income (4±.1% $p<.001$) households in 2014. NH black and low-income households purchased a lower proportion of sugar-free beverages that contained LCS-only, and a higher proportion that were unsweetened, than NH white and high-income households.

Conclusions: Over a time period where there were public and private efforts to promote no and low-sugar alternatives, sugar-free beverage and low-sugar food purchases were lower for NH black, Hispanic, and low-income households in our examined food groups.

Introduction

Race/ethnic and socioeconomic disparities in excess sugar consumption and related diseases such as obesity and diabetes have been well documented. [2,83,84,115,126] Although there have been recent declines in added sugar consumption, non-Hispanic (NH) black and low-income adults continue to consume more added sugars than NH white and high-income adults. [6,127] There have been numerous public and private efforts over the past 15 years to shift store purchases towards low-sugar alternatives to the foods and beverages that contribute the most sugar to the U.S. diet. [6,41,48,50,51,85,101,128,129] A central goal of national efforts are to reduce sugar consumption for the entire U.S. population. [41,48,85] However these efforts, including reformulating products, marketing efforts, and educational efforts, may not equitably impact low-income and NH black and Hispanic households. [5,8–11,16–23]

It is unknown there are race/ethnic and income disparities in household purchases for a broad range of no- and low-sugar products. NH black, Hispanic, and low-income adults consume more sugar-sweetened beverages and fewer low-calorie sweeteners (LCS) than NH white and high-income adults. [75,77–80] However, not all no-and low-sugar products contain LCS; no- and low-sugar products may be unsweetened or contain caloric sweeteners (CS).[130] Further, LCS sweetened products are not necessarily low in sugar. In a previous study examining this broader range of no- and low-sugar products in eight key food group sources of added sugar, over two thirds of U.S. households purchased ≥1 serving per week of no- and low-sugar products.[130] Further, mean U.S. household sugar-free beverage purchases rose significantly from 2002 to 2014.[130] Determining whether no-and low-sugar products are being purchased to the same extent across household race/ethnicities and incomes is needed to inform future interventions and policy efforts that aim to promote no- and low-sugar products.

A key debate around these efforts to increase no- and low-sugar purchases is whether LCS sweetened products are an acceptable alternative to their full sugar counterparts. More than three quarters of low-sugar beverage purchases and more than half of low-sugar food purchases contained low-calorie sweeteners.[130] Currently lower income, and non-Hispanic black and Hispanic children and adults have a lower prevalence of LCS consumption than non-Hispanic white children and adults. [75] In addition to not knowing whether there are race/ethnic and income differences in no- and low-sugar product purchases, we also do not know whether these subpopulations have lower LCS purchases *among* no- and low-sugar product purchases. Such baseline information can be used to monitor whether future efforts to reduce disparities in no- and low-sugar product purchases have the unintended consequence of increasing LCS purchases in these populations.

To address these gaps, we examined no- and low-sugar packaged food purchases in eight categories identified as top contributors of added sugar to the U.S. diet. [6,85] We examined purchases in a nationally representative sample of U.S. households to determine differences across race/ethnicity and income in U.S. household low-sugar product purchases. We then examined the percent of no- and low-sugar product purchases that contain different types of sweeteners.

Methods

Study design and population

This analysis used the 2002-2014 Nielsen Homescan panel (Homescan), a longitudinal study of packaged food and beverage purchases by U.S. households. [104] Households were provided with a barcode scanner and instructed to scan all items after each shopping trip. This includes purchases from all store types, such as supermarkets, grocery, warehouse-club, mass-merchandise, convenience and drug stores.

Households are sampled from 76 markets (52 metropolitan and 24 non-metropolitan geographical areas). Households must report for ≥10 months in a year (mean 4.2y), after which they may exit the study at any time. New households are enrolled to replace households that drop out and rebalance the sociodemographic characteristics of the panel. Race (white, black or other), Hispanic ethnicity (yes/no) and highest level of education are self-reported by the male and female heads of households.[109] Multiracial households are categorized by the race/ethnicity of the head of household, which is self-identified by the participants. We then collapsed households into four race/ethnic groups: NH white, NH black, Hispanic, and Other.[109,110] Household income is also self-reported.

Household purchasing was analyzed by year. Year-level household observations were excluded if they contained >1 quarter of unreliable reporting (2.4% excluded). A household's quarter was deemed unreliable if it included ≥4 weeks of inconsistent reporting (<$45/month for a single person household, <$135/month for a multiple person household). [105] The final analytical sample included 655,948 household-year observations, from 152, 987 unique households. This secondary analysis was exempt from IRB approval.

Food and beverage purchasing

Households scanned the barcode of each purchased packaged food or beverage. The product's barcode, product weight (grams) or volume (mL), and product specific attributes were recorded. Each barcode recorded is linked to a corresponding Nutrition Facts Panel (NFP) and ingredients list. Methodology for this process has been described elsewhere. [14,106]

Food and beverage groups

We examined food and beverage purchases from eight key groups, which represent the top sources of store-bought added sugars in the U.S. [6] These eight groups are soft drinks and energy drinks; fruit drinks, sports drinks and flavored waters; ready-to-drink teas; grain-based desserts; candy; flavored yogurts; dairy-based desserts; and ready-to-eat cereals. Powders and concentrates were excluded because we cannot confirm whether these products remain sugar-free or low-sugar when consumed, as sugar may be added during preparation.

Classifying products as low-sugar and by presence of sweetener

Previous work classified products in our examined food groups separately as sugar-free beverages, low-sugar beverages, or low-sugar foods; this process is summarized below.[130] All products in our examined groups were also classified by presence of sweetener. A detailed table of food and beverage products classified as low-sugar and by sweetener has been previously published and is provided in **Supplemental Table 1.** (cite paper 1)

Classifying products as no- or low-sugar

There is currently no U.S. definition of 'low sugar'. [12] We defined low-sugar foods using the U.K.'s Food Standards Agency criteria for low-sugar, ≤5g of sugar per 100g of product. The Food Standards Agency cut point for low-sugar beverages is ≤2.5g of sugar per 100 mL. We examined sugar-free beverages separately from low-sugar beverages, because there has been extensive focus on sugar-free beverages. [1,36,41,53–56] Thus sugar-free beverages were classified as having 0g of sugar, and low-sugar beverages were classified as those with >0g - ≤2.5g of sugar per 100mL. NFP rounding rules allow products with <0.5g of sugar per serving to be reported as 0g, thus these beverages were classified as sugar-free.

Products which met our criteria for sugar-free and low-sugar were flagged using SAS (SAS version 9.3, SAS Institute Inc, Cary, NC).

Classifying no- and low-sugar products by presence of LCS or caloric sweeteners

Sugar-free and low-sugar products were classified according to whether they contained caloric sweeteners (CS), low-calorie sweeteners (LCS), both, or no sweeteners. (**Supplemental Table 1)** A keyword search was performed on the ingredient lists of the products examined to identify presence of sweeteners. [65] Caloric sweeteners were defined as those that provide ≥3.8 kcal per gram. Fruit juice concentrate was included as a caloric sweetener unless the ingredients list also included water. This reflects the FDA's definition of fruit juice concentrate as an added sugar, which includes fruit juice concentrate but excludes it when it has been diluted to single strength juice.[65] Low-calorie sweeteners were defined as those with <3.8 kcal/g or those that are used in such small quantities that they provide negligible calories. [27,73] A complete list of keywords used to identify sweeteners has been previously published. [65]

Statistical Analysis

Trends were analyzed using survey commands in Stata 14 (Stata Corp, College Station, TX) to account for survey design while accounting for repeated observations, and projection weights were used to create nationally representative estimates. Projection weights were created using iterative proportional fitting. The Current Population Survey's (CPS) household data were used to create nationally representative estimates based on the CPS distribution of household size, head of household age, presence of children, and the joint distribution of race (white, black, Other), Hispanic origin, and household income. [112]

Proportion of households that purchased no- and low-sugar products

We first explored the percent of households that purchased sugar-free beverages, low-sugar beverages, or low-sugar foods were examined by race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, and Other), by household income (<185% federal poverty limit (FPL), 185% FPL-400% FPL, >400% FPL) in each year from 2002 to 2014. While consumers are typically identified as those who consume any amount in a 24 hr period, Homescan captures an entire year of purchases. Thus, we defined purchasers in each year as households that purchased an average of $\geq$1 serving per week for that year to meaningfully examine the proportion of households that purchased low-sugar products. [27] A serving was defined as 50g for foods and 100mL for beverages. This method has been previously published. [27] Survey weighted proportions stratified by race/ethnicity and income were determined for each year. For each year, a student's t-test was used to test differences across race/ethnicity and across income.

Household purchases of no- and low-sugar products

We examined survey weighted mean sugar-free beverage, low-sugar beverage and low-sugar food purchases separately, stratified by race/ethnicity and by household income for each year from 2002 through 2014. We measured household no- and low-sugar beverage purchases as a percent of total purchases (mL) from our three beverage groups, and low-sugar food purchases as a percent of total purchases (g) from our five examined food groups to control for differences in total purchase amounts across households and variance in household size. We also examined no-and low-sugar product purchases by volume (mL or g) per capita per day. We further explored race/ethnic and income differences in household purchases of no- and low-sugar products by food and beverage group. Students *t*-tests were used to test for significance in each year between race/ethnicity groups and between income groups.

Household no- and low-sugar product purchases containing different types of sweeteners.

We examined survey-weighted means in the proportion of sugar-free beverage, low-sugar beverage and low-sugar food purchases that contained different types of sweeteners. Students *t*-tests were used to test for significance in each year, across race/ethnicity and income.

Changes in no- and low-sugar product purchases over time

To test whether changes in low-sugar food and beverage purchases were different across household race and income, survey weighted linear regression models with clustering at the household were used, regressing low-sugar product purchasing on year (dummy variable), household sociodemographic characteristic (race or income), and an interaction of the demographic and year. For all analysis, $P<0.001$ was considered significant, to account for multiple comparisons and to account for the large sample size. [27,109]

Results

The sociodemographic characteristics of the study sample are presented in **Supplemental Table 2.** The Homescan study population has a higher proportion of NH white and high-income households, and the NH black and Hispanic households are higher income than the general U.S. population. All results are weighted to generate nationally representative estimates.

Race/ethnic and income differences in the proportion of households that purchased no- and low-sugar products

In 2014, 74±.2% of NH white households purchased sugar-free beverages, while 60±.9% of NH black households (p<.001 vs NH white) and 68±1.2% of Hispanic households (p<.001 vs NH white) purchased sugar-free beverages. (**Figure 1a)** Similarly, across the study period a greater percent of high-income households purchased sugar-free beverages than middle and low-income households. (**Figure 1d**) In 2002 there was no difference in low-sugar beverage purchases across income groups, however in 2014 high-income households had significantly lower low-sugar beverage purchases than middle and low-income households (**Figure 1e)**

In 2014, 53±.3% of NH white households, 47±1.3% of Hispanic households (p<.001 vs NH white), and 37±.9% of NH black households (p<.001 vs NH white) purchased low-sugar foods. (**Figure 1c)** A higher proportion of NH white households purchased low-sugar foods across the survey period. Across the study period, a lower proportion of low-income (44±.7%) households purchased low-sugar foods than high-income (53±.5%, $p<.001$) households. (**Figure 1f)**

Household no- and low-sugar purchases by race/ethnicity and income.

In 2014, sugar-free beverage purchases were greatest for NH white households (34±.2%), followed by Hispanic (23±.7%, $p<.001$) and NH black (17±.4%, $p<.001$) households. (**Figure 2a)** Sugar-free beverage purchases by high-income households (38±.3%) were significantly higher than middle income (28±.3%, $p<.001$) and low-income (21±.4%, $p<.001$) households in 2014 (**Figure 2d)**. The change in sugar-free beverage purchases from 2002- 2014 was not significantly different between race/ethnic and income groups. (**Table 2)** There were not consistent differences in low-sugar beverage purchases across race/ethnic and income groups across the years examined. **(Figure 2b and 2e)** The volume of sugar-free beverage purchases per capita per day (mL/capita/day) were similarly greatest for NH white households and for high-income households in each year. There were not consistent differences in low-sugar beverages per capita per day. (**Supplemental Figure 1)**

In 2014, there was a small but significant difference in low-sugar food purchases between NH white (5±.06) and NH black (3±.09%, $p<.001$), and higher income (6±.1%) and lower income (4±.1%, $p<.001$). (**Figure 2c and 2f)** These differences occurred in each year of the study period.

Race/ethnic and income differences in no- and low-sugar purchases by presence of sweeteners

More than two thirds of sugar-free beverage purchases contained LCS across race/ethnic and income groups. However, NH black household sugar-free beverage purchased a higher proportion of LCS-only beverages (68±1.2%) than NH white households (84±.3%, p<.001), and lower income households purchased a lower proportion (77±.9%) than high-income households (84±.4%, p<.001) households in 2002. This pattern was similar in 2014. (**Table 2)** NH black and Hispanic households sugar-free beverage purchases contained a higher proportion of unsweetened sugar-free beverages in 2002 (17±1%, 14±1.2% respectively) and in 2014 (22±.9%,18±.9% respectively) than NH white households

In 2002, CS-only low-sugar beverage purchases represented more than 40% of low-sugar beverage purchases; Hispanic households had the highest purchases of these beverages (53±1.6%). In 2014, fewer than 12% of low-sugar purchases were CS-only across race/ethnic groups. In that year Hispanic households had higher purchases of CS+LCS low-sugar beverages (30±1.1%) than NH white (25± 0.3%, p<.001) or NH black households (23±0.8%, p<.001).

In 2014, lower income and Hispanic households purchased a higher proportion of low-sugar foods containing CS-only (46±.8% and 44±1.3% respectively), compared to higher income (36±.5%, p<.001) and NH white (40±.3%, p<.001). (**Table 2**)

Race/ethnic and income differences in low-sugar product purchases by food group

In 2014, NH black household purchases of sugar-free soft drinks and energy drinks (22±.6%), sugar-free fruit drinks (11±.4%), and sugar-free RTD teas (27±.4%) were significantly lower than NH white households (39±.2%, 17±.2%, and 27±.4%, respectively. p<.001 for all). (**Table 2)** NH white households also had a larger increase in sugar-free fruit drink (+9±0.2%) and sugar-free RTD teas (+10±0.3%) from 2002 to 2014 than NH black households (+5±0.5% and +1±1.1% respectively). Higher income households purchased more sugar-free soft drinks and energy drinks, fruit drinks and flavored waters, and RTD teas than lower income households. Additionally, high-income households had a larger increase in sugar-free soft drink and energy drink purchases (+8±.7%) than middle (+6±.4%, p<.001) and low-income households (+4±.7%, p<.001).

Across survey years, there were significant differences in household purchases of low-sugar flavored yogurts and low-sugar RTE cereals by race/ethnicity and income. In 2014, NH black and low-income households purchased significantly fewer low-sugar flavored yogurts and low-sugar RTE Cereals than NH white and higher income households, respectively. (**Table 1)** Purchases of low-sugar grain-based desserts, low-sugar candy, and low-sugar dairy based desserts were similar across race/ethnic and income groups.

Discussion

This study presents novel nationally representative estimates of no- and low-sugar product purchases by household race/ethnicity and income. Examining purchases from eight food groups that are top sources of store-bought added sugars, our study found that from 2002 through 2014, NH black and Hispanic households had significantly lower sugar-free beverage purchases than NH white households. Low- and middle-income households also had lower sugar-free beverage purchases than high-income households. There were also small but significant differences in low-sugar food purchases by race/ethnicity and income. However, there were not consistent differences in low-sugar beverage purchases. Throughout the study period, NH white and high-income households purchased a higher proportion of sugar-free beverages containing LCS than NH black and low-income households, respectively. There were significant race/ethnic and income differences in the change in no- and low-sugar product beverages in certain beverage groups over time.

Throughout the study period, sugar-free beverage purchases were significantly higher for NH white households compared to NH black and Hispanic households and higher for high-income households than middle and low-income households. These findings are consistent with findings that NH white children and adults had higher consumption of diet beverages in 2009-10. [58] It also parallels consistent findings of higher sugar-sweetened beverage consumption by NH black, Hispanic, and low-income children and adults. [131–133] Despite increasing public concern about sugar-sweetened beverages, [5] cost of sugar-free beverages, education, marketing, health literacy, and preferences may also contribute to these disparities.[16,134,135] While higher sugar-sweetened beverage purchasing among low-income consumers has been partially attributed to their low cost, it is unknown whether sugar-free beverages are more expensive than their sugary counterparts across markets. [136,137] Even small price gaps have been shown to shift purchases of beverages, particularly among low-income consumers. [138–140]

There were not consistent race/ethnic or income differences in low-sugar beverage purchases from our selected beverage groups. Low-sugar purchases in absolute terms across subgroups were low; mean low-sugar beverage purchases were less than 20 mL per capita per day across race/ethnic and income groups. We have previously found that a smaller number of beverages were classified as low-sugar in our examined beverage groups than were classified as sugar-free. (cite paper 1) Key efforts to promote low-sugar beverages, including Balance Calories initiative which includes the American Beverage Association, the Coca-Cola company, Dr. Pepper Snapple Group, Pepsi-Co and the Alliance for Healthier Generation, began after our study period. [103] It is unclear whether differences in low-sugar purchases across race/ethnic and income groups will emerge, similar to those that exist for sugar-free purchases, as the number of low-sugar beverages increases.

Low-sugar food purchases remained under 6% of food purchases in our examined food groups across race/ethnic and income groups from 2002-2014. There were significant disparities by race and income in purchases of low-sugar yogurts and RTE cereals, but no substantial differences in low-sugar grain-based desserts, dairy based desserts, or candies. Previous studies have found that there has been little change in consumption of LCS-containing foods from 2000 through 2008. [76] Our studies add to these findings by demonstrating that there has not been an increase in a broader range of low-sugar foods. Previous studies have found that television advertising promotes foods higher in sugar, including higher sugar RTE cereals, towards NH black and low-income households.[16,88,141] Low-sugar foods may also be more likely to have a front of package nutrient claim, which may influence more educated and higher income consumers. [57,120,142] While access may also be an issue, previous studies have not found racial differences in the quality of packaged foods purchased in different types of stores. [110] The new U.S. nutrition facts panel includes a line for added sugars and is supposed to be implemented in 2018. [122] If implemented, this may widen disparities in low-sugar food purchases between consumers that use food labels to make purchasing decisions and those who do not. [86,102] Women, higher educated and higher income consumers are more likely to read and use nutrition labels. [22,86,87]

Across our study period, NH white and high-income households purchased a higher proportion of LCS sweetened sugar-free beverages. These results are consistent with previous studies that NH black and low-income households purchase and consume fewer beverages with LCS. [27,74,75] NH black households purchased significantly more unsweetened low-sugar beverages. Unsweetened low-sugar beverages in our study included flavored tea, sparkling water, seltzer, and flavored waters. While bottled water was not included as a sugar-free beverage in our study, this is complementary with findings that NH black and Mexican American adults consume more bottled water than NH whites. [143] While in 2002 Hispanic households purchased more CS-only low-sugar beverages, by 2014 there were no race/ethnic differences in CS-only low-sugar beverage purchases.

A central concern about policies and interventions that aim to increase sugar-free and low-sugar beverage purchases is that they may increase LCS consumption among populations that currently consume less LCS. [63,65,68] Findings on the relationship between LCS consumption and diet quality, obesity and other health outcomes have been discrepant, and whether LCS is an acceptable substitute for sugary beverages is a matter of ongoing debate. [67–69,71,94,144] Our results indicate that when NH black and low-income households purchase sugar-free beverages, they purchase fewer containing LCS but there is no difference in purchases of unsweetened sugar-free or low-sugar beverages. However, this could be shifted by changes in these beverages' price, availability, or marketing. Our findings establish nationally representative baseline trends which can be used to examine whether future efforts to promote sugar-free and low-sugar beverages increase purchasing of unsweetened or LCS containing options.

While the change in sugar-free beverage purchases over time did not significantly differ across race/ethnic or income groups, disparities did widen in certain beverage groups. High-income households had a larger increase in low-sugar soft drink and energy drink purchases than low-income households. NH white households had a larger increase in purchases of low-sugar fruit drinks and RTD teas than NH black households. Although widening disparities are a concern, studies are discrepant on whether purchasing sugar-free beverages leads to lower overall sugar intake and lower energy intake. [32,68,71,91,94,145–147] A better understanding of the relationship between purchasing sugar-free beverages, total sugar intake, and health outcomes across race/ethnic groups is needed in order to contextualize the findings that there are widening race/ethnic disparities in certain sugar-free beverage purchases.[29,69,146,148] Future research should also consider the patterns of beverages and foods purchased alongside sugar-free beverages where widening disparities are observed. [91,149]

While survey weights are used to create nationally representative estimates, households that participate in Homescan must scan all groceries at home after each shopping trip. A key limitation of this study is that households that are able to handle the considerable study burden may not be representative of households nationally in ways that are not accounted for in the weights, particularly for low-income households. Further, households may underreport beverages and foods that are purchased and consumed on the go (e.g., a single bottle of soda or candy purchased and consumed away from home), thus underreporting of these foods and beverages is possible.

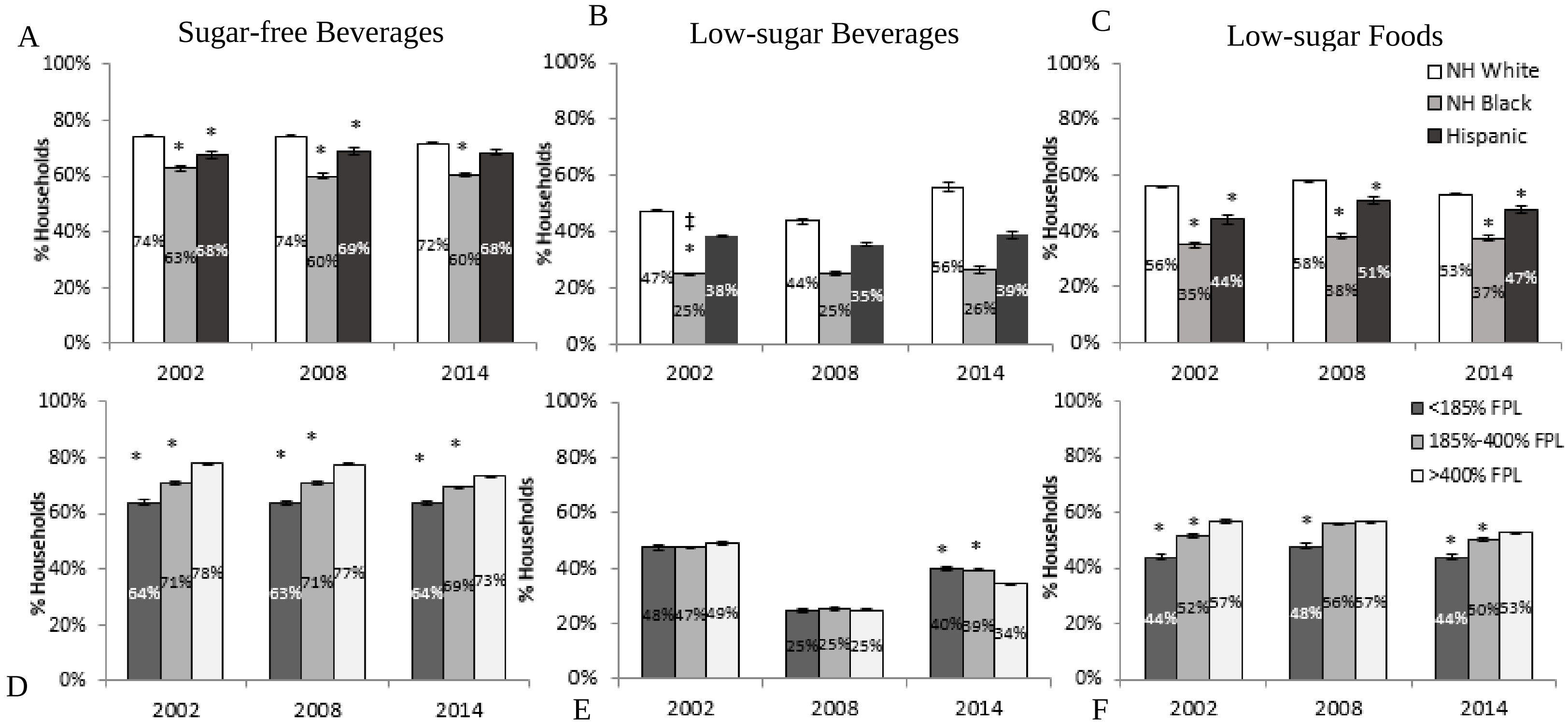
Our study also only examined products with barcodes that were purchased and brought into the home; it did not examine foods purchased away from home (e.g. at school, restaurants), foods purchased and consumed before returning home, or non-packaged foods (e.g. loose produce). By assessing foods and beverages purchased in stores, rather than assessing total diet, certain beverage or food groups that are more frequently consumed away from home may be underrepresented. Further our dataset does not report whether purchases are consumed, and food waste may vary differently across product groups, particularly for foods. Importantly, food waste might differ by sociodemographic characteristics, particularly by household income, yet race/ethnic and income differences in consumer-level food waste remain understudied. Thus, our results should only be interpreted as an analysis of food purchases, and not of diet as consumed. Finally, there is currently no universally accepted definition of a low-sugar product, which limits study generalizability.

Despite these limitations, a major strength is that our study is unique in using objective purchasing measures to examine no- and low-sugar product purchases. This avoids bias from dietary self-reported methods which can confound studies on disparities in sugar consumption and diet quality. Further, we measured purchases over an entire year; many low-sugar products may be episodically consumed, and so 24 hr recalls may not accurately estimate usual intake. Finally, product-specific sugar contents and ingredients list allow for accurate classification of low-sugar products, and products that contain low-calorie sweeteners. Publicly available datasets lack brand specific and product specific information, instead relying on aggregated estimates to determine the sugar content of each food item, making it difficult to accurately identify whether a product is 'low-sugar' or contains LCS. [14,15]

In conclusion, this study provides novel, nationally representative trends in no- and low-sugar food and beverage purchases by household race/ethnicity and household income. We found that there are persistent disparities in sugar-free beverage purchases and low-sugar food purchases for NH black, Hispanic, and low-income households. We examined these purchases over a period where there were substantial national efforts to promote no- and low-sugar products. Our findings indicate that no- and low-sugar product purchases are not penetrating the population equitably. Future public efforts such as the new nutrition facts panel should ensure that they do not contribute to widening disparities. Further research is needed to examine the relationship between no- and low-sugar food and beverage purchases and overall diet quality, and whether race/ethnicity or income modify that relationship.

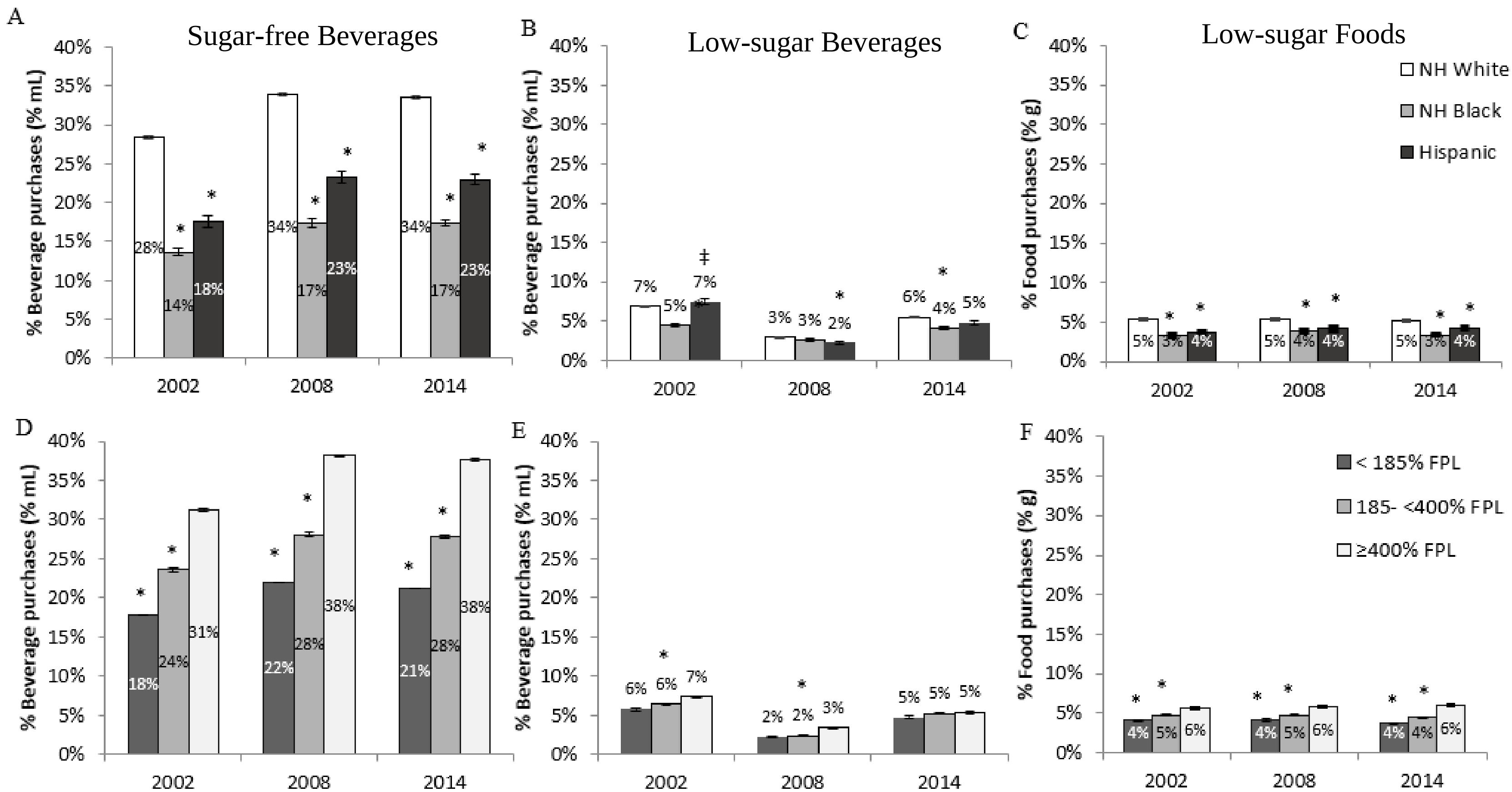
Tables and Figures

Figure 4.1: Weighted percent of U.S. Households that purchased no- and low-sugar products by household race/ethnicity and income, 2002-14[1]



[1] Values are weighted unadjusted means in the percent of households that purchased ≥1 serving/week of sugar-free beverages (A and D), low-sugar beverages (B and E) and LS foods (C and F). One serving was defined as 50g for food and 100mL for beverages. Sugar-free beverages were defined as those with 0g/100mL sugar in examined groups, low-sugar beverages were defined as those with <2.5g/100mL sugar in examined groups, and low-sugar foods were defined as those with ≤5g/100g of sugar in examined groups.* Significant compared to NH white (A, B and C) or high-income (>400% FPL) (D, E and F) Students t-test, *P*<.001 to account for sample size ‡ Significant compared to NH black. Students t-test, *P*<.001 to account for sample size Source: Data from the 2002-2014 Nielsen Homescan longitudinal panel of household purchases of consumer packaged foods. *University of North Carolina calculation based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol for the 2002-2014 periods across the U.S. market. The Nielsen Company, 2015.*

Figure 4.2. Weighted mean no- and low-sugar product purchases, by household race/ethnicity and income, 2002-2014[1]



[1]Weighted unadjusted mean household purchases of (A and D) sugar-free beverages, (B and D) low-sugar beverages (% mL from examined beverage groups) and (C and F) LS foods (% grams from examined food groups). Examined beverage groups were soft drinks and energy drinks; fruit drinks and flavored waters; and ready-to-drink teas, food groups were grain-based desserts, dairy-based desserts, candy, flavored yogurts, and ready-to-eat cereal. Sugar-free beverages were defined as those with 0g/100mL sugar in examined groups, low-sugar beverages were defined as those with <2.5g/100mL sugar in examined groups, and low-sugar foods were defined as those with ≤5g/100g of sugar in examined groups.

* Significant compared to NH white (A, B and C) or high-income (>400% FPL) (D, E and F) Students t-test, *P*<.001 to account for sample size

‡ Significant compared to NH black. Students t-test, *P*<.001 to account for sample size

FPL, Federal Poverty Limit; NH, Non-Hispanic Source: Data from the 2002-2014 Nielsen Homescan longitudinal panel of household purchases of consumer packaged foods. *University of North Carolina calculation based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol for the 2002-2014 periods across the U.S. market. The Nielsen Company, 2015.*

Table 4.1. Changes in no- and low-sugar food and beverage purchases by food group, by household race/ethnicity and income, 2002-2014[1]

	2002			2014			Change, 2002-2014		
	NH white	NH black	Hispanic	NH white	NH black	Hispanic	NH white	NH black	Hispanic
Soft drinks and energy drinks									
Sugar-free	33 (0.3)	17 (0.6)[a]	21 (0.9)[a]	39 (0.2)	22 (0.6)[a]	27 (0.8)[a]	6 (0.4)	5 (0.8)	6 (1.2)
Low-sugar	7 (0.1)	5 (0.3)[a]	9 (0.5)[c]	5 (0.1)	5 (0.3)	5 (0.4)[c]	-3 (0.2)	0 (0.4)[a]	-4 (0.6)[c]
Non low-sugar	58 (0.3)	77 (0.6)	70 (1.0)	55 (0.3)	73 (0.6)	67 (0.9)			
Fruit drinks, sports drinks, and flavored waters									
Sugar-free	9 (0.2)	6 (0.4)[a]	6 (0.6)[a]	17 (0.2)	11 (0.4)[a]	12 (0.6)[a]	9 (0.3)	5 (0.5)[a]	6 (0.8)[a]
Low-sugar	4 (0.1)	3 (0.2)[a]	3 (0.3)	7 (0.1)	3 (0.2)[a]	5 (0.4)[a c]	3 (0.2)	0 (0.3)[a]	2 (0.5)
Non low-sugar	87 (0.2)	91 (0.4)	91 (0.7)	75 (0.3)	86 (0.5)	83 (0.7)			
Ready to drink tea									
Sugar-free	17 (0.5)	10 (1.0)[a]	10 (1.2)[a]	27 (0.4)	11 (0.6)[a]	19 (1.1)[a]	10 (0.6)	1 (1.1)[a]	8 (1.6)[a]
Low-sugar	4 (0.3)	3 (0.5)	6 (1.2)	6 (0.2)	3 (0.3)[a]	5 (0.7)	1 (0.3)	0 (0.5)	-1 (1.4)
Non low-sugar	77 (0.58)	87 (1.0)	83 (1.6)	66 (0.4)	85 (0.7)	76 (1.3)			
Total Sugar-free Beverages	28(.2)	14(.5)[a]	18(.8)[a]	34(.2)	17(.4)	23(.7)	5 (0.3)	4 (0.6)	5 (1)
Total Low-sugar Beverages	7 (.1)	5 (0.2)	7 (0.4)[c]	6 (0.1)	4 (0.2)[a]	5 (0.3)	-1 (0.1)	0 (0.3)	-3 (0.5)[c]
Grain-based desserts									
Low-sugar	2 (0.1)	2 (0.1)	2 (0.3)	1 (0.0)	1 (0.1)	1 (0.1)	-1 (0.1)	-1 (0.2)	-1 (0.3)
Non low-sugar	98 (0.1)	98 (0.2)	98 (0.3)	99 (0.0)	99 (0.1)	99 (0.1)			
Candy									
Low-sugar	2 (0.1)	2 (0.2)	2 (0.2)	3 (0.1)	3 (0.2)	3 (0.3)	0 (0.1)	1 (0.2)	1 (0.4)
Non low-sugar	98 (0.1)	98 (0.2)	98 (0.2)	97 (0.1)	97 (0.2)	97 (0.4)			
Flavored yogurt									

LS	11 (0.2)	8 (0.5) [a]	6 (0.6) [a]	9 (0.1)	7 (0.5)[a]	6 (0.4)[a]	-2 (0.3)	0 (0.7)	1 (0.7)[a]
Non low-sugar	89 (0.2)	92 (0.5)	94 (0.6)	91 (0.2)	92 (0.7)	94 (0.5)			
Dairy-based desserts									
Low-sugar	4 (0.1)	3 (0.2)[a]	3 (0.5)	5 (0.1)	3 (0.2)[a]	5 (0.3)	1 (0.2)	0 (0.3)	2 (0.7)
Non low-sugar	96 (0.1)	97 (0.2)	96 (0.6)	94 (0.1)	97 (0.2)	94 (0.5)			
Ready-to-eat cereal									
Low-sugar	10 (0.1)	5 (0.3)[a]	5 (0.3)[a]	9 (0.1)	6 (0.2)[a]	6 (0.3)[a]	-1 (0.2)	0 (0.4)[a]	0 (0.5)
Non low-sugar	90 (0.1)	95 (0.3)	95 (0.3)	91 (0.1)	94 (0.3)	94 (0.4)			
Total LS Foods	5(.1)	3(.2)[a]	4(.1)[a]	5(.1) [a]	3(.1) [a]	4(.1) [a]	0 (0.1)	0 (0.2)	1 (0.3)

	2002			2014			Change, 2002-2014		
	<185% FPL	185%-<400% FPL	≥400% FPL	<185% FPL	185%-<400% FPL	≥400% FPL	<185% FPL	185%-<400% FPL	≥400% FPL
Soft drinks and energy drinks									
Sugar-free	21 (0.5) [b]	28 (0.3) [b]	36 (0.4)	25 (0.5) [b]	33 (0.3) [b]	44 (0.4)	4 (0.7)[b]	6 (0.4)[b]	8 (0.5)
Low-sugar	6 (0.3) [b]	7 (0.2)	8 (0.2)	5 (0.3)	5 (0.1)[b]	4 (0.1)	-1 (0.4) [b]	-2 (0.2) [b]	-4 (0.2)
Non low-sugar	73 (0.6)	65 (0.4)	56 (0.4)	70 (0.6)	62 (0.4)	52 (0.4)			
Fruit drinks, sports drinks, and flavored waters									
Sugar-free	5 (0.3) [b]	7 (0.2) [b]	10 (0.3)	13 (0.4)[b]	15 (0.3) [b]	19 (0.3)	7 (0.5)	7 (0.3)	9 (0.5)
Low-sugar	3 (0.2) [b]	3 (0.1) [b]	4 (0.2)	4 (0.2) [b]	5 (0.2) [b]	7 (0.2)	2 (0.3) [b]	2 (0.2)	3 (0.3)
Non low-sugar	92 (0.5)	90 (0.2)	86 (0.3)	83 (0.5)	80 (0.3)	74 (0.4)			
Ready to drink tea									
Sugar-free	11 (0.9) [b]	14 (0.6) [b]	18 (0.7)	16 (0.6) [b]	22 (0.4) [b]	30 (0.6)	5 (1.1)[b]	8 (0.7)	12 (0.9)
Low-sugar	5 (0.8)	4 (0.4)	4 (0.4)	4 (0.4)[b]	5 (0.4)	6 (0.3)	-1 (0.9)	1 (0.5)	1 (0.5)
Non low-sugar	85 (1.3)	82 (0.7)	77 (0.8)	81 (0.8)	73 (0.6)	64 (0.6)			
Total Sugar-free beverages	18(0.4) [b]	24(0.3) [b]	31(0.3)	21 (0.4) [b]	28 (0.3) [b]	38 (0.3)	3 (0.5)	4 (0.4)	6 (0.5)

Total Low-sugar beverages	6 (0.2)	6 (0.1)[a]	7 (0.2)	5 (0.2)	5 (0.1)	5 (0.1)	-1 (0.3)	-1 (0.2)	-2 (0.2)
Grain-based desserts									
Low-sugar	2 (0.2)	2 (0.1)	2 (0.1)	1 (0.1)	1 (0.1)	1 (0.1)	-1 (0.2)	-1 (0.1)	-1(0.1)
Non low-sugar	98 (0.2)	98 (0.1)	98 (0.1)	99 (0.1)	99 (0.1)	99 (0.1)			
Candy									
Low-sugar	2 (0.1)	2 (0.1)	2 (0.1)	2 (0.1) [b]	3 (0.1)	3 (0.1)	0 (0.2)[b]	0 (0.1)	1 (0.1)
Non low-sugar	98 (0.1)	98 (0.1)	98 (0.1)	98 (0.1)	97 (0.2)	97 (0.1)			
Flavored yogurt									
Low-sugar	7 (0.4) [b]	9 (0.2) [b]	12 (0.3)	6 (0.3) [b]	8 (0.2) [b]	11 (0.2)	-1 (0.49)	-1 (0.28)	-2(0.39)
Non low-sugar	93 (0.4)	91 (0.2)	88 (0.3)	93 (0.4)	92 (0.2)	89 (0.3)			
Dairy-based desserts									
Low-sugar	4 (0.3)	4 (0.1)	4 (0.1)	4 (0.2)	4 (0.1)	5 (0.1)	0 (0.3)	1 (0.2)	2 (0.2)
Non low-sugar	96 (0.3)	96 (0.1)	96 (0.2)	96 (0.2)	95 (0.2)	94 (0.2)			
Ready-to-eat cereal									
Low-sugar	8 (0.3)[b]	8 (0.2)	10 (0.2)	7 (0.2)	7 (0.1)	9 (0.2)	-1 (0.3)	-1 (0.2)	-1(0.3)
Non low-sugar	92 (0.3)	92 (0.2)	90 (0.2)	93 (0.2)	92 (0.2)	91 (0.2)			
Total Low-sugar Foods	4(.2) [b]	5(.1) [b]	6(.1)	4(.1) [b]	4(.1) [b]	6(.1)			

[1]Weighted unadjusted mean percent of purchases in each food group that are low-sugar and non-low-sugar (% mL for beverages, % grams for foods). Change is the change in the mean percent of purchases within each row from 2002 to 2014. Values are expressed as mean (SE). Low-sugar beverages were defined as all beverages with 0g of sugar in examined groups (soft drinks and energy drinks; fruit drinks and flavored waters; and ready-to-drink teas). Low-sugar foods were defined as all foods with ≤5g/100g of sugar in examined groups (grain-based desserts, dairy-based desserts, candy, flavored yogurts, and ready-to-eat cereal.)

[a] Significant compared to the NH white in same year, student's *t* test (*P*<0.001 to account for sample size)
[b] Significant compared to the high-income (≥400% FPL) in same year, student's *t* test (*P*<0.001 to account for sample size)
[c] Significant compared to the NH black in same year, student's *t* test (*P*<0.001 to account for sample size)
To examine changes over time, OLS linear regression was used to test significance (P<.001)
LS, Low-sugar; FPL, Federal Poverty Limit; NH, Non-Hispanic
Source: Data from the 2002-2014 Nielsen Homescan longitudinal panel of household purchases of consumer packaged foods. *University of North Carolina calculation based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol for the 2002-2014 periods across the U.S. market. The Nielsen Company, 2015.*

Table 4.2: Racial/ethnic and income differences in the percent of no- and low-sugar product purchases that contain low-calorie sweeteners, caloric sweeteners, both or none, 2002-14[1]

	2002				2014			
	CS	LCS	CS+LCS	None	CS	LCS	CS+LCS	None
Sugar-free Beverages								
Race/ethnicity								
NH white	5 (0.18)	84 (0.29)	0 (0.04)	10 (0.24)	2 (0.09)	81 (0.24)	3 (0.09)	14 (0.22)
NH black	14 (0.87)[a]	68 (1.16)[a]	1 (0.12)	17(0.95)[a]	4 (0.39)[a]	67 (1.01)[a]	6 (0.51)[a]	22 (0.92)[a]
Hispanic	9 (1.03)[a]	76 (1.45)[a]	0 (0.07)	14(1.17)[a]	4 (0.63)[a]	73 (1.14)[a]	4 (0.53)[a]	18 (0.95)[a]
Income								
<185% FPL	10 (0.62)[b]	77 (0.87)[b]	0 (0.16)	12 (0.69)	4 (0.35)[b]	75 (0.69)[b]	6 (0.33)[b]	16 (0.6)
185%-<400% FPL	7 (0.29)[b]	82 (0.42)[b]	0 (0.04)	11 (0.33)	3 (0.15)[b]	79 (0.36)	3 (0.18)[b]	15 (0.31)
≥400% FPL	5 (0.21)	84 (0.39)	0 (0.06)	11 (0.33)	2 (0.12)	80 (0.36)	2 (0.1)	15 (0.31)
Low-sugar Beverages								
Race/ethnicity								
NH white	44 (0.4)	1 (0.1)	4 (0.2)	0 (0)	11 (0.2)	6 (0.1)	25 (0.3)	0 (0)
NH black	42 (1.1)	1 (0.2)	5 (0.5)	0 (0)	11 (0.5)	4 (0.3)[a]	23 (0.8)	0 (0.1)
Hispanic	53 (1.6)[a c]	1 (0.2)[a]	4 (0.6)	0 (0)	8 (0.6)[a c]	5 (0.5)	30 (1.1)[ac]	0 (0.2)
Income								
<185% FPL	46 (1.1)	1 (0.2)	4 (0.4)	0 (0)	10 (0.4)[b]	4 (0.3)[b]	29 (0.8)[b]	0 (0.1)
185%-<400% FPL	45 (0.5)	1 (0.1)	4 (0.2)	0 (0)	12 (0.3)	6 (0.2)	26 (0.4)	0 (0.1)
≥400% FPL	45 (0.5)	1 (0.1)	5 (0.2)	0 (0)	8 (0.2)	6 (0.2)	23 (0.4)	0 (0.1)
Low-sugar Foods								
Race/ethnicity								
NH white	50 (0.37)	22 (0.31)	18 (0.28)	10 (0.19)	40 (0.31)	14 (0.2)	38 (0.3)	7 (0.15)
NH black	55 (1.35)[a]	21 (1.15)	18 (0.93)	6 (0.52)[a]	41 (1.08)	15 (0.71)	37 (1.04)	5 (0.43)[a]
Hispanic	53 (1.72)	21 (1.3)	19 (1.27)	8 (0.86)	44 (1.31)	14 (0.85)	36 (1.2)	5 (0.57)
Income								

<185% FPL	55 (0.95)[b]	18 (0.74)[b]	18 (0.71)	9 (0.48)	46 (0.75)[b]	14 (0.49)	34 (0.69)[b]	7 (0.34)
185%-<400% FPL	52 (0.5)[b]	20 (0.4)[b]	19 (0.36)	9 (0.24)	42 (0.44)[b]	14 (0.29)	37 (0.42)[b]	6 (0.19)[b]
≥400% FPL	47 (0.55)	25 (0.47)	19 (0.42)	9 (0.27)	36 (0.46)	15 (0.31)	41 (0.46)	7 (0.25)

[1] Percents are unadjusted means and were calculated as the grams of household purchases from each sweetener category divided by total grams of low-sugar beverages or foods purchased by households in that row. Values are expressed as mean (SE). Low-sugar beverages were defined as all beverages with 0g of sugar in examined groups (soft drinks and energy drinks; fruit drinks and flavored waters; and ready-to-drink teas). Low-sugar foods were defined as all foods with ≤5g/100g of sugar in examined groups (grain-based desserts, dairy-based desserts, candy, flavored yogurts, and ready-to-eat cereal.)

[a] Significant compared to the NH white in same year, student's *t* test (*P*<0.001 to account for sample size)

[b] Significant compared to the high-income (≥400% FPL) in same year, student's *t* test (*P*<0.001 to account for sample size)

[c] Significant compared to the NH black in same year, student's *t* test (*P*<0.001 to account for sample size

LCS, low-calorie sweeteners; CS, caloric sweeteners FPL, Federal Poverty Limit; NH, Non-Hispanic

Source: Data from the 2002-2014 Nielsen Homescan longitudinal panel of household purchases of consumer packaged foods. *University of North Carolina calculation based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol for the 2002-2014 periods across the U.S. market. The Nielsen Company, 2015.*

Supplemental Materials

Table 4.3. Classification of barcoded packaged foods and beverages as sugar-free and low-sugar, by presence of sweetener[1]

Food Group	Sweetener type	Food and beverages included		
		Sugar-free beverages (total sugar 0g/100g)	Low-sugar beverages	Not Low-sugar beverages
Soft drinks and energy drinks	CS only	Sparkling water	None identified	Soft drinks, energy drinks, kombucha, tonic waters,
	LCS only	Diet soft drinks, diet energy drinks, sparkling water, diet tonic water	Diet soft drinks, diet energy drinks, sparkling flavored water	Soft drinks, energy drinks, sparkling water with juice, sparkling juice drinks
	CS + LCS	Diet energy drinks	Diet soft drinks, diet energy drinks, sparkling flavored water	Soft drinks, energy drinks, sparkling juice drinks
	Unsweetened	Sparkling water, seltzer, club soda	Sparkling flavored water	Sparkling water with fruit juice
Fruit drinks[2], sports drinks, and flavored waters[3]	CS only	None identified	Flavored water, maple water	Sports drinks, fruit drinks, vegetable drinks, combined fruit/vegetable drinks, flavored water, tonic water
	LCS only	Diet sports drinks, flavored water, coconut water	Flavored water	Fruit drinks, vegetable drinks, flavored water
	CS + LCS	Flavored water	Low-calorie sports drinks, aloe water, flavored water, diet energy drinks	Sports drinks, flavored water, energy drinks, smoothie mixes, fruit drinks, combined fruit/vegetable drinks,
	Unsweetened	Flavored water, unflavored mineral water, aloe vera juice	Coconut milk, Kraut juice	Fruit drinks, combined fruit/vegetable drinks
Ready-to-drink teas	CS only	Unflavored tea	Kombucha, flavored tea, unflavored tea	Sweet tea, half tea/half lemonade (or other fruit flavors), flavored tea
	LCS only	Flavored tea, unflavored tea, half tea/half lemonade (or other fruit flavors)	Half tea/half lemonade, flavored tea	Half tea/half lemonade (or other fruit flavors), flavored tea, tea with caffeine
	CS + LCS	Unflavored tea, flavored tea, half tea/half lemonade (or other fruit flavors)	Kombucha, unflavored tea, flavored tea	Sweet tea, flavored tea, tea with caffeine, flavored tea, half tea/half lemonade, (or other fruit flavors)
	Unsweetened	Unflavored tea, flavored tea	None identified	Kombucha, tea flavored with fruit juice
		Low-sugar foods (total sugar ≤5g/100g)		Not Low-sugar foods
Candy	CS only	Mints		Chocolate bars and pieces, hard candy, gummy candy, chocolate coated candies (e.g. peanut butter cups, candy bars).
	LCS only	Mints; chocolate bars, hard candy, gummy candy, and licorice		Chocolate bars

Food Group	Sweetener type	Food and beverages included	
	CS + LCS	Chocolate bars, chocolate pieces, mints	Caramel, toffee, gummy candy, licorice, hard candy
	Unsweetened	None identified	None identified
Grain-based desserts	CS only	Croissants, puff pastry cups, crumpet, mousse cake	Cakes, pies, cookies, rolls, toaster pastries, doughnuts, strudels
	LCS only	Cookies, cakes, cupcake, brownie, muffins	None identified
	CS + LCS	Muffin tops, carrot cake, cookies, cakes, pies	Muffin tops, scones, cookies, cakes, pies
	Unsweetened	Cookies, crumpets	Mochi, fig 'cake'
Dairy-based desserts	CS only	None identified	Ice cream, ice cream cake, frozen yogurt, cheesecake, pudding, custard
	LCS only	Ice cream, pudding, rice pudding, cheesecake	Ice cream
	CS + LCS	Pudding	Ice cream, frozen yogurt, dairy free frozen desserts, sherbet, ice cream cake
	Unsweetened	None identified	None identified
Flavored yogurt[4]	CS only	Regular[5] yogurts	Greek yogurt, regular yogurt, non-dairy yogurt substitute (soy, coconut, almond)
	LCS only	Greek yogurt, regular yogurt	Regular yogurt
	CS + LCS	Greek yogurt, regular yogurt, non-dairy yogurt substitute	Regular yogurt, Greek yogurt, non-dairy yogurt substitute (coconut, almond)
	Unsweetened	Kefir, non-dairy yogurt substitute, Greek yogurt	Goat milk yogurt, sheep milk yogurt, non-dairy yogurt substitute (soy)
Ready-to-Eat Cereal	CS only	Oat rings, whole grain flakes, crispy rice cereal	Flakes, clusters, loops, frosted cereals, granola, cereal with candy pieces (e.g. marshmallows)
	LCS only	Corn bran, wheat fiber cereal	None identified
	CS + LCS	None identified	Shredded wheat, granola, whole grain corn cereal, O's, flakes
	Unsweetened	Shredded wheat, puffed rice, puffed corn	Seed, grain and fruit cereal; muesli, granola, multigrain squares

[1] Beverage and food types may appear in multiple categories. This is because similar products from different brands or different flavors may have different amounts of sugar. For example, brand A fruit drink may contain LCS and have 0g of sugar, while brand B fruit drink may have 14g of sugar and contain CS.

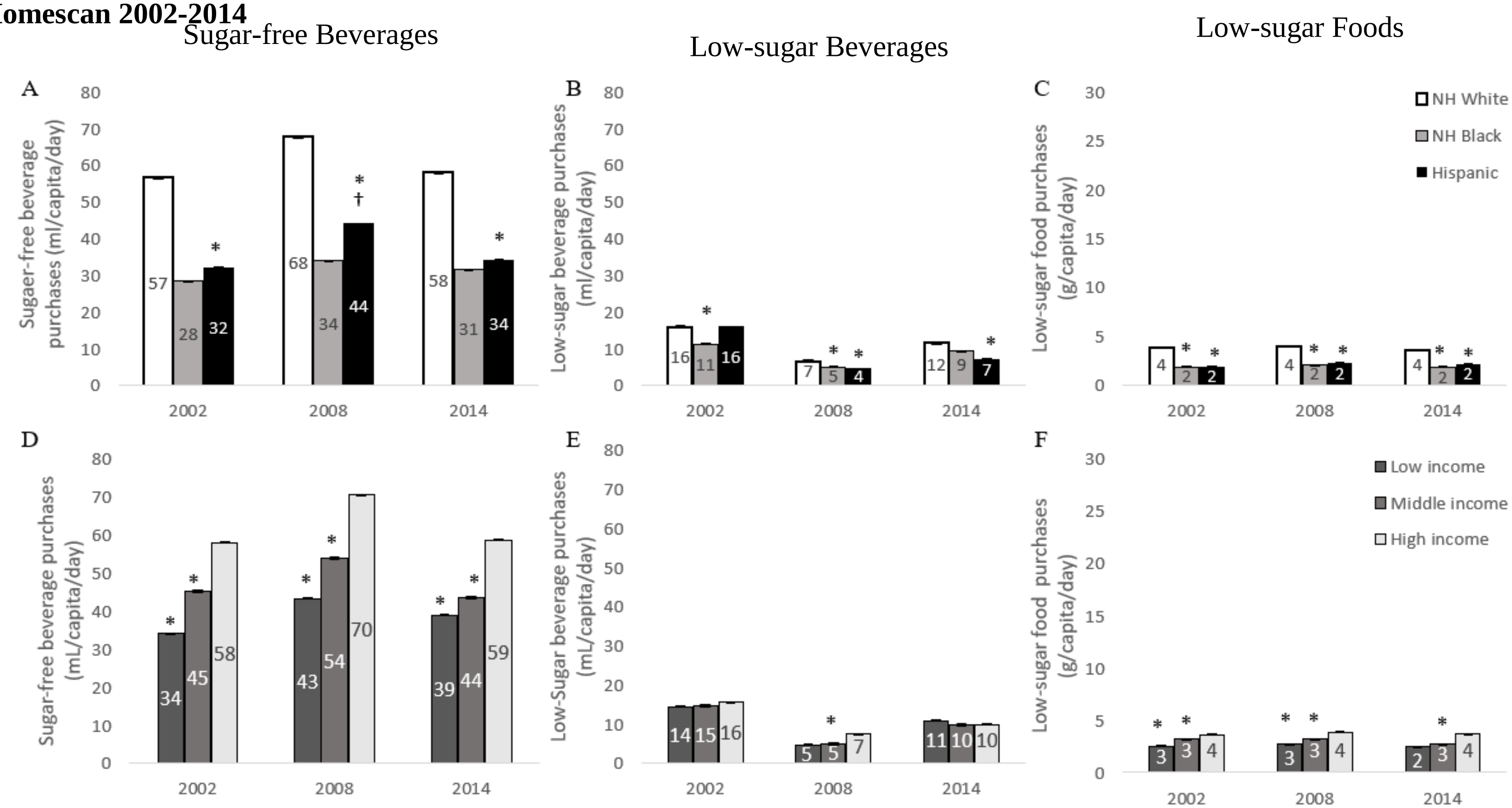
[2] Fruit drinks are defined as beverages primarily composed of sugar or sweetener (as 1st or 2nd ingredients) with fruit juice or fruit juice concentrate as a lesser ingredient.
[3] Flavored waters are defined as beverages that contain flavors but no fruit juice or fruit juice concentrate.
[4] Flavored yogurts are defined as yogurts that contain some type of flavoring; plain unflavored yogurt is not included.
[5] Regular, as opposed to Greek style yogurt
CS= caloric sweetener, LCS= low-calorie sweetener
Data from the 2002-2014 Nielsen Homescan longitudinal panel of household purchases of consumer packaged foods.
Source: University of North Carolina calculation based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol for the 2002-2014periods across the U.S. market. The Nielsen Company, 2015.

Table 4.4: Sociodemographic characteristics of U.S. households participating in the 2002-2014 Homescan Panel[1]

	2002		2004		2006		2008		2010		2012		2014		Total	
Household characteristics	**n**	**%[2]**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Race/ethnicity[3]																
Non-Hispanic white	28,769	73%	28,624	72%	45,306	71%	45,523	71%	44,987	69%	44,268	68%	44,862	68%	529,373	70%
Non-Hispanic black	3,587	12%	3,461	12%	4,840	12%	5,003	12%	5,059	12%	5,356	13%	5,738	13%	61,522	12%
Hispanic	2,191	10%	2,312	11%	3,010	11%	2,872	12%	2,962	12%	2,933	13%	3,150	13%	36,199	12%
Non-Hispanic Other	1,287	5%	1,362	5%	2,227	6%	2,335	6%	2,595	6%	2,769	6%	2,922	7%	28,854	6%
Income[4]																
<185% FPL	6,082	26%	6,792	27%	10,573	27%	10,428	27%	10,572	29%	12,091	30%	12,128	28%	127,976	28%
185%-<400% FPL	16,131	35%	14,768	33%	21,955	32%	24,178	35%	24,950	37%	23,035	35%	24,999	36%	280,431	35%
≥400% FPL	13,621	39%	14,199	40%	22,855	41%	21,127	38%	20,081	34%	20,200	36%	19,545	36%	247,541	38%
Household Education																
Less than high school diploma	913	11%	761	8%	963	8%	861	7%	743	6%	757	7%	743	7%		2%
Graduated high school	7,445	19%	7,257	18%	10,302	17%	10,137	16%	9,650	15%	9,049	14%	10,602	16%	119,442	16%
Some College	11,547	31%	11,307	31%	17,471	30%	16,757	28%	16,297	28%	16,160	28%	16,397	28%	198,269	29%
Graduate College	10,746	31%	11,046	32%	18,144	34%	18,933	36%	19,544	37%	19,855	38%	19,018	35%	221,193	35%
Post College graduate	5,261	16%	5,456	16%	8,598	17%	9,129	18%	9,447	18%	9,566	19%	9,972	19%	107,315	18%
Household Composition																
Single adult, no children[6]	9,485	26%	9,761	26%	13,476	26%	14,363	27%	14,432	26%	13,846	27%	14,285	27%	168,022	27%
Single adult, with children	1,125	4%	946	3%	1,485	3%	1,307	2%	1,136	3%	908	2%	1,069	2%	14,871	3%
Multiple adults, with children	9,480	30%	8,603	30%	14,577	30%	13,319	29%	12,285	28%	12,079	28%	12,343	27%	153,816	29%

[1] Percentages of households weighted to be nationally representative
[2] Race/ethnicity self-reported by head of household
[3] Income calculated as a percent of the Federal Poverty Limit (% FPL)
[4] Highest level of education self-reported by male or female head of household
Source: Data from the 2002-2014 Nielsen Homescan longitudinal panel of household purchases of consumer packaged foods. *University of North Carolina calculation based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol for the 2002-2014 periods across the U.S. market. The Nielsen Company, 2015.*

Figure 4.3: Mean household no- and low-sugar purchases in examined food and beverage groups, per capita per day, Homescan 2002-2014



[1]Weighted unadjusted mean household purchases of (A and D) sugar-free beverages, (B and E) low-sugar beverages (mL per capita per day) and (C and F) low-sugar foods (g per capita per day). Examined beverage groups were soft drinks and energy drinks; fruit drinks, sports drinks and flavored waters; and ready-to-drink teas. Examined food groups were grain-based desserts, dairy-based desserts, candy, flavored yogurts, and ready-to-eat cereal. Sugar-free beverages were defined as those with 0g/100mL sugar in examined groups, low-sugar beverages were defined as those with >0g- <2.5g/100mL sugar in examined groups, and low-sugar foods were defined as those with ≤5g/100g of sugar in examined groups.
* Significant compared to NH white (A, B and C) or high-income (>400% FPL) (D, E and F) Students t-test, *P*<.001 to account for sample size
† Significant compared to NH black. Students t-test, *P*<.001 to account for sample size
LS, Low-sugar; FPL, Federal Poverty Limit; NH, Non-Hispanic ource: Data from the 2002-2014 Nielsen Homescan longitudinal panel of household purchases of consumer packaged foods. *University of North Carolina calculation based in part on data reported by Nielsen through its Homescan Services for all food categories, including beverages and alcohol for the 2002-2014 periods across the U.S. market. The Nielsen Company, 2015.*

CHAPTER 5. SYNTHESIS

Overview of findings

This research provided a novel examination of nationally representative trends in U.S. household store purchases of no- and low-sugar products in eight key food and beverage groups that represent the top sources of added sugar. The analyses used data from the 2002 – 2014 Nielsen Homescan Consumer Panel, a national dataset of household packaged food and beverage purchases from stores. This unique dataset captures unique barcodes, which have been linked to product-specific nutrition information and ingredients lists.

There is not currently a consistent, comprehensive definition of low-sugar; this contributes to the lack of research on U.S. trends in no- and low-sugar purchases. We therefore used the U.K. FSA's definition of low-sugar. [61,62] We used these cut points to identify sugar-free beverages (0g of sugar), low-sugar beverages (>0g - ≤2.5g sugar/100mL), and low-sugar foods (≤5g sugar/100g) in eight food and beverage groups. These groups have been previously identified as contributing more than 75% of the added sugar consumed by the U.S. population ≥6y, and are key targets of reformulation. [6,7] We also examined no- and low-sugar products in these food and beverage groups because we were interested in products that were low-sugar alternatives to traditionally sugary products.

We first determined the number and proportion of products captured by the 2002-2014 Homescan dataset in our eight food and beverage groups meeting our criteria for sugar-free and low-sugar. We then examined 12-year nationally representative trends in household sugar-free beverage, low-sugar beverage, and low-sugar food purchases in these food and beverage groups. We further determined the proportion of no-and low-sugar purchases that contained CS, LCS, both, or no sweeteners. We then examined whether there were disparities in each of these measures by household race/ethnicity and household income.

The proportion of beverages classified as sugar-free in our examined groups increased, but the proportion of foods and beverages classified as low-sugar did not.

Previous studies have solely focused on products that contain LCS, or have focused on low-calorie beverages using a cut point that is not consistent across products. [29,58–60,75] To address these limitations, we consistently applied the U.K. FSA's low-sugar cut offs to the foods and beverages in our examined categories.

The number and proportion of barcoded beverages classified as sugar-free increased over the study period, with 28% of barcoded beverages classified as sugar-free in 2014. The number of foods and beverages in our examined groups meeting the low-sugar criteria grew from 2002-2014, however this was consistent with overall growth of the number of new products in these categories. We examined these changes over a time period when food and beverage manufacturers implemented initiatives to improve the healthfulness of the products they manufacture, often by reducing calories from sugar. [7,11,103] For example, Walmart reduced the added sugars in certain foods and beverages, including dairy items and fruit drinks, by 10%.[11] Our results indicate that in our examined categories, this growth has been largely limited to sugar-free beverages. Public health efforts have specifically targeted sugary beverages because of the strong research linking them to increased energy intake, obesity, and diabetes. [1–5,8,40,42] There is also greater complexity involved in reformulating foods as opposed to beverages. In foods, sugar serves many purposes, including providing structure and texture as well as enhancing shelf life.[49]

We rely on unique barcodes to identify foods, but it is important to note that tracking the number of barcoded products does not necessarily track the number of unique products. Products may have unique barcodes because they are different products, or because they are different flavors, sizes, or packaging of the same product. Further research is needed to determine whether the increased number of products reflects new products coming to market, or an expansion or reformulation of previously existing products.

U.S. household sugar-free beverage purchases increased from 2002 to 2008, and then did not substantially change through 2014.

In our nationally representative estimates, more than two thirds of U.S. households purchased foods or beverages in our eight no- and low-sugar products groups. Mean household purchases of sugar-free beverages, as a percent of beverage purchases from our examined groups, increased from 2002 through 2008, and then did not substantially change during the second half of the study period. Low-sugar beverage purchases remained ≤7% of examined beverage purchases. Purchases of low-sugar foods remained ≤5% of examined food purchases. Our studies add to the literature with a novel examination of nationally representative trends in household store purchases of no- and low-sugar products in eight key food and beverage sources of added sugar, and show that low-sugar products are not widely purchased.

The increase in sugar-free beverage purchases occurred over the same period as the first decline in consumption of sugar sweetened beverages and overall added sugars in decades. [24,113–115] Our findings are consistent with increases found in LCS sweetened beverage purchases and consumption, which our study found to represent more than three quarters of sugar-free beverages. [26,27] Studies which examine sugar-free beverage trends are limited. Two studies using NHANES data did not find significant changes in the prevalence of non-caloric beverages consumers from 2001 to 2014. [59,60] We similarly did not find substantial changes in the percent of households that purchased sugar-free beverages. Only one of these studies examined changes in the volume of non-caloric beverages and did not find a significant change in consumption in children. We extend the literature by quantifying nationally representative trends in sugar-free beverage purchases, using a dataset which objectively captures product-specific information on total sugar content, as well as an entire year of purchases to better capture episodically consumed products.

Over the second half of the study period we found that sugar-free beverage purchases did not substantially change. This is consistent with industry reports that show a reduction in beverage sales volume for no-calorie carbonated soft drinks in 2014-15. [103] Our findings persisted in terms of mL per capita per day, so these findings are not explained by rising total beverage purchases in our examined groups. The number and proportion of products that were classified as sugar-free continued to increase from 2008 through 2014. From 2008, there was an increase in the prevalence of water consumption as well as purchases of bottled water, and so there may have been a shift towards options not captured by our beverage groups. [59,60,103,150]

Low-sugar beverage purchases remained under 7% of beverage purchases from our examined beverage groups. Studies that examine low-sugar beverages are limited, and our study is novel in quantifying low-sugar beverage purchases in the U.S. Maurissa et al. found that the consumption of low-calorie beverages among U.S. children increased from 2001 to 2010. Industry studies also found that low-calorie beverages, defined as those with 5-40 calories per 8 oz, were only 1.5% of beverage sales volume. In our examined beverage groups, a limited number of beverages were classified as low-sugar compared to the number classified as sugar free, which may have contributed to low levels of purchasing.

Similarly, low-sugar food purchases remained at approximately 5% of the total gram purchases from our examined food groups. Our findings are consistent with reports that reduced sugar foods remains a niche category globally. [5] The industry efforts to increase purchases of healthier options, including lower sugar options, included both foods and beverages. However, consumer awareness of low-sugar foods may be low. Public policy efforts and public marketing campaigns to promote lower sugar alternatives have largely focused on beverages, not foods. [8,45,117–119] It is unclear what kind of industry marketing efforts accompanied these low-sugar foods.[151,152]

The contribution of products containing low-calorie sweeteners to low-sugar beverage and low-sugar food purchases shifted substantially

In 2014, LCS sweetened products, including LCS-only or in combination with CS, were more than three quarters of no- and low-sugar beverage purchases, and more than half of low-sugar food purchases. While previous research has found consistent increases in the purchases and consumption of LCS, we observed a decline in the proportion of sugar-free beverages that contained LCS-only. [27,74–76] However, this decline appears to be driven by a decline in LCS sweetened soft drinks and energy drinks, partially offset by increases in LCS-only sugar-free fruit drinks, sports drinks, and flavored waters. For our analysis, fruit juice concentrate was not considered a caloric sweetener when water was listed in the ingredients list. Thus this decline in LCS-only soft drinks and energy drinks could potentially be a shift towards beverages containing FJC. Our results are consistent with more recent reports of declining purchases of diet soft drinks from major beverage brands. [103,150] These declines occurred concurrent with the ongoing debate about the healthfulness of low-calorie sweeteners, leading some to hypothesize that LCS purchases would drop among diet or reduced calorie products. [66–68,150] However, our studies found that the decline in LCS sweetened products among sugar-free soft drinks has not extended to our other examined beverage groups. These findings may represent a broader shift away from sugar-free soft drinks, and towards sugar-free or low-sugar beverages that are marketed as healthier, independent of ingredients. [116]

Low-sugar food purchases also shifted away those containing CS-only, and towards those containing a combination of LCS and CS. Nationally and globally there has been an increase in products and purchases containing both LCS and CS. [27,65] Combining the two sweeteners allows for a reduction in sugar, while still including regular sugars for the structural, textural, and shelf life properties for which they have been traditionally used.[49] Demand for plant derived LCSs that are perceived as natural, such as Stevia, are projected to continue to grow in the U.S.. [153] Thus we may see this trend continue to grow in subsequent years. Our findings extend current knowledge by determining that proportion of *low-sugar* purchases that contain LCS. This can be used in future evaluation efforts, including whether efforts to promote low-sugar alternatives has increased purchasing of foods with LCS.

There are race/ethnic and income disparities in sugar-free beverage and low-sugar food purchases

Throughout our study period, NH white households had consistently higher sugar-free beverage purchases than NH black and Hispanic households. High-income households also had consistently higher sugar-free beverage purchases. The disparities in sugar-free beverage purchases are consistent with findings that NH white children and adults had higher consumption of low-calorie beverages in (?) 2009 to 10. [58] Cost, education, marketing, health literacy, and preferences may contribute to these disparities.[16,134,135] While higher sugar-sweetened beverage purchases among low-income consumers has been partially attributed to their low cost, it is unknown whether sugar-free beverages are more expensive than their sugary counterparts. [136,137] Even small price gaps have been shown to shift purchases of beverages, particularly among low-income consumers. [138–140]

There were small but significant differences in low-sugar food purchases across race/ethnic and income groups. NH black and low-income households had significantly lower purchases of low-sugar yogurts and RTE cereals. Previous studies have found that television advertising promotes foods higher in sugar, including higher sugar RTE cereals, targeting NH black and low-income households.[16,88,141] Low-sugar foods may also be more likely to have a front of package nutrient claim, which may influence more educated and higher income consumers. [57,120,142] While availability may also be an issue, previous studies have not found racial differences in the nutritional quality of packaged foods purchased in different types of stores. [110]

There were some differences in the change in no- and low-sugar beverage purchases over time. High-income households had a larger increase in low-sugar soft drink and energy drink purchases than low-income households. NH white households had a larger increase in purchases of low-sugar fruit drinks, sports drinks and flavored waters and RTD teas than NH black households. NH black and Hispanic children and adults have previously been reported to be higher consumers of fruit-flavored drinks.[77] However, as all forms of soft drinks gain attention for potential negative health effects, NH white households, which are overall higher purchasers of sugar-free beverages, may be shifting their purchases towards beverage categories that are perceived as healthier. [5,116] Hispanic households also had a faster decline of low-sugar beverage purchases than NH white households. Why there are widening gaps in purchases of these products merits further study. Although increasing differences are concerning, it is also critical to understand whether low-sugar beverages are associated with lower total sugar purchasing, and overall healthier dietary patterns before intervening.

Our results indicate that when NH black, Hispanic and low-income households purchase sugar-free beverages, a lower proportion of those purchases contain LCS. Low-income households also had lower purchases of LCS sweetened low-sugar foods. These results are consistent with previous studies that NH black and low-income households purchase and consume less LCS. [27,74,75] We extend the literature with our finding that NH black households purchased significantly more unsweetened sugar-free beverages. Examples of unsweetened low-sugar beverages in our study include flavored tea, sparkling water, seltzer, and flavored waters. While bottled water was not included as a sugar-free beverage in our study, this is complementary with findings that NH black and Mexican American adults consume more bottled water than NH whites. [143]

Limitations

Although product-specific nutrition facts panel information was important for providing accurate sugar content of products, the accuracy of nutrition facts panel also introduces limitations. Nutrition fact panels allow for rounding, including allowing products with <0.5g of total sugar per serving to report 0g of sugar.[12] In the case of beverages, these would be classified as sugar-free in our study, as we cannot distinguish between beverages that report 0g due to rounding and those that are truly 0g. The FDA only requires that the nutrition facts panel be within 20% of the true nutrient content of that food and beverage. This further introduces potential error into our classification of no- and low-sugar products.

In these analyses, we examined purchases from eight food and beverage groups. We focused on these groups because they are top contributors of added sugar to the U.S. diet, and are therefore targets of reformulation, education, and policy. [46,85] Focusing on these categories also ensures that the products we examined were low-sugar alternatives to sugary foods. However, this potentially misses changes in no- and low-sugar product purchases in other categories. For example, there may be higher low-sugar purchases, or more of a change in low-sugar purchases, in groups that are already marketed towards health conscious consumers, such as granola bars.

The aim of our study was to assess packaged foods and beverages purchased from stores. A key limitation of our studies is that the findings cannot be generalized to total diet. Homescan does not capture products purchased away from home. Some of the food and beverage groups examined, such as soft drinks, may be more likely to be consumed away from home. NH black adults consume a higher percentage of calories away-from-home, including at fast-food restaurants. [154,155] Overall the percent of calories away-from-home locations declines slightly from 2003 to 2010 among U.S. adults. [156] We examined all no-and low-sugar purchases as a percent of total purchases in our examined groups, in part to help control for household variations in purchasing and potentially increasing store purchases as away-from-home food purchases declined. However, the extent to which products from our examined groups are not captured because they were consumed away from home may vary across subgroups and across time. Further, Homescan does not capture how much of foods and beverages purchased are consumed. Food waste may be higher among certain groups that we examined, such as products with shorter shelf lives like grain-based desserts and dairy-based desserts. Food waste may also vary over time and be different across socioeconomic groups. Foods and beverages purchased in stores but consumed prior to returning home would not be captured by our dataset. This may be more likely to occur for such as beverages or candy purchased from convenience stores. It is unclear whether no-and low-sugar items might be more or less likely to be underreported in this way than their high-sugar counterparts. While this may broadly cause underreporting, validation of Homescan found that the fraction of variance explained by errors between quantity of purchases scanned and retailer data is similar to that of other large scale, commonly used datasets. [99]

Homescan collects purchases at the household-level, and thus the intra-household distribution of food products is not known. Disparities in added sugar consumption are different between children, where NH white children are the highest consumers, and adults, where NH black adults are the highest consumers. [6,24,80] Examining purchases at the household level combines the consumption of children and adults. This may mask divergent trends between children and adults. Examining low-sugar purchases across the whole household may in some cases underrepresent the contribution of low-sugar products to the purchases of the household member who consumes them.

An important limitation to this study is the selection bias potentially caused by the high study burden of participating in Homescan. Those who are willing and able to participate, in particular among low-income households, may have unmeasured characteristics that are associated with no- or low-sugar beverage purchases. While results were weighted to be nationally representative, weights would not incorporate these unobserved characteristics. This may limit generalizability to the national population. We further eliminated households with implausible reporting based on low household expenditure for all packaged goods purchased, as has been published previously. [27,109,110,157] However, there is not a standardized method to identify implausible reporting for purchases, and this approach may eliminate households with legitimately low packaged food expenditure. Finally, in Homescan race and ethnicity is identified by the head of the household. This is a limitation in being able to identify and categorize mixed race households. There are also limited race and ethnicity categories; all Hispanics are grouped together, although there is important evidence that diet differs within Hispanic groups. Further, all race/ethnicities outside of white, black and Hispanic are categorized as ‘Other’; we cannot draw conclusions about those categorized as other because of the wide range of groups included in this category.

Strengths

Homescan provides a unique opportunity to study no- and low-sugar products. The product-specific total sugar content and ingredients list allowed us to more accurately classify products as no- and low-sugar, as well as according to presence of sweetener. Product nutrient information and ingredients lists are frequently updated to supply more accurate information in a rapidly changing food supply. [13–15] This accuracy allowed us to use the FSA's gram cut-point to classify products as low-sugar.[61] A central reason for the lack of research on low-sugar products is the lack of a comprehensive definition of low-sugar, such as that used by the FSA. Homescan's detailed product level information also allowed us to classify products according to presence of sweetener. Traditional dietary assessment methods do not collect sufficient detail to accurately categorize products based on sugar content. The enormous range of sweeteners used by food manufacturers, as well as inconsistent nomenclature, limits the ability of self-reported measures to accurately capture presence of sweeteners.

Self-reported measures are further limited by respondents' knowledge of the sugar contents, portion sizes, and ingredients of the products they consume. Because Homescan provides households with a barcodes scanner, there is an objective measure of purchases. This helps reduce measurement error due to recall errors or underreporting. Underreporting is a particular problem with sugar in self-reported measures, and can occur differently by gender, age and weight status as well as by race, ethnicity, and SES. [93,94] Purchases are also collected for a minimum of 10 months; thus for each time point purchases have been collected year round. This means that we may better capture usual purchasing patterns than 24-hour recalls for episodically consumed foods, like no- and low-sugar products.

A strength of our analysis is we used a comprehensive definition of low-sugar to provide a novel examination of no-and low-sugar products across the U.S.. In previous studies, products have alternatively been identified as 'diet' based on calories per labelled serving, reduced sugar from a standard reference product, or containing LCS.[60,132,158,159] Applying this definition more comprehensively captures a broader range of low-sugar purchases. Our research questions were motivated by industry efforts, and policy and programmatic efforts that were happening across the country. We therefore examined descriptive, unadjusted estimates to best understand the changes that were happening at the national level. While previous studies used weights provided by Nielsen, these weights did not sufficiently adjust the population to create nationally representative estimates. In these analyses we used weights created by our team using iterative proportional fitting. The Current Population Survey's (CPS) count of households for each year were used as control totals to create nationally representative estimates based on the CPS distribution of household size, head of household age, presence of children, and the joint distribution of race, Hispanic origin, and household income. [112]

Significance and public health impact

The turn of the millennium signified an important period of transition with regard to sugar. After steady increases since the 1970's, added sugar consumption declined for the first time. [24] Concurrently there was growing public concern about sugar, and numerous national efforts to promote low-sugar alternatives to products that contribute the most sugar to the U.S. diet. [5,160–163] Because of this, some predicted an increase in low-sugar or reduced sugar products, including beverages, candy, grain-based desserts, and dairy based desserts. [164,165]

Our studies found that over this time period, U.S. household purchases of sugar-free beverages increased, but purchases of low-sugar foods and beverages did not. Further, sugar-free beverages only increased during the first half of the study period; the trend levelled off after 2008. It appears that this period of change did not also include a widespread increase in purchases of no- or low-sugar alternatives in key food and beverage sources of sugar. While we only examined purchases in certain food and beverage categories, focusing on key food and beverage categories is an approach also being used in low-sodium evaluation efforts.[50,51] Thus our results can inform evaluations of these or future efforts to promote low-sugar alternatives.

Our results can also be used as baseline trends for future efforts that may increase purchases of no- or low-sugar products. Several major initiatives were announced or implemented after the end of our study period. The new Nutrition Facts panel, which includes a required line for added sugars, will be implemented.[122] A stated goal of this addition is to encourage manufacturers to reduce the sugar in products, and also to guide consumers towards lower sugar alternatives. [7,102,122] In 2014 The American Beverage Association, the Coca-Cola Company, Pepsi-Co and the Dr. Pepper-Snapple group pledged to reduce beverage calories in the U.S. diet by 20% by 2025 through a combination of reformulation and marketing efforts. [103] All of these efforts may impact no- and low-sugar purchases.

Our results also have established baselines for the proportion of no-and low-sugar purchases in our examined groups that contain LCS by race/ethnicity and income. A central concern about policies and programs to promote lower sugar alternatives is that they will unintentionally increase consumption of LCS. NH black, Hispanic, and low-income populations currently have lower levels of LCS consumption and purchases. [26,27] We find that these subpopulations also have a lower proportion of no-and low-sugar product purchases that contain LCS, and a higher proportion of these purchases that do not contain sweeteners. These data can be used to examine whether efforts to promote no-and low-sugar products have the unintended consequence of increasing LCS purchases in these populations.

A novel feature of our studies was applying the U.K. FSA's cut points for packaged food and beverage purchases in the U.S.. Dunford et al. had previously applied it to a database of Nutrition Facts Panel including a subset of uniquely barcoded multi-ingredient products; however, that analysis did not capture all barcoded products at the national level and reflected only products available, rather than what households actually buy; we extended these findings by examining changes over time and volume of household purchases using this definition.[62] A central barrier to studying national trends of these products was the lack of a comprehensive definition. While a gram cut point per weight does have some limitations, such as fairly comparing serving sizes; 100g of ready to eat cereal may be a different serving size than a heavier product like a dairy based dessert. However, the U.K. FSA's gram cut point provides a definition of low-sugar that is consistent across brands and includes all low-sugar products regardless of presence of sweetener. Improved monitoring of new and emerging products, like low-sugar products, has been repeatedly cited as a key research need. [13,14,36,41] The FDA does not define low-sugars, and the current myriad of definitions used prevents comparing findings and can produce discrepant results.[59,60,74,166] A consistently used definition is needed to better monitor trends of low-sugar products in the food supply and in consumption and purchases.

Future directions

The results presented in these studies lay the groundwork for a number of potential different investigations. One area of research needed is elucidating the relationship between purchases of the no- and low-sugar products examined and diet quality. Promoting low-sugar alternatives has been presumed to be a good strategy to reduce population sugar consumption by virtue of the products themselves having less sugar.[7,48,49,85] However, limited research linking the consumption of low-sugar products to total sugar consumption and diet quality has yielded discrepant results. A randomized control crossover study found that men and women assigned to eat lower sugar products consumed less sugar, but ate more fat and just as many calories, compared to when they were assigned to eat full sugar versions of the same foods and beverages. [167] A separate RCT found that participants randomized to drink diet beverages reduced calorie, carbohydrate, added sugar, and fat intake. [32] Studies of LCS products are similarly discrepant; LCS consumption has been associated with a better Healthy Eating Index score, but purchases of LCS beverages were associated with an increased purchasing of total calories. [74,91] During the analogous low-fat trend of the 80's and 90's, consuming low-fat products in some cases led to greater energy intake by increasing the perceived appropriate serving size,[168] compensating with fat, refined carbohydrates and calories from other sources, and lending a 'health halo' to products that weren't healthier.[169]

Understanding whether increasing purchases of no- and low-sugar products decreases total sugar purchases or improves overall dietary patterns can help contextualize and translate our findings. [149] For example, we found that low-income and NH black households purchased fewer no- and low-sugar products in our examined groups. However, without knowing whether consuming these products is related to improved diet quality, it is difficult to discern whether this is an opportunity for intervention. Similarly, understanding the relationship between these products and total sugar intake is critical to determining whether national efforts to promote these products will be an effective strategy to reduce population sugar consumption.

Another potential future direction would be to examine no- and low-sugar product purchases in other food and beverage groups. We examined purchases in the eight food and beverage categories that contribute the most added sugar to the U.S. diet, making these products key targets of reformulation and policy efforts. [48,85] We further took this approach because we wanted to make sure that the no-and low-sugar products we examined were alternatives to traditionally sugary products. However, there may be interesting trends in no- and low-sugar product purchases outside of our examined food and beverage groups. For example, there may be more low-sugar purchases in products already marketed as healthier, such as granola bars and RTD coffee drinks. Any such analysis would have to make decisions about how to handle categories that don't traditionally contain much sugar, like soups and savory snacks. Most or all of these products may meet the FSAs low-sugar cut points but labelling them as low-sugar may not make sense.

Large scale efforts to promote healthier products have previously been criticized for failing to reach low-income and minority populations. [17] We found racial/ethnic and income disparities in no- and low-sugar product purchases. Environmental drivers, including marketing, price, and availability of no- and low-sugar products, may partially contribute to these differences. [170–177] Previous studies have found that television advertising promotes foods higher in sugar, including higher sugar RTE cereals, towards NH black and low-income households.[16,88,141] Low-sugar foods may also be more likely to have a front of package nutrient claim, which may influence more educated and higher income consumers. [57,120,142] While Stern et al. did not find differences in the nutritional quality of packaged foods purchased at different types of stores , smaller stores like convenience and drug stores which are more prevalent in predominantly black and low SES neighborhoods may be less likely to carry no- and low-sugar alternatives. [178–181] While the relatively low price of sugary foods has been a driver of higher consumption in low-income populations, further research is needed to examine whether the no- and low-sugar alternatives are more expensive. [177,182,183] Individual drivers that may contribute to these differences include nutrition education, individual and cultural preferences, cooking and shopping behaviors.[23,184–186] Future research is needed to better understand the effect of environmental and individual drivers of those disparities.

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