Published in final edited form as:

Pediatr Obes. 2017 April ; 12(2): 146–154. doi:10.1111/ijpo.12121.

SSB taxes and diet quality in U.S. preschoolers: Estimated changes in the 2010 Healthy Eating Index

Christopher N. Ford,

Department of Epidemiology, MD Anderson Cancer Center, The University of Texas

Jennifer M. Poti,

Department of Nutrition, Carolina Population Center, The University of North Carolina at Chapel Hill

Shu Wen Ng, and

Department of Nutrition, Carolina Population Center, The University of North Carolina at Chapel Hill

Barry M. Popkin

Department of Nutrition, Carolina Population Center, The University of North Carolina at Chapel Hill

Abstract

Background—Taxing sugar-sweetened beverages (SSBs) has been proposed as a strategy to combat child obesity. Yet, it is unclear how a tax on SSBs might influence the overall quality of diet in preschool children. Thus, we use simulated price increases and the 2010 Healthy Eating Index (HEI-2010) to explore the relationship between SSB taxes and diet quality in preschool children.

Methods—Price and purchase data from the 2009–2012 Nielsen Homescan Panel and a two-part marginal effects model were used to estimate relative changes in purchases with a 20% increase in the price of SSBs. Demand elasticities were applied to dietary intake data for children ages 2–5y from the National Health and Nutrition Examination Survey (NHANES) (2009–10 and 2011–12) to estimate the impact of a 20% SSB tax on dietary intake and quality (HEI-2010).

Results—A 20% increase in the price of SSBs was associated with lower total caloric intake (–28 kcal/d, $p<0.01$), caloric intake from juice drinks (–20 kcal/d, $p<0.01$), added sugars (–4.1 servings/d, $p=0.03$), refined grains (–0.63 servings/d, $p<0.01$), and total meat (–0.56 servings/d, $p<0.01$). Beneficial decreases in empty calories and refined grains were offset by unfavorable changes in fatty acid profile, total protein, vegetables, and fruit, such that total HEI scores (0–100 range) were not meaningfully changed with a 20% increase in SSB price (difference: –0.85, $p<0.01$).

Corresponding author address: Barry M. Popkin, Department of Nutrition and Carolina Population Center, University of North Carolina at Chapel Hill, 137 East Franklin St., Chapel Hill, NC 27516, Phone: 919-962-6139, Fax: 919-966-9159, popkin@unc.edu.

Conflict of interest statement: None of the authors have any conflicts of interest of any type with respect to this manuscript.

Conclusions—A 20% tax on SSBs could decrease total caloric intake, and intakes of added sugars and SSBs, but is unlikely to improve total diet quality among U.S. preschool children.

Keywords

Sugar-sweetened beverages; preschool child; beverage tax; sugar-sweetened beverage tax; obesity prevention

Introduction

In recent years, the diets of preschool children (ages 2–5 years) have become a major focus for preventing excess weight gain in children. As this period is marked by the formation of dietary preferences and behaviors that may track into later stages of life¹, the preschool years have particular importance for diet. Thus, encouraging healthy eating behaviors in preschool children could reduce the likelihood of excess weight gain at later stages. Sugar-sweetened beverages are the leading source of added sugars in the diets of U.S. preschool children², making them the focus of a prominent strategy for preventing excess weight gain – a 20% tax on sugar-sweetened beverages (SSBs)³. Critics of the tax, however, have cautioned that, although it may decrease intakes of SSBs, an SSB tax might otherwise adversely affect diet quality by shifting consumers toward other foods/beverages high in fat and/or sugar^{4,5}. Although several studies have reported that a 20% tax on SSBs would decrease total energy intake and intakes of foods/beverages high in fats and/or sugar^{5–9}, there remain two important research gaps. First, it is unclear how a 20% tax on SSBs might influence the diets of preschool children, as prior studies have been limited to older children and adults. Unlike these populations, preschool children consume fewer calories from SSBs than older children and adults^{10–12}, and their diets are largely determined by parents and/or caregivers. In addition, although some have examined an SSB tax in relation to intakes of particular foods/beverages, no study has included a measure of diet quality. Thus, although most studies show decreases in caloric intakes and intakes of SSBs, it is yet unclear whether an SSB tax would adversely influence preschool children's diet quality, including their adherence to prevailing dietary recommendations.

To address these important research gaps, we used dietary intake data from children ages 2–5 years who participated in the 2009–2012 National Health and Nutrition Examination Survey (NHANES) and computed intakes of total calories, caloric intakes of eight key beverages and diet quality using the 2010 Healthy Eating Index (HEI). We estimate the relationship between an SSB tax and diet, using the 2009–2012 Nielsen Homescan Panel (demand model). Estimates from the demand model were applied to corresponding food/beverage groups in NHANES to predict differences in dietary intakes with a 20% tax on SSBs. HEI-2010 scores and intakes of total calories and select beverages were computed with and without a simulated 20% tax on SSBs to determine: 1) how a 20% tax on SSBs might influence total energy intake and intakes of beverages; and 2) how a 20% SSB tax might influence overall diet quality among U.S. preschool children.

Methods

Data

We used food and beverage purchase and price data from the 2009–2012 Nielsen Homescan Panel, which comprises a prospective survey of U.S. households from across 76 major markets (52 metropolitan and 24 non-metropolitan areas in 48 contiguous states) who report purchases of all barcoded food and beverage consumer packaged goods (CPGs) using scanner technology. To best approximate beverage demand relationships for preschool children and their families, we included households with a single child between the ages of two and five who participated in Homescan during survey years 2009–2012. In addition, unemployment rate data, from the U.S. Bureau of Labor Statistics Local Area Unemployment Statistics (<http://www.bls.gov/data/#employment>), were matched by market and quarter with the Homescan data.

Average quarterly market-level prices were computed for all foods/beverages by group as the weighted average price per 100g or 100ml, by food or beverage category, market, quarter and year. Additionally, a Food Price Index (FPI) index was created to scale costs relative to a single geographic location and time point in order to account for differences in costs of living (including the costs of foods/beverages) by region and time.

To estimate the relationship between a targeted beverage ‘tax’ and food and beverage purchases, demand models were used in which food and beverage purchases by group (dependent variable) were regressed on the SSBs prices (primary independent variable). The impact of a simulated 20% beverage tax was thereby estimated from the association between higher market-level prices of the ‘taxed’ beverage and CPG purchases. Of note, this approach positions parents of preschool children, who are presumably responsible for purchasing foods/beverages for the household (including the preschool child), as the substantive target of the ‘tax’. Moreover, we assume complete transference of ‘tax’-related changes in parent/household’s purchasing behavior to child diet. Moreover, we assume complete transference of ‘tax’-related changes in parent behavior to child diet. A detailed description of these methods has been published previously¹³, and additional details are given in Appendix Exhibit A.

Dietary and demographic data were included from children ages 2–5 years who participated in NHANES years 2009–10 and 2011–12. NHANES comprises a nationally representative survey administered by the U.S. Department of Health and Human Services and the U.S. Department of Agriculture in order to monitor the diets and health of the U.S. population. Respondents’ dietary intake was ascertained using interviewer-administered 24-hour dietary recalls using the five-step automated multipass method¹⁴. For all children younger than six, dietary intake was reported by the child’s primary guardian/caretaker. Nutrient intakes were derived using a survey-specific version of the USDA Food and Nutrient Database for Dietary Studies¹⁵. The first of two 24-hour recalls was used to compute total energy intake, intakes of eight key beverages (described below), and intakes (in USDA Food Pyramid servings/ equivalents) of 37 USDA Food Patterns food and nutrient groups, including added sugars (teaspoons/d) and solid fats (in grams/d), using the HEI-2010 SAS macros (available at: <http://appliedresearch.cancer.gov/hej/tools.html>)¹⁶, and the population ratio approach¹⁷.

Briefly, the HEI-2010 uses either the USDA MyPyramid Equivalents Database (MPED)¹⁸, or the USDA Food Patterns Equivalents Database (depending on survey year of data used) FPED¹⁹, to compute intakes (in servings/equivalents) of 37 food patterns. Descriptions of the HEI and component groups have been previously published in greater detail¹⁶.

Beverages were partitioned into 8 mutually exclusive groups: 1) caloric soft drinks; 2) sports and energy drinks; 3) juice drinks; 4) >1% fat, high-sugar milk; 5) >1% fat, low-sugar milk; 6) low-fat, high-sugar milk; 7) low-fat, low-sugar milk; and 8) 100% juice. Sugar-sweetened beverages included caloric soft drinks, sports and energy drinks, and juice drinks¹².

Comparable beverage groups were created using both the Homescan and NHANES data. Detailed descriptions of these methods have been published^{12, 13}. Briefly, groups were created in the Homescan purchase data using ingredient lists and product descriptions. In the NHANES intake data, groups were created using food code descriptions; when necessary, nutrition information from the USDA food database was examined and a criterion of 9.0% sugar by volume was used to identify SSBs, which was consistent with recommendations from the Institute of Medicine (IOM)²⁰. Milk groups were also based on fat and sugar content cut-points specified by the IOM.

To predict changes in dietary intake and quality with a 20% increase in the price of SSBs, demand model estimates (elasticities) were linked by level of household income and applied to individual dietary intake data from NHANES (including calories, sodium, monounsaturated fat, polyunsaturated fat, added sugar and solid fat content corresponding to specific foods/beverages). Mean values were estimated for total caloric intake, and caloric intake from the 8 beverage groups. In addition, intakes (in servings/equivalents) of 37 food/beverage groups defined by the 2010 HEI were estimated. For intakes of food/beverage groups, simple means were computed, while the population ratio approach was used to compute mean HEI-2010 total and component scores¹⁷. NHANES survey weights were used to account for differential probability of selection, and values were computed with and without a simulated 20% increase in the price of SSBs. Following previous works⁵⁻⁹, we assumed 100% transference of the simulated tax to 'shelf' price.

Statistical analyses

All analyses were conducted in Stata (version 13, 2011, StataCorp, College Station, TX), using appropriate survey weighting procedures for both the Homescan and NHANES data.

Results

Selected characteristics of the NHANES sample are shown in Table 1 (n = 1,706).

Estimates from demand models using the Homescan data are shown in Appendix Table 2. Values given represent the percent change in amount purchased in grams with a 20% increase in the prices of soft drinks, juice drinks, and sports and energy drinks (elasticities). Overall, juice drinks were most amenable to SSB price increases (-26.1%), followed by sports and energy drinks (12.2%), fruits (-11.2%), 100% juice (9.9%), and total meats (-9.6%). Elasticities from the demand model were matched to the closest corresponding

food/beverage group. The linkage between elasticities and USDA Food Pyramid groups is given in Appendix Table 3.

Mean daily total caloric intake and caloric intakes from selected beverages under the two conditions are given in Table 2. Total caloric intake (-28 kcal/d per capita, $p<0.01$) and intake of juice drinks (-20 kcal/d per capita, $p<0.01$) was significantly lower with a 20% tax on SSBs. Intakes of $>1\%$ fat, high-sugar milk ($+7$ kcal/d per capita) and 100% juice ($+5$ kcal/d per capita) were higher under the tax condition. Intakes of low-fat low-sugar milk, low-fat, high-sugar milk, soft drinks and sports and energy drinks differed by fewer than five calories between the two conditions.

The HEI, which comprises a summary score out of 100 (higher = greater compliance with the 2010 Dietary Guidelines for Americans [DGA]), is computed from the summation of scores from 12 food/nutrient categories (Table 3). For all categories but sodium, there were significant differences in scores under the null condition (no price increases applied) and under the conditions of a 20% increase in the price of SSBs (tax condition). Under the tax condition, scores for fatty acids (-1.03 $p<0.01$) and total protein (-0.55 , $p<0.01$) were significantly lower (less compliant with DGA recommendations) compared to the no-tax condition. Conversely, scores for refined grains ($+0.94$, $p<0.01$) and empty calories (0.89 , $p<0.01$) were higher (more compliant with DGA recommendations) for the tax condition. The price increase changed the total HEI-score from 46.5 to 45.6 (difference: -0.85 , $p<0.01$).

Mean daily Food Pyramid Equivalents consumed by children in the sample are shown in Appendix Table 1. There were higher intakes of fluid milk ($+0.74$ servings/d, $p<0.01$) and total dairy ($+0.67$ servings/d, $p<0.01$) under the tax compared to no-tax. There were also reductions in the intakes of added sugars (-4.10 teaspoons/d, $p=0.03$), oils (-1.57 grams/d, $p<0.01$), total grains (-0.65 , $p<0.01$), refined grains (-0.63 , $p<0.01$), and total meat (including eggs, soy and nuts) (-0.56 servings/d, $p<0.01$).

Discussion

Our main finding was that a 20% increase in the price of SSBs was a small, but significant decrease in diet quality in U.S. preschoolers, which appeared largely to be driven by decreases in component scores for fatty acids, total protein, and total vegetables. There were also marginal decreases in HEI component scores for total fruit, whole fruit, whole grains, seafood and plant proteins, and dark green vegetables (net: -2.68). Although there were concomitant increases in component scores for refined grains and empty calories, their total impact on HEI score was smaller (net: $+1.83$). Moreover, some USDA Food Patterns food groups that decreased with a tax were reflected in more than one HEI component, which may have given them greater influence on total HEI score. These included ‘total fruit and fruit juices’ (reflected in both the total fruit and whole fruit HEI components), ‘total dark green, red and organ, starch, and other vegetables (excluding legumes)’ (reflected in both the total vegetables and dark green vegetables HEI components), and ‘total meat, poultry, seafood, organ meats, and cured meats’ (reflected in both the total protein and seafood and plant proteins HEI components).

Taken together, these findings suggest that a tax on SSBs should be coupled with other interventions/policies in order to *improve* diet quality.

Overall, we found that the diet quality among U.S. preschool children was low, as indicated by the mean HEI score (46.5 of a possible 100 pts). This result is supported by a number of prior studies in which the diets of U.S. preschool children were shown to be high in intakes of SSBs¹², savory and sweet snacks, pizzas/calzones²¹, and other foods and beverages high in fat and sugar². Importantly, ours is the first study to examine how a tax on SSBs might influence adherence to the 2010 Dietary Guidelines for Americans. Nonetheless, our findings are consistent with prior studies in adults. Finkelstein et al. (2012), who used data from the 2006 Homescan Panel, observed that a 20% increase in the price of SSBs was associated with 24 fewer total calories purchased, of which 13 calories were attributable to reductions in SSB purchases⁵. Others who have used the Homescan data have reported similar relationship between a 20% increase in the price of SSBs and total calories purchased and purchases of SSBs⁶⁻⁹. By comparison, we found that a 20% increase in the price of SSBs was associated with 28 fewer total calories consumed, 20 of which were attributable to decreases in intake of SSBs. We found a particularly strong relationship between the price of SSBs and juice drinks purchases, which may be in part due to higher purchases of juice drinks among households with a preschool child (compared to a general sample of households).

In addition to being unique in examining the relationship between the price of SSBs and the diets of U.S. preschoolers, our study is the first to use ingredient lists and product-specific attributes to categorize food and beverage purchases in this way, which is an essential step enabling us to translate purchase elasticities to dietary intake in order to estimate the influence on HEI. Thus, there is no study with which to directly compare our particular findings relating to the HEI. Nonetheless, analogous findings from the extant literature support our results. Harding et al. used data from the Nielsen Homescan Panel to examine the relationship between the price of SSBs and macronutrient intake. They found that a 20% increase in the price of SSBs was associated with a nearly 20% decrease in total grams of sugar purchased²². Similarly, although we did not examine *total* sugars, we saw an 11% reduction in purchases of *added* sugars with a 20% increase in the price of SSBs.

There are several important limitations to our study. Foremost, because our study conforms to a 'natural experiment' in which observed differences in price were used to simulate a tax, the directionality of the relationship between SSB price and diet is ambiguous. Consequently, we are limited in our ability to draw causal inferences from our findings. In addition, our demand relationships are based on data from the Nielsen Homescan Panel, which is limited to items with barcodes. Fresh meats and produce, restaurant foods/beverages, and foods/beverages without barcodes or without nutrition facts panels, are not well-represented in the Homescan data²³. Thus, following previous works^{7, 8}, we assumed the demand relationships for the foods/beverages in our analyses did not differ for barcoded and non-barcoded items.

Furthermore, we assumed proportional transference of 'tax'-related changes in per capita household changes and changes in child diet^{7, 8}. However, in light of previous research

indicating economic stress is associated with greater reductions in food purchases in households *with* children than in those without, this may be a conservative assumption. In addition, our approach does not directly account for discounts associated with purchasing greater volume of SSBs (e.g., two-liter vs. 20-oz), the impact of which would be expected to increase the variance in estimation of our estimates, potentially biasing our estimates toward a null association. Our use of a single 24-hour recall to estimate mean intakes of selected foods and beverages among U.S. preschool children is another limitation. As not all respondents provided recalls on both days, choosing to use both days of recall would significantly limit our already limited sample size. Even with the use of a single 24-hour recall, however, unbiased estimates of mean usual intakes of even episodically-consumed foods/beverages for a sample can be obtained²⁴. Lastly, we did not incorporate participation in food assistance programs, such as WIC or SNAP, into our analyses. While these data were available for NHANES, there were no comparable variables with which to estimate stratum-specific demand estimates in Homescan. Thus, we instead presented our findings by level of household income with attention to relevant income cut-points and sample size constraints.

In addition, the HEI has limitations. The HEI relies on the USDA Food Patterns food/beverage groups, among which some specific foods, such as grain-based desserts, candy and sweets, and salty snacks, are not individually represented. However, these foods *do* contribute to the HEI scoring algorithm through the ‘refined grains’, ‘added sugars’, and ‘solid fats’ components¹⁶. In addition, the HEI scoring algorithm gives greater weight to some component groups (e.g., ‘discretionary calories’) and less weight to others (e.g., ‘total protein’)¹⁶, which likely influenced our overall findings. Lastly, given the differences between the Homescan food/beverage groups, and the USDA Food Patterns groups, determining which Homescan elasticity estimates to apply to which USDA Food Patterns groups was based on closest approximation. For some groups, there was no suitable approximation in Homescan (e.g., soy products), while others groups may have been loosely matched.

Conclusion

As the first to examine such a tax in relation to the HEI and its components, our study provides unique insights into the consequences of an SSB tax on the diets of preschool-age children. Our findings suggest that an SSB tax might achieve the intended result of reducing intakes of SSBs and total calories in preschool children. However, an SSB tax could also have a small, but negative, impact on diet quality. Taken together, these findings offer limited support for a tax on SSBs on the diet of preschoolers, but suggest that *if* a tax on SSBs is to be used, it must be combined with other efforts in order to improve the diets of preschool children. Our findings run contrary to studies on older children, adolescents and young adults, suggesting this population with its lower intake of SSBs represents a unique subpopulation deserving of future attention.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

We also wish to thank Dr. Donna Miles for exceptional assistance with the data management and programming, Ms. Frances L. Dancy for administrative assistance, Mr. Tom Swasey for graphics support, and Dr. David Guilkey, Dr. Penny Gordon-Larsen, and Dr. Anna Maria Siega-Riz for assistance in this effort. C. N. F. was primarily responsible for conducting the analyses, creating tables/figures, interpreting results, and writing the manuscript. J. M. P. conducted much of the analyses related to the creation of food and beverage groups in NHANES and Homescan, and provided critical review and edits to the manuscript. S. W. N. and B. M. P. provided general guidance and oversight for the manuscript and related analyses. S. W. N. and B. M. P. also provided critical review and edits to the manuscript, tables, and figures. All authors have read and approved the final manuscript.

Financial disclosure: The Robert Wood Johnson Foundation (Grants 67506, 68793, 70017, 71837) and the National Institutes of Health (R01DK098072 and CPC 5 R24 HD050924).

Appendix Exhibit A. Description of demand model

As the outcome of interest, food and beverage purchase data were grouped at the UPC-level into food and beverage groups (see Supplemental Table 1) following the approach of Poti et al. (2015)²⁵. Demand relationships were estimated from 33 Homescan food and beverage groups that best corresponded to USDA Food Pattern components. Prices, modeled as price per 100 grams, were modeled as the main independent variable, whereas quantity purchased in grams/d per capita was modeled as the dependent variable. Either a two-part model or ordinary least square regression was used. For foods/beverages purchased by 80% of households, a two-part marginal effects model was used to obtain estimates of demand relationships among *all* households (both reporters and non-reporters of the target outcome of interest). This approach, which incorporates the probability of reporting the food/beverage of interest, is suitable for modeling outcomes with a significant proportion of non-reporters²⁶. The two-part model, which has been used previously in this capacity^{27, 28}, was chosen over a demand systems approach (AIDS/QUAIDS) in order to accommodate zero-censoring values while retaining individual-level observations. This approach has tended to yield smaller estimates than studies using demand systems^{27, 28}.

In the first part of the two-part model, probit regression was used to estimate the overall probability of purchasing the outcome food/beverage of interest conditioned on food/beverage prices and other covariates. In part two of the model, the same regressors were used as in part one, and the amount purchased (in grams per capita) among reported purchasers was estimated using conditional OLS regression. Lastly, estimates from both models were algebraically combined to obtain predicted amounts purchased in all households included in the sample. To account for correlation in repeated measures, and potential market-level correlation between households, corrected standard errors were computed using 1000 bootstrap replications with clustering at the market level. For more commonly purchased foods/beverages, only part two of the two-part model was used. Survey weighting was used in all statistical models with appropriate variance adjustments.

All prices were entered into the models as natural logs, as the distribution of prices was skewed. Similarly, all outcome variables were transformed using natural logs to account for skewness and to simplify the interpretability of coefficients as elasticities (defined as the change in amount purchased relative to the change in price). As log-transformation of the dependent variable may induce bias upon simple retransformation using the anti-log, Duan's smearing estimators were computed for each model²⁹, and model coefficients were

multiplied by the appropriate estimator upon retransformation. Because resulting coefficients from the log-log model can be interpreted as elasticities without retransformation, this approach was applied only to compute predicted changes in amounts purchased under each tax condition.

As it had been previously shown that the relationship between SSB price in food/beverage purchases differs by level of household income^{4, 7}, demand relationships were estimated for each of three categories of household income (0–185% FPL; >185–350% FPL; and >350% FPL). All models were adjusted for household composition (including the number of individuals by age and gender), head of household race/ethnicity, head of household education level, Food Price Index (FPI), quarterly market prices of all foods/beverages other than the main exposure, and market-level unemployment rate, year (using 2-year increments corresponding to NHANES survey years) and quarter (both using disjoint indicator variables). In addition, to adjust for potential heterogeneity in the relationship between beverage price and purchases over time, terms were included to represent time (year) interactions with the prices of regular soft drinks; juice drinks; low-fat, high-sugar milk; >1% fat, low-sugar milk; >1% fat, high-sugar milk; and sport and energy drinks.

List of abbreviations and their definitions

CPG	Consumer-packaged goods
d	Day
FPI	Food price index
FPL	Federal Poverty Level
g	Grams
HEI	Healthy Eating Index
Kcal	Kilocalories
RTE	Ready-to-eat
SSBs	Sugar-sweetened beverages
y	Year

References

1. Birch LL, Fisher JO. Development of eating behaviors among children and adolescents. *Pediatrics*. 1998; 101:539–49. [PubMed: 12224660]
2. Slining M, Popkin B. Trends in intakes and sources of solid fats and added sugars among US children and adolescents: 1994–2010. *Pediatric obesity*. 2013; 8:307–24. [PubMed: 23554397]
3. Brownell KD, Farley T, Willett WC, Popkin BM, Chaloupka FJ, Thompson JW, et al. The public health and economic benefits of taxing sugar-sweetened beverages. *N Engl J Med*. 2009; 361:1599–605. [PubMed: 19759377]
4. Zhen C, Wohlgenant MK, Karns S, Kaufman P. Habit formation and demand for sugar-sweetened beverages. *Am J Agric Econ*. 2011; 93:175–93.

5. Finkelstein EA, Zhen C, Bilger M, Nonnemaker J, Farooqui AM, Todd JE. Implications of a sugar-sweetened beverage (SSB) tax when substitutions to non-beverage items are considered. *J Health Econ.* 2012; 32:219–39. [PubMed: 23202266]
6. Dharmasena S, Capps O. Intended and unintended consequences of a proposed national tax on sugar-sweetened beverages to combat the US obesity problem. *Health Econ.* 2011; 21:669–94. [PubMed: 21538676]
7. Lin BH, Smith TA, Lee JY, Hall KD. Measuring weight outcomes for obesity intervention strategies: the case of a sugar-sweetened beverage tax. *Econ Hum Biol.* 2011; 9:329–41. [PubMed: 21940223]
8. Smith TA, Lin B-H, Lee JY. Taxing Caloric Sweetened Beverages. United States Department of Agriculture, Economic Research Report. 2010
9. Zhen C, Finkelstein EA, Nonnemaker JM, Karns SA, Todd JE. Predicting the Effects of Sugar-Sweetened Beverage Taxes on Food and Beverage Demand in a Large Demand System. *Am J Agric Econ.* 2014; 96:1–25. [PubMed: 24839299]
10. Wang YC, Bleich SN, Gortmaker SL. Increasing caloric contribution from sugar-sweetened beverages and 100% fruit juices among US children and adolescents, 1988–2004. *Pediatrics.* 2008; 121:e1604–14. [PubMed: 18519465]
11. Usual Dietary Intakes: Food Intakes, U.S. Population, 2007–10. Epidemiology Research Program Web site. National Cancer Institute; <http://epi.grants.cancer.gov.libproxy.lib.unc.edu/diet/usualintakes/pop/2007-10/>. Updated May 20, 2015. Accessed November 11, 2015
12. Ford CN, Ng SW, Popkin BM. Ten-year beverage intake trends among US preschool children: rapid declines between 2003 and 2010 but stagnancy in recent years. *Pediatr Obes.* 2015
13. Ford CN, Ng SW, Popkin BM. Targeted Beverage Taxes Influence Food and Beverage Purchases among Households with Preschool Children. *The Journal of nutrition.* 2015; 145:1835–43. [PubMed: 26063069]
14. Moshfegh AJ, Rhodes DG, Baer DJ, Murayi T, Clemens JC, Rumpler WV, et al. The US Department of Agriculture Automated Multiple-Pass Method reduces bias in the collection of energy intakes. *The American Journal of Clinical Nutrition.* 2008; 88:324–32. [PubMed: 18689367]
15. Raper N, Perloff B, Ingwersen L, Steinfeldt L, Anand J. An overview of USDA's dietary intake data system. *Journal of Food Composition and Analysis.* 2004; 17:545–55.
16. Guenther PM, Casavale KO, Reedy J, Kirkpatrick SI, Hiza HA, Kuczynski KJ, et al. Update of the healthy eating index: HEI-2010. *Journal of the Academy of Nutrition and Dietetics.* 2013; 113:569–80. [PubMed: 23415502]
17. Freedman LS, Guenther PM, Krebs-Smith SM, Kott PS. A population's mean Healthy Eating Index-2005 scores are best estimated by the score of the population ratio when one 24-hour recall is available. *The Journal of nutrition.* 2008; 138:1725–29. [PubMed: 18716176]
18. Bowman, S., Friday, J., Moshfegh, A. MyPyramid Equivalents Database 2.0 for USDA Survey Foods, 2003–2004. Food Surveys Research Group, Beltsville Human Nutrition Research Center, Agricultural Research Service, U.S. Department of Agriculture; Beltsville, MD: 2008.
19. Bowman, S., Clemens, J., Friday, J., Moshfegh, A. Food Patterns Equivalents Database 2011–12: Methodology and User Guide. Food Surveys Research Group, Beltsville Human Nutrition Research Center, Agricultural Research Service, U.S. Department of Agriculture; Beltsville, Maryland: 2014.
20. IOM (institute of Medicine). Local government actions to prevent childhood obesity. Washington, DC: National Academies Press; 2009.
21. Ford CN, Slining MM, Popkin BM. Trends in Dietary Intake among US 2- to 6-Year-Old Children, 1989–2008. *J Acad Nutr Diet.* 2013; 113:35–42.e6. [PubMed: 23260722]
22. Harding M, Lovenheim M. The Effect of Prices on Nutrition: Comparing the Impact of Product- and Nutrient-Specific Taxes. 2014
23. Zhen C, Taylor JL, Muth MK, Leibtag E. Understanding Differences in Self-Reported Expenditures between Household Scanner Data and Diary Survey Data: A Comparison of Homescan and Consumer Expenditure Survey. *Rev Agr Econ.* 2009; 31:470–92.

24. National Cancer Institute (NCI), National Institutes of Health (NIH). Usual Dietary Intakes: Background. In: Applied Research; Cancer Control and Population Sciences. , editor. Exposure Assessment Methods. 2013.
25. Poti J, Mendez M, Ng SW, Popkin B. Are Food Processing and Convenience Linked with the Nutritional Quality of Foods Purchased by US Households? The FASEB Journal. 2015; 29:587.9.
26. Haines PS, Popkin BM, Guilkey DK. Modeling food consumption decisions as a two-step process. Am J Agric Econ. 1988; 70:543–52.
27. Duffey KJ, Gordon-Larsen P, Shikany JM, Guilkey D, Jacobs DR Jr, Popkin BM. Food price and diet and health outcomes: 20 years of the CARDIA Study. Archives of Internal Medicine. 2010; 170:420. [PubMed: 20212177]
28. Finkelstein EA, Zhen C, Bilger M, Nonnemaker J, Farooqui AM, Todd JE. Implications of a sugar-sweetened beverage (SSB) tax when substitutions to non-beverage items are considered. J Health Econ. 2013; 32:219–39. [PubMed: 23202266]
29. Duan N. Smearing estimate: a nonparametric retransformation method. J Amer Statistical Assoc. 1983; 78:605–10.

What is known

- Sugar-sweetened beverages, a key source of discretionary calories in children, are thought to play a critical role in child obesity
- A tax on sugar-sweetened beverages may discourage intake of sugar-sweetened beverages, but how such a tax might influence overall diet quality in preschool children is unclear

What this study adds

- This study uses price and purchase data to simulate the relationship between a 20% tax on sugar-sweetened beverages and food and beverage intakes among U.S. preschool children. The 2010 Healthy Eating Index was used to ascertain diet quality in US children ages 2–5y who participated in the National Health and Nutrition Examination Survey (2009–2012)
- A 20% increase in the price of SSBs was associated with lower total caloric intake, caloric intake from juice drinks, added sugars, refined grains, and total meat. However, intakes of total protein, vegetables, and fruit, were lower with a tax.
- Total HEI score was 0.85 points lower with a tax, which while statistically significant, represented less than a 2% change.
- Thus, this finding would appear to suggest that a tax on SSBs could have the intended reduction in intake of SSBs among U.S. preschool children without appreciably influencing diet quality.

Table 1

Selected sociodemographic characteristics of children ages 2–5 years who participated in the National Health and Nutrition Examination Survey, years 2009–2012¹

Number of observations	1,706
<-----Percent ± standard error----->	
Age	
2–3 years	53% ± 2%
4–5 years	47% ± 2%
Gender	
Male	48% ± 2%
Female	52% ± 2%
Race/ethnicity	
Non-Hispanic White	54% ± 3%
Non-Hispanic Black	13% ± 1%
Hispanic	24% ± 3%
Other	9% ± 2%
Education level ²	
Less than a high-school diploma	21% ± 2%
High-school diploma or equivalent	20% ± 2%
Some college	31% ± 2%
Bachelor's degree or more	28% ± 3%
Household income level	
0–185% FPL	50% ± 2%
>185–350% FPL	20% ± 2%
>350% FPL	30% ± 3%

Abbreviations: FPL, Federal Poverty Level

¹Values are given as mean proportion ± standard error, computed using survey weights to account for complex multi-stage sampling design

²Highest education level completed by household reference individual

Table 2

Mean daily intake of total calories and calories from selected beverages among children ages 2–5 years who participated in NHANES 2009–2012

	No tax condition ^I	Tax condition ^I	Difference	P-value
Total calories	1560 ± 14	1532 ± 14	–28	<0.001
Low-fat, low-sugar milk	30 ± 6	33 ± 7	3	0.007
Low-fat, high-sugar milk	7 ± 1	7 ± 1	0	0.054
High-fat, low-sugar milk	125 ± 7	123 ± 7	–2	<0.001
High-fat, high-sugar milk	49 ± 6	56 ± 7	7	<0.001
100% juice	35 ± 4	41 ± 4	5	<0.001
Juice drinks	72 ± 4	52 ± 3	–20	<0.001
Sports and energy drinks	2 ± 1	3 ± 1	1	0.002
Soft drinks	17 ± 1	16 ± 1	–1	<0.001

^I Values are given as mean ± standard error, computed using survey weights to account for complex multi-stage sampling design

Mean healthy eating index scores before and after a simulated 20% increase in the price of sugar-sweetened beverages among U.S. children ages 2–5 years^{1–4}

Table 3

	Points possible	No-tax condition		Tax condition		Difference	
		Mean	SE	Mean	SE	Mean	p
Total vegetables	5	1.96	0.09	1.53	0.07	−0.43	<0.001
Greens and beans	5	0.53	0.05	0.41	0.04	−0.12	<0.001
Total fruit	5	3.62	0.08	3.42	0.08	−0.20	<0.001
Whole fruit	5	2.74	0.08	2.60	0.08	−0.14	<0.001
Whole grains	10	1.06	0.11	0.96	0.11	−0.11	<0.001
Total dairy	10	8.56	0.15	8.50	0.15	−0.06	<0.001
Total protein	5	2.63	0.07	2.09	0.07	−0.55	<0.001
Seafood and plant proteins	5	0.84	0.06	0.79	0.07	−0.05	0.014
Fatty acids	10	5.00	0.14	3.97	0.14	−1.03	<0.001
Sodium	10	5.91	0.10	5.91	0.10	0.00	1.00
Refined grains	10	6.56	0.14	7.50	0.12	0.94	<0.001
Empty calories (solid fats; added sugars)	20	7.05	0.32	7.94	0.34	0.89	<0.001
Total HEI score	100	46.48	0.55	45.62	0.53	−0.85	<0.001

Abbreviations: HEI, Healthy Eating Index; SE, standard error

¹ Means and standard errors were computed using survey weights to account for complex multi-stage sampling design

² No tax condition Healthy Eating Index scores were computed using the 2009–2012 NHANES data

³ Tax condition Healthy Eating Index scores were computed after applying demand model estimates (elasticities) to the 2009–2012 NHANES data

⁴ P-values shown correspond to a two-tailed paired t-test of category-specific means by tax condition