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Association of a Sweetened Beverage Tax With Soda Consumption in High School Students

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IMPORTANCE Sweetened beverage taxes are one policy approach to reduce intake of added sugars. Soda is the leading source of added sugars in the US diet, but few studies have examined how such taxes influence sweetened beverage intake in youth.

OBJECTIVE To estimate the association between the Philadelphia, Pennsylvania, beverage tax and adolescent soda intake.

DESIGN, SETTING, AND PARTICIPANTS This economic evaluation of school district–level Youth Risk Behavior Surveillance System data from September 2013 to December 2019 compared weekly soda intake in high school students in Philadelphia, a city with a sweetened beverage tax, with that in 7 comparison cities without beverage taxes. Difference-in-differences regression modeling was used to estimate change in soda intake in Philadelphia compared with control cities. Secondary analyses compared 100% juice and milk intake to explore potential substitution associations. Subgroup analyses evaluated differences by race and ethnicity and weight status (obesity and overweight or obesity). Analyses were performed between August 20 and October 20, 2020. School districts that had weighted data and a survey question on weekly soda intake from 2013 to 2019 were included. The study included high school students, grades 9 to 12, in school districts participating in the Youth Risk Behavior Surveillance System from 2013 to 2019.

EXPOSURES Implementation of a sweetened beverage tax in Philadelphia, Pennsylvania, in January 2017.

MAIN OUTCOMES AND MEASURES Reported weekly servings of soda, 100% juice, and milk.

RESULTS A total of 86 928 participants (weighted mean [SD] age, 15.8 [1.3] years; 49% female) from 8 US cities (including Philadelphia) were included. Before the tax, adolescents in the 7 comparison cities had a mean intake of 4 servings of soda per week compared with 5.4 servings per week in Philadelphia. Philadelphia's tax was associated with a reduction of 0.81 servings of soda per week (95% CI, −1.48 to −0.14 servings; *P* = .02) 2 years after tax implementation. There was no significant difference in 100% juice or milk intake, although Philadelphia adolescents consumed more juice than those in nontaxed cities. In subgroup analyses, the tax was associated with a reduction of 1.13 servings per week in Hispanic/Latinx adolescents (95% CI, −2.04 to −0.23 servings; *P* = .01) and 1.2 servings per week in adolescents with obesity (95% CI, −2.33 to −0.13 servings; *P* = .03).

CONCLUSIONS AND RELEVANCE This economic evaluation found that a sweetened beverage tax was associated with a reduction in soda intake among adolescents, providing evidence that such taxes can improve dietary behaviors.

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Supplemental content

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Nearly half of added sugars in the US diet comes from beverages, with one-quarter of added sugars from soda alone.[1-3] Adolescents and young adults consume more sweetened beverages than any other age group, and high sweetened beverage consumption is linked to obesity, type 2 diabetes, cardiovascular disease, and many types of cancers.[1-8] Sweetened beverage consumption and obesity prevalence are highest among Black and Hispanic/Latinx adolescents, aligning with broader health disparities in the US population that are rooted in structural racism and income inequality.[9-11] The type of sweetened beverages consumed also differs by race and ethnicity, with Hispanic/Latinx and White adolescents consuming more soda and Black adolescents consuming more sweetened fruit drinks.[1,2,12,13] One in 5 US adolescents has obesity, and, for most, obesity persists and worsens in adulthood.[11,14] Adolescence is thus a crucial time to intervene in unhealthy dietary habits and ameliorate health disparities that only widen in adulthood.[11,14]

Excise taxes on sweetened beverages are one policy approach to decrease consumption of added sugars.[15] Numerous countries and 8 US cities have implemented sweetened beverage taxes.[16-19] The largest of these cities is Philadelphia, Pennsylvania, which implemented a per-ounce tax of $0.015 on sugar-sweetened and artificially sweetened beverages on January 1, 2017 (all other US cities with beverage taxes tax only sugar-sweetened beverages). Sweetened beverage taxes have been associated with consistent reductions in sales of taxed beverages.[20-28] The data on whether taxes resulted in decreased sweetened beverage consumption are less clear, perhaps owing to reliance on self-reported data and small or modest sample sizes.[25-32]

In Berkeley, California, a sweetened beverage tax was associated with a sustained reduction in adults' reported consumption of sweetened beverages up to 3 years after tax implementation.[29,30] In 1 Philadelphia study with a small sample size, the probability of being a daily adult consumer of sugar-sweetened soda decreased by 40% shortly after tax implementation, but other measures of sweetened beverage intake did not change.[31] Null effects on consumption were also reported 1 year later.[32]

Results among youth are similarly mixed, although existing studies have small, nonrepresentative samples.[25,28] Two studies evaluating beverage taxes in Oakland, California, and Philadelphia found no change in added sugar consumption among all youth (age 2-17 years), although Philadelphia's tax was associated with a 22% reduction in sweetened beverage intake among youth who were heavy baseline sweetened beverage drinkers (consuming added sugars equivalent to at least one 20-ounce soda per day pretax).[25,28] To our knowledge, no studies have focused specifically on adolescent sweetened beverage consumption in response to beverage taxes, and studies with large sample sizes are lacking.

To better understand the influence of sweetened beverage taxes on adolescent sweetened beverage consumption, we used data from the Youth Risk Behavior Surveillance System (YRBSS), which collects surveys from representative samples of high school students in cities throughout the US. Using YRBSS school district-level data, we conducted a difference-in-differences analysis to examine the association between Philadelphia's sweetened beverage tax and self-reported soda consumption in high school students in Philadelphia compared with control locations without taxes. We also examined self-reported milk and 100% juice consumption. We hypothesized that Philadelphia's tax would be associated with reduced soda consumption and there would be no meaningful changes in milk and 100% juice intake.

Key Points

Question Is a sweetened beverage tax associated with reduced soda consumption in high school students?

Findings In this economic evaluation of representative data from 8 US school districts from 2013 to 2019, self-reported soda consumption among high school students in Philadelphia, Pennsylvania, which has a sweetened beverage tax, was compared with that of students in cities without taxes. Philadelphia's tax was associated with a statistically significant reduction in soda consumption of 0.81 servings of soda per week 2 years after tax implementation.

Meaning Sweetened beverage taxes are associated with improved dietary behaviors, such as reduced soda consumption, among high school students.

Methods

Data and Sample

The YRBSS is a biennial survey of high school students' risk behavior, supported by the Centers for Disease Control and Prevention. For this economic evaluation, we obtained deidentified school district-level YRBSS data that contained self-reported weekly soda, milk, and 100% juice consumption, as well as demographic information. The school district-level YRBSS uses 2-stage sampling of high schools and classrooms to create a representative sample of all students in grades 9 to 12 in each school district.[33] We included school districts that had weighted data and a survey question on weekly soda intake from September 2012 to December 2019, which includes 2 sampling cycles before and after the implementation of Philadelphia's sweetened beverage tax, to capture secular trends in beverage consumption.[34] This sampling included data from 86 928 high school students who participated in the YRBSS in 8 US school districts: Philadelphia, Pennsylvania; New York, New York; Baltimore, Maryland; Orange County, Florida; Palm Beach County, Florida; Broward County, Florida; San Diego, California; and Los Angeles, California. Written parental consent for participation was obtained by each school.[35] The Children's Hospital of Philadelphia's institutional review board deemed this study not human subjects research and therefore exempt from review.

We conducted the primary analysis with the full population of high school students participating in YRBSS from the included sites. Covariates included age, sex, race and ethnicity, body mass index, year, and school district. We then conducted subgroup analyses by race and ethnicity and by weight status (overweight or obesity) to identify groups that may have been more responsive to the tax. We identified adolescents with overweight or obesity according to pediatric definitions by body mass index percentiles (between the 85th and 95th percentiles for overweight and above the 95th percentile for obesity).[36] Race and ethnicity were self-reported and condensed to a 4-level variable within the YRBSS (including Black or African American, Hispanic/Latinx, White, and all other races).[34]

Exposure and Outcome

The exposure was Philadelphia's city-level sweetened beverage tax that went into effect on January 1, 2017. Because the data collection period for YRBSS is between March and May in a given year, we considered students as exposed to the policy beginning in the 2017 YRBSS cycle. None of the other cities included in the analysis enacted sweetened beverage taxes during the study period.

The primary outcome was the number of reported servings of soda consumed per week, in response to the question, "During the past 7 days, how many times did you drink a can, bottle, or glass of soda or pop, such as Coke, Pepsi, or Sprite (do not count diet soda or diet pop)?" The response options were 0, 1 to 3 times, 4 to 6 times, 1 time per day, 2 times per day, 3 times per day, and 4 or more times per day. We transformed the response options into number of servings of soda per week (eg, 3 times per day was transformed to 21 servings in the last 7 days). When the response included a range, we used the midpoint (eg, 1 to 3 times during the last 7 days was transformed to 2 servings of soda during the last 7 days). Our secondary outcomes were reported servings of milk and 100% juice per week. The soda question and those regarding milk and 100% juice were worded similarly.

All responses were self-reported by high school students using instruments that the YRBSS refined to improve reliability and validity.[33] Further background on the reliability of YRBSS data can be found in eAppendixes 1-3 in the Supplement.

Statistical Analysis

We estimated the association between implementation of a sweetened beverage tax and the number of servings of soda consumed per week using a difference-in-differences approach, which compares the mean change of an outcome before and after a policy implementation in groups exposed and unexposed to the policy.[37] All analyses were conducted with Stata version 15 (StataCorp LLC).

The difference-in-differences approach relies on a parallel-trends assumption that asserts that had there been no tax in Philadelphia, the soda consumption trend would have been similar to that in the nonintervention cities. This counterfactual assumption is not directly testable, but we assessed its feasibility by assessing whether the soda consumption trend in the pretax period in Philadelphia was parallel to that in the comparison cities combined. We accomplished this by performing a linear regression analysis of reported weekly servings of soda consumed before implementation of the tax, estimating an interaction term between year and city with a tax (Philadelphia) and controlling for age, sex, race and ethnicity, and body mass index. We included school district as a covariate to adjust for the time-variant characteristics that could produce differences in absolute levels of soda consumption by school district. We performed χ^2 tests to evaluate for changes in demographic composition over time in the intervention and nonintervention groups.

We also reviewed news articles and health department websites in all of the cities included in the analysis for policies or campaigns that could have affected sweetened beverage consumption to assess the "common shock" assumption, which assumes that any event that occurs during the intervention period affects all groups equally. New York City was the only site that had a public health campaign aimed at decreasing sweetened beverage consumption. Because its potential influence would likely decrease sweetened beverage consumption in New York City and possibly lead to underestimation of the tax effect in Philadelphia, we included New York City in the main analysis and performed sensitivity analyses without it.

In the difference-in-differences analysis, we estimated the change in weekly soda consumption in the pretax vs posttax period in Philadelphia compared with all other comparison cities by estimating the interaction between binary indicators for presence of a tax and time in a linear regression model and controlling for school district, year, age, sex, race and ethnicity, and body mass index. Because 11.9% of the main outcome variable was missing at random, we performed multiple imputations with chained equations and 20 iterations to impute missing values. Predictors used in the equations included age, sex, race and ethnicity, body mass index, city, and year. We accounted for the survey-weighted design of YRBSS by using svy estimation in Stata.

We then performed subgroup analyses to obtain estimates of reduction in soda consumption by racial or ethnic group and by weight status (obesity and overweight or obesity) to explore whether consumption habits would differ by these groups. We included race and ethnicity because Black and Hispanic/Latinx youth have different beverage consumption patterns compared with White youth and higher rates of chronic diseases associated with overconsumption of sweetened beverages.[10-13] These disparities are driven by structural racism and inequality in opportunity to engage in healthier behaviors.[38,39] Furthermore, because Black and Hispanic/Latinx youth are more likely to live in lower-income households, we hypothesized that they might be more influenced by a beverage tax, as has been observed with tobacco taxes.[40,41] To account for multiple comparisons, a Bonferroni correction was used in which $P < .013$ for the 4 analyses conducted within racial or ethnic group (Black, Hispanic/Latinx, White, and other) and $P < .03$ for the 2 analyses conducted within weight status (obesity and overweight or obesity) was deemed statistically significant. All P values were 2 sided.

Sensitivity Analyses

We performed sensitivity analyses to assess the robustness of our findings. First, to assess the association of using multiple imputation, we repeated the primary analysis as a complete case analysis. We then repeated the primary analysis with the

Table 1. Participant Characteristics Across All Years of the Youth Risk Behavior Surveillance System, 2013-2019

Characteristic	Weighted %: Philadelphia (SB tax) (n = 5799)	Weighted %: All other cities (no SB tax) (n = 81 129)	P value
Age, mean (SD), y	16.04 (1.2)	15.74 (1.3)	<.001
Sex			
Male adolescents	50.1	50.8	.62
Female adolescents	49.9	49.2	
Race and ethnicity			
Black	53.5	26.6	<.001
Hispanic/Latinx	18.7	42.4	
White	13.9	17.7	
Other[a]	13.9	13.3	
BMI			
Mean	23.8	23.2	<.001
Overweight	17.0	16.4	
Obesity	15.4	12.9	

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); SB, sweetened beverage.

[a] "Other" includes American Indian or Alaska Native, Asian, Native Hawaiian or Other Pacific Islander, and any respondent who selected multiple responses to the question about race and ethnicity (respondents were instructed to select all that applied).

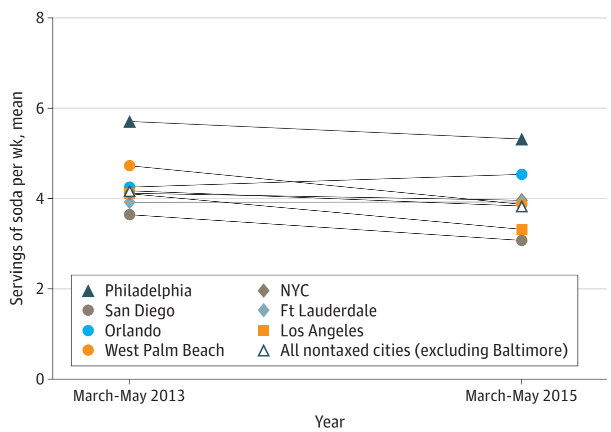
main outcome variable defined as the minimum soda servings per week instead of the midpoint to ensure we were not overestimating an association. We performed an analysis excluding New York City because it ran a public health campaign aimed at decreasing sweetened beverage consumption during the study period. We included Baltimore City School District data in the main analysis because of its nearby location and sociodemographic similarities to Philadelphia, but Baltimore's data collection years were off cycle compared with those of the other cities (Baltimore collected data in 2013, 2014, 2016, and 2018).[20,34,42] This meant that we had only 1 year post-Philadelphia tax in Baltimore, so we also conducted a sensitivity analysis excluding Baltimore. Further sensitivity analyses are shown in the eMethods in the Supplement.

Results

Data were available for a total of 86 928 participants (weighted mean [SD] age, 15.8 [1.3] years; 49% female and 51% male adolescents). Twenty-eight percent of participants were Black; 41%, Hispanic/Latinx; 18%, White; and 13%, of other race or ethnicity. Adolescents in Philadelphia and the comparison cities were similar in terms of sex (male adolescents, 50.1% vs 50.8%, respectively; female adolescents, 49.9% vs 49.2%) (**Table 1**). Students in Philadelphia were slightly older than those in cities without a tax (weighted mean [SD] age, 16.0 [1.2] years vs 15.7 [1.3] years). Philadelphia also had more Black students (53.5% vs 26.6%) and fewer White students (13.9% vs 17.7%) and Hispanic/Latinx students (18.7% vs 42.4%). There was a larger proportion of Philadelphia students vs those in comparison cities with overweight (17.0% vs 16.4%) or obesity (15.4% vs 12.9%). Demographic characteristics in Philadelphia and comparison cities remained stable over time except for a statistically significant increase in proportion of students with obesity in comparison cities in the posttax period.

Trends in weekly soda consumption were parallel and declining in Philadelphia and the comparison cities in the preintervention period (**Figure 1**). Before tax implementation, temporal trends in weekly soda consumption were not statistically significantly different between Philadelphia and the comparison. Trends in weekly 100% juice consumption were not parallel in the pretax period. Philadelphia lacked 2013 data on milk consumption, so we were unable to adequately assess milk for parallel trends. Analyses including 100% juice and milk are thus exploratory.

Figure 1. Parallel-Trends Assessment Comparing Philadelphia With All Other Nontaxed Cities in the Preintervention Period



Trends in weekly soda consumption in Philadelphia and nontaxed comparison cities in the preintervention period. Other plotted lines represent individual cities' soda consumption trends. To test the parallel-trends assumption, we performed a linear regression analysis of reported weekly servings of soda consumed before implementation of the tax and estimated an interaction term between year and city with a sweetened beverage tax (Philadelphia), controlling for school district, year, age, sex, race and ethnicity, and body mass index. Temporal trends in weekly soda consumption were not significantly different between Philadelphia and the comparison cities in the pretax period (Philadelphia students consumed 0.06 servings per week more than students in comparison cities) (95% CI, −0.95 to 1.10 servings; *P* = .90). NYC indicates New York City.

Table 2 and **Table 3** show the net change in student-reported weekly servings of soda, 100% juice, and milk consumed after tax implementation in Philadelphia compared with

Table 2. Regression Results for Weekly Servings of Soda (Taxed Beverage) Consumed Pretax and Posttax Comparing Philadelphia With All Other Cities

		Mean servings consumed per week							
		Philadelphia			All other cities				
Variable	No. of individuals	Pretax	Posttax	Within-group difference	Pretax	Posttax	Within-group difference	Difference-in-differences estimate (95% CI)	*P* value
All	74 346	5.4	3.9	−1.5	4.0	3.4	−0.6	−0.81 (−1.48 to −0.14)	.02
Subgroup analysis by race and ethnicity									
Black	21 189	5.7	4.4	−1.3	4.5	3.8	−0.7	−0.68 (−1.65 to 0.29)	.17
Hispanic/Latinx	29 125	5.7	4.1	−1.6	4.2	3.6	−0.6	−1.13 (−2.04 to −0.23)	.01
White	11 927	4.9	3.0	−1.9	3.6	2.8	−0.8	−1.24 (−2.64 to 0.16)	.08
Other[a]	12 105	3.6	2.8	−0.8	3.1	2.8	−0.3	−0.39 (−1.43 to 0.64)	.46
Subgroup analysis by weight status									
Normal weight	52 084	5.5	4.1	−1.4	4.0	3.3	−0.7	−0.78 (−1.66 to 0.09)	.08
Obesity	9876	5.5	3.7	−1.8	4.2	3.7	−0.5	−1.23 (−2.33 to −0.13)	.03
Overweight or obesity	22 262	5.1	3.8	−1.3	4.1	3.5	−0.6	−0.80 (−1.58 to −0.02)	.04

[a] Race and ethnicity were self-reported and condensed to a 4-level variable within the Youth Risk Behavior Surveillance System (including Black, Hispanic/Latinx, White, and all other races).

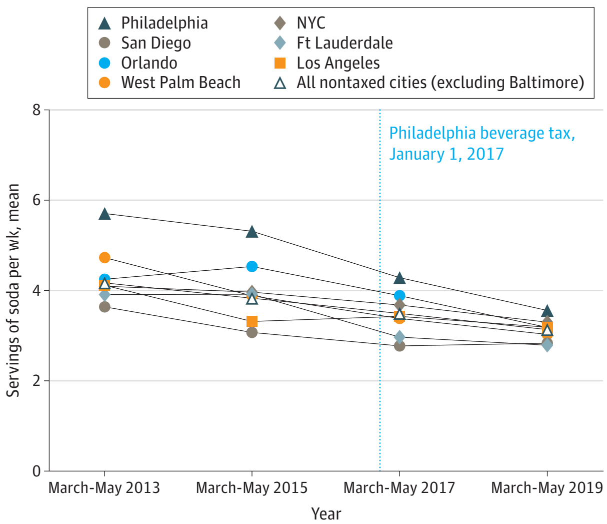
Table 3. Regression Results for Weekly Servings of 100% Juice and Milk (Nontaxed Beverages) Consumed Pretax and Posttax Comparing Philadelphia With All Other Cities

		Mean servings consumed per week							
		Philadelphia			All other cities				
Variable	No. of individuals	Pretax	Posttax	Within-group difference	Pretax	Posttax	Within-group difference	Difference-in-differences estimate (95% CI)	*P* value
100% Juice									
All	74 346	5.6	4.9	−0.7	5.4	4.5	−0.9	0.50 (−0.09 to 1.08)	.10
Subgroup analysis by race and ethnicity									
Black	21 189	5.8	5.5	−0.3	6.5	5.5	−1.0	1.20 (0.30 to 2.11)	.01
Hispanic/Latinx	29 125	6.1	4.8	−1.3	5.6	4.6	−1.0	−0.18 (−1.35 to 1.00)	.77
White	11 927	4.5	3.6	−0.9	4.2	3.2	−1.0	0.10 (−1.05 to 1.25)	.87
Other[a]	12 105	5.4	3.8	−1.6	4.0	3.5	−0.5	−0.91 (−1.94 to 0.12)	.08
Subgroup analysis by weight status									
Normal weight	52 084	5.7	4.9	−0.8	5.4	4.4	−1.0	0.34 (−0.46 to 1.14)	.41
Obesity	9876	5.2	5.1	−0.1	5.4	4.5	−0.9	0.88 (−0.40 to 2.17)	.18
Overweight or obesity	22 262	5.1	5.0	−0.1	5.4	4.5	−0.9	0.82 (−0.10 to 1.73)	.08
Milk									
All	74 346	4.7	4.1	−0.6	5.0	4.3	−0.7	0.02 (−0.50 to 0.50)	.95
Subgroup analysis by race and ethnicity									
White	11 927	5.1	4.7	−0.4	5.4	4.2	−1.2	0.45 (−0.83 to 1.73)	.49
Black	21 189	4.5	3.6	−0.9	4.2	3.9	−0.3	−0.67 (−1.40 to 0.08)	.08
Hispanic/Latinx	29 125	5.0	4.4	−0.6	5.5	4.4	−1.1	0.56 (−0.48 to 1.60)	.29
Other[a]	12 105	4.8	4.6	−0.2	5.0	4.5	−0.5	0.07 (−1.22 to 1.36)	.92
Subgroup analysis by weight status									
Normal weight	52 084	4.7	4.0	−0.7	5.0	4.3	−0.7	−0.01 (−0.68 to 0.67)	.99
Obesity	9876	4.9	4.6	−0.3	5.5	4.5	−1.0	0.39 (−1.03 to 1.81)	.59
Overweight or obesity	22 262	4.7	4.2	−0.5	5.1	4.3	−0.8	0.04 (−0.82 to 0.91)	.92

[a] Race and ethnicity were self-reported and condensed to a 4-level variable within the Youth Risk Behavior Surveillance System (including Black, Hispanic/Latinx, White, and all other races).

cities without taxes. Before tax implementation, Philadelphia high school students reported a mean weekly consumption of 5.4 servings of soda vs 4 servings of soda per week consumed in the comparison cities. The tax was associated with

Figure 2. Mean Servings of Soda per Week, Comparing Philadelphia With Nontaxed Cities Across All Years, 2013-2019



Trends in weekly soda consumption in Philadelphia and nontaxed comparison cities across all years included in the analysis. Other plotted lines represent individual cities' soda consumption trends. The vertical blue line denotes implementation of the Philadelphia beverage tax in 2017. Youth Risk Behavior Surveillance System survey sampling occurred after implementation of the tax in 2017, so the 2017 Philadelphia data point reflects the tax's influence in that year. NYC indicates New York City.

a statistically significant reduction of 0.81 servings of soda per week (95% CI, −1.48 to −0.14 servings per week; *P* = .02) 2 years after tax implementation. **Figure 2** shows the unadjusted mean weekly servings of soda consumed by school district.

High school students reported consuming similar amounts of 100% juice and milk in the preintervention period in Philadelphia and comparison cities. After tax implementation, adolescents in Philadelphia consumed 0.5 more servings of 100% juice per week (95% CI, −0.09 to 1.08 servings) compared with those in cities without a tax, but this difference was not statistically significant (Table 3). There was no significant difference in reported weekly servings of milk consumed after tax initiation.

In a subgroup analysis stratified by race and ethnicity, the tax was associated with a statistically significant reduction of 1.13 servings of soda per week (95% CI, −2.04 to −0.23 servings; *P* = .01) among Hispanic/Latinx high school students (Table 2). The tax was associated with 1.2 more servings of 100% juice consumed per week among Black students in Philadelphia compared with those in other cities, although juice consumption declined overall in both Philadelphia and nontaxed cities. When stratified by weight status, the tax was associated with a reduction of 1.2 servings of soda per week (95% CI, −2.33 to −0.13 servings; *P* = .03) among students with obesity and 0.8 servings per week (95% CI, −1.58 to −0.02 servings; *P* = .04) among students with either overweight or obesity, although these findings were not statistically significant after accounting for multiple comparisons. The sensitivity analyses yielded nearly identical results (eAppendix 3 in the Supplement).

Discussion

In this economic evaluation, we observed that a citywide sweetened beverage tax was associated with a significant reduction in soda consumed by high school students in Philadelphia compared with 7 other US cities without sweetened beverage taxes. To our knowledge, this is the first evidence from a large, representative sample of adolescents that sweetened beverage taxes are associated with the reduction of a behavioral risk factor for obesity. We observed no statistically significant substitution toward 100% juice or milk.

To our knowledge, this is the largest study to date assessing the association of a sweetened beverage tax with soda consumption in adolescents. We conducted multiple sensitivity analyses that demonstrated consistency in our results. Our findings contribute to the literature and suggest that prior studies that reported null consumption effects among smaller samples may have been underpowered, likely because of inherent error in self-reported data, necessitating larger sample sizes, although the population in this study differed from others.[25,31,32] Our findings are consistent with data from store sales, which show large declines in purchases.[20]

To our knowledge, our study is unique in its focus on adolescents, who are known to be more price responsive to excise taxes than adults and may have more difficulty avoiding such taxes through cross-border shopping.[41,43,44] Because obesity in adolescence often portends obesity in adulthood, improving health behaviors in adolescents supports a healthier lifelong trajectory.[14]

We observed the largest reductions in soda consumption among Hispanic/Latinx adolescents and those with overweight or obesity, groups with high baseline soda consumption.[13,45,46] These findings are consistent with a smaller study evaluating the association of Philadelphia's tax with youth sweetened beverage consumption, which showed a significant reduction in sweetened beverage consumption only among youth who were heavy sweetened beverage consumers pretax.[25]

We found that Black adolescents in Philadelphia consumed more 100% juice than adolescents in nontaxed cities after tax implementation, which suggests some degree of substitution toward 100% juice that may offset the potential caloric deficit from decreased soda consumption. However, because the juice consumption trends in the pretax period were not parallel in Philadelphia and comparison cities (a key assumption of our analytic methods), these findings must be interpreted with caution. More research is needed to understand whether and to what extent adolescents are substituting 100% juice for soda in cities with sweetened beverage taxes.

Race has no biological basis, and there is no physiologic mechanism to explain the higher rates of sweetened beverage consumption or differences in sweetened beverage preference among Black and Hispanic/Latinx adolescents. Rather, these consumption patterns are likely the result of racist policies and practices, such as targeted junk food advertisement to communities of color.[47-49] Because sweetened beverage consumption and obesity prevalence are highest among Black and Hispanic/Latinx adolescents, our findings suggest that sweetened beverage taxes could improve health disparities, especially if tax revenue is directed toward programming that supports communities of color or addresses social determinants of health.

Limitations

Our study has several limitations. First, it relies on self-reported data, which are limited by measurement error and recall bias.[50] Second, trends in 100% juice and milk consumption were not parallel in the pretax period; thus, we could not evaluate for substitution of these beverages in response to the tax beyond exploratory analyses. Third, the survey captured only soda, milk, and 100% juice intake, so we were unable to assess the association between the tax and consumption of a range of other sweetened beverages such as iced teas, sports drinks, and fruit drinks. Without these data, we likely underestimated the tax response in Black adolescents, given previous studies reporting that Black youth drink more sweetened fruit drinks than soda.[12,13] Our study was also limited by lack of data about respondents' socioeconomic status, so we were unable to explore differential effects by income level, and we did not control for economic changes in each city, such as changes in unemployment rates. Fourth, our study design cannot demonstrate causality owing to the possible presence of uncontrolled confounding factors.

Conclusions

This economic evaluation provides evidence that the implementation of a sweetened beverage tax was associated with reduced weekly servings of soda consumed by high school students. These findings suggest that beverage taxes may be an effective policy approach to improving health behaviors tied to adolescent obesity.

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Author Contributions: Dr Edmondson had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Edmondson, Roberto, Gregory, Virudachalam.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Edmondson.
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REFERENCES

1. Bailey RL, Fulgoni VL, Cowan AE, Gaine PC. Sources of added sugars in young children, adolescents, and adults with low and high intakes of added sugars. *Nutrients*. 2018;10(1):E102. doi:10.3390/nu10010102

2. Reedy J, Krebs-Smith SM. Dietary sources of energy, solid fats, and added sugars among children and adolescents in the United States. *J Am Diet Assoc*. 2010;110(10):1477-1484. doi:10.1016/j.jada.2010.07.010

3. US Department of Agriculture; US Department of Health and Human Services. 2015-2020 Dietary guidelines for Americans 2015-2020. Accessed February 10, 2020. https://health.gov/sites/default/files/2019-09/2015-2020_Dietary_Guidelines.pdf

4. Malik VS, Schulze MB, Hu FB. Intake of sugar-sweetened beverages and weight gain: a systematic review. *Am J Clin Nutr*. 2006;84(2):274-288. doi:10.1093/ajcn/84.2.274

5. Malik VS, Popkin BM, Bray GA, Després J-P, Willett WC, Hu FB. Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: a meta-analysis. *Diabetes Care*. 2010;33(11):2477-2483. doi:10.2337/dc10-1079

6. Vartanian LR, Schwartz MB, Brownell KD. Effects of soft drink consumption on nutrition and health: a systematic review and meta-analysis. *Am J Public Health*. 2007;97(4):667-675. doi:10.2105/AJPH.2005.083782

7. National Institutes of Health. *Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The Evidence Report*. National Institutes of Health, National Heart, Lung, and Blood Institute; 1998. Accessed February 8, 2020. https://www.nhlbi.nih.gov/files/docs/guidelines/ob_gdlns.pdf

8. American College of Cardiology/American Heart Association Task Force on Practice Guidelines, Obesity Expert Panel, 2013. Executive summary: guidelines (2013) for the management of overweight and obesity in adults: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and the Obesity Society published by the Obesity Society and American College of Cardiology/American Heart Association Task Force on Practice Guidelines: based on a systematic review from the Obesity Expert Panel, 2013. *Obesity (Silver Spring)*. 2014;22(S2)(suppl 2):S5-S39. doi:10.1002/oby.20821

9. Skinner AC, Ravanbakht SN, Skelton JA, Perrin EM, Armstrong SC. Prevalence of obesity and severe obesity in US children, 1999-2016. *Pediatrics*. 2018;141(3):e20173459. doi:10.1542/peds.2017-3459

10. Mendez MA, Miles DR, Poti JM, Sotres-Alvarez D, Popkin BM. Persistent disparities over time in the distribution of sugar-sweetened beverage intake among children in the United States. *Am J Clin Nutr*. 2019;109(1):79-89. doi:10.1093/ajcn/nqy123

11. Hales CM, Carroll MD, Fryar CD, Ogden CL. Prevalence of obesity among adults and youth: United States, 2015-2016. *NCHS Data Brief*. 2017;(288):1-8.

12. Russo RG, Northridge ME, Wu B, Yi SS. Characterizing sugar-sweetened beverage consumption for US children and adolescents by race/ethnicity. *J Racial Ethn Health Disparities*. 2020;7(6):1100-1116. doi:10.1007/s40615-020-00733-7

13. Han E, Powell LM. Consumption patterns of sugar-sweetened beverages in the United States. *J Acad Nutr Diet*. 2013;113(1):43-53. doi:10.1016/j.jand.2012.09.016

14. Gordon-Larsen P, The NS, Adair LS. Longitudinal trends in obesity in the United States from adolescence to the third decade of life. *Obesity (Silver Spring)*. 2010;18(9):1801-1804. doi:10.1038/oby.2009.451

15. Brownell KD, Farley T, Willett WC, et al. The public health and economic benefits of taxing sugar-sweetened beverages. *N Engl J Med*. 2009;361(16):1599-1605. doi:10.1056/NEJMhpr0905723

16. Redondo M, Hernández-Aguado I, Lumbreras B. The impact of the tax on sweetened beverages: a systematic review. *Am J Clin Nutr*. 2018;108(3):548-563. doi:10.1093/ajcn/nqy135

17. Popkin BM, Ng SW. Sugar-sweetened beverage taxes: lessons to date and the future of taxation. *PLoS Med*. 2021;18(1):e1003412. doi:10.1371/journal.pmed.1003412

18. Bank W. *Taxes on Sugar-Sweetened Beverages: Summary of International Evidence and Experiences.* World Bank; 2020. doi:10.1596/33969

19. Busey E. *Sugary Drink Taxes Around the World.* Carolina Population Center; 2020.

20. Roberto CA, Lawman HG, LeVasseur MT, et al. Association of a beverage tax on sugar-sweetened and artificially sweetened beverages with changes in beverage prices and sales at chain retailers in a large urban setting. *JAMA*. 2019;321(18):1799-1810. doi:10.1001/jama.2019.4249

21. Powell LM, Leider J, Léger PT. The impact of a sweetened beverage tax on beverage volume sold in Cook County, Illinois, and its border area. *Ann Intern Med*. 2020;172(6):390-397. doi:10.7326/M19-2961

22. Powell LM, Leider J. The impact of Seattle's sweetened beverage tax on beverage prices and volume sold. *Econ Hum Biol*. 2020;37:100856. doi:10.1016/j.ehb.2020.100856

23. Cawley J, Frisvold D, Jones D. The impact of sugar-sweetened beverage taxes on purchases: Evidence from four city-level taxes in the United States. *Health Econ*. 2020;29(10):1289-1306. doi:10.1002/hec.4141

24. Cawley J, Frisvold D, Hill A, Jones D. The impact of the Philadelphia beverage tax on prices and product availability. *J Policy Anal Manag*. 2020;39(3):605-628. doi:10.1002/pam.22201

25. Cawley J, Frisvold D, Hill A, Jones D. The impact of the Philadelphia beverage tax on purchases and consumption by adults and children. *J Health Econ*. 2019;67:102225. doi:10.1016/j.jhealeco.2019.102225

26. Cawley J, Thow AM, Wen K, Frisvold D. The economics of taxes on sugar-sweetened beverages: a review of the effects on prices, sales, cross-border shopping, and consumption. *Annu Rev Nutr*. 2019;39(1):317-338. doi:10.1146/annurev-nutr-082018-124603

27. Silver LD, Ng SW, Ryan-Ibarra S, et al. Changes in prices, sales, consumer spending, and beverage consumption one year after a tax on sugar-sweetened beverages in Berkeley, California, US: a before-and-after study. *PLoS Med*. 2017;14(4):e1002283. doi:10.1371/journal.pmed.1002283

28. Cawley J, Frisvold D, Hill A, Jones D. Oakland's sugar-sweetened beverage tax: impacts on prices, purchases and consumption by adults and children. *Econ Hum Biol*. 2020;37:100865. doi:10.1016/j.ehb.2020.100865

29. Falbe J, Thompson HR, Becker CM, Rojas N, McCulloch CE, Madsen KA. Impact of the Berkeley excise tax on sugar-sweetened beverage consumption. *Am J Public Health*. 2016;106(10):1865-1871. doi:10.2105/AJPH.2016.303362

30. Lee MM, Falbe J, Schillinger D, Basu S, McCulloch CE, Madsen KA. Sugar-sweetened beverage consumption 3 years after the Berkeley, California, sugar-sweetened beverage tax. *Am J Public Health*. 2019;109(4):637-639. doi:10.2105/AJPH.2019.304971

31. Zhong Y, Auchincloss AH, Lee BK, Kanter GP. The short-term impacts of the Philadelphia beverage tax on beverage consumption. *Am J Prev Med*. 2018;55(1):26-34. doi:10.1016/j.amepre.2018.02.017

32. Zhong Y, Auchincloss AH, Lee BK, McKenna RM, Langellier BA. Sugar-sweetened and diet beverage consumption in Philadelphia one year after the beverage tax. *Int J Environ Res Public Health*. 2020;17(4):1336. doi:10.3390/ijerph17041336

33. Underwood JM, Brener N, Thornton J, et al. Overview and methods for the Youth Risk Behavior Surveillance System—United States, 2019. *MMWR Suppl*. 2020;69(1):1-10. doi:10.15585/mmwr.su6901a1

34. Centers for Disease Control and Prevention. Youth Risk Behavior Surveillance System (YRBSS): 2019 YRBS national, state, and district combined datasets user's guide. Accessed August 20, 2020. https://www.cdc.gov/healthyyouth/data/yrbs/pdf/2019/2019_YRBS_SADC_Documentation.pdf

35. Brener ND, Kahn L, Shanklin S, et al. *Methodology of the Youth Risk Behavior Surveillance System—2013*. Centers for Disease Control and Prevention; 2013.

36. Cheung PC, Cunningham SA, Narayan KMV, Kramer MR. Childhood obesity incidence in the United States: a systematic review. *Child Obes*. 2016;12(1):1-11. doi:10.1089/chi.2015.0055

37. Dimick JB, Ryan AM. Methods for evaluating changes in health care policy: the difference-in-differences approach. *JAMA*. 2014;312(22):2401-2402. doi:10.1001/jama.2014.16153

38. Boyd RW, Lindo EG, Weeks LD, McLemore MR. On racism: a new standard for publishing on racial health inequities. *Health Affairs* blog. July 2, 2020. Accessed June 14, 2021. https://www.healthaffairs.org/do/10.1377/hblog20200630.939347/full/

39. Phelan JC, Link BG. Is racism a fundamental cause of inequalities in health? *Annu Rev Sociol.* 2015;41(1):311-330. doi:10.1146/annurev-soc-073014-112305

40. Hawkins SS, Bach N, Baum CF. Impact of tobacco control policies on adolescent smoking. *J Adolesc Health*. 2016;58(6):679-685. doi:10.1016/j.jadohealth.2016.02.014

41. Chaloupka FJ, Powell LM, Warner KE. The use of excise taxes to reduce tobacco, alcohol, and sugary beverage consumption. *Annu Rev Public Health*. 2019;40(1):187-201. doi:10.1146/annurev-publhealth-040218-043816

42. Lawman HG, Bleich SN, Yan J, et al. One-year changes in sugar-sweetened beverage consumers' purchases following implementation of a beverage tax: a longitudinal quasi-experiment. *Am J Clin Nutr*. 2020;112(3):644-651. doi:10.1093/ajcn/nqaa158

43. Powell LM, Chaloupka FJ. Food prices and obesity: evidence and policy implications for taxes and subsidies. *Milbank Q*. 2009;87(1):229-257. doi:10.1111/j.1468-0009.2009.00554.x

44. Andreyeva T, Chaloupka FJ, Brownell KD. Estimating the potential of taxes on sugar-sweetened beverages to reduce consumption and generate revenue. *Prev Med*. 2011;52(6):413-416. doi:10.1016/j.ypmed.2011.03.013

45. Powell LM, Nguyen BT. Fast-food and full-service restaurant consumption among children and adolescents: effect on energy, beverage, and nutrient intake. *JAMA Pediatr*. 2013;167(1):14-20. doi:10.1001/jamapediatrics.2013.417

46. Park S, Sherry B, Foti K, Blanck HM. Self-reported academic grades and other correlates of sugar-sweetened soda intake among US adolescents. *J Acad Nutr Diet*. 2012;112(1):125-131. doi:10.1016/j.jada.2011.08.045

47. Harris JL. Targeted food marketing to Black and Hispanic consumers: the tobacco playbook. *Am J Public Health*. 2020;110(3):271-272. doi:10.2105/AJPH.2019.305518

48. Fleming-Milici F, Harris JL, Sarda V, Schwartz MB. Amount of Hispanic youth exposure to food and beverage advertising on Spanish- and English-language television. *JAMA Pediatr*. 2013;167(8):723-730. doi:10.1001/jamapediatrics.2013.137

49. Harris JL, Frazier W III, Kumanyika S, Ramirez AG. Increasing disparities in unhealthy food advertising targeted to Black and Hispanic youth. UConn Rudd Center for Food Policy and Obesity. Accessed June 12, 2021. https://media.ruddcenter.uconn.edu/PDFs/TargetedMarketingReport2019.pdf

50. Park Y, Dodd KW, Kipnis V, et al. Comparison of self-reported dietary intakes from the Automated Self-Administered 24-h recall, 4-d food records, and food-frequency questionnaires against recovery biomarkers. *Am J Clin Nutr*. 2018;107(1):80-93. doi:10.1093/ajcn/nqx002