Sugar-Sweetened Beverage Consumption Three Years After the Berkeley Sugar-Sweetened Beverage Tax

Matthew M. Lee, BA,1 Jennifer Falbe, ScD MPH,2 Dean Schillinger, MD,3 Sanjay Basu, MD PhD,4 Charles E. McCulloch, PhD,5 Kristine A. Madsen, MD MPH1*

* madsenk@berkeley.edu
Abstract

Objectives: To estimate changes in sugar-sweetened beverage (SSB) and water consumption three years after an SSB tax in Berkeley, California, relative to unexposed comparison neighborhoods.

Methods: Repeated annual cross-sectional beverage frequency questionnaires from 2014-2017 in demographically-diverse Berkeley (N=1,513) and comparison (San Francisco/Oakland, N=3,712) neighborhoods. Pre-tax consumption (2014) was compared to a weighted average of 3 years of post-tax consumption.

Results: At baseline, SSBs were consumed 1.25 times/day (95% CI: 1.00, 1.50) in Berkeley and 1.27 times/day (95% CI: 1.13, 1.42) in comparison city neighborhoods. Adjusting for covariates, consumption in Berkeley declined by 0.55 times/day (95% CI: -0.75, -0.35) for SSBs and increased by 1.02 times/day (95% CI: 0.54, 1.50) for water. Changes in consumption in Berkeley were significantly different from those in the comparison group, which saw no significant changes.

Conclusions: Reductions in SSB consumption were sustained in demographically-diverse Berkeley neighborhoods over the first three years of an SSB tax, relative to comparison cities.

Policy Implications: This study, demonstrating longer-term reductions in SSB consumption following SSB taxation in a U.S. city, suggests SSB taxes are an important public health intervention.
Introduction

SSB consumption, a major contributor to obesity, cardiometabolic disease, and dental caries, carries significant health care costs.\textsuperscript{1,2} SSB consumption has declined but remains high in the U.S. (50% of adults and 61% of children consume SSBs daily\textsuperscript{3}) particularly among low-income and racial/ethnic minority populations, who bear a disproportionate burden of diet-related disease.\textsuperscript{4}

SSB consumption fell in the short-term after SSB excise taxes were introduced into U.S. cities. Consumption in demographically-diverse neighborhoods in Berkeley, California declined by 21\%\textsuperscript{5} four months after Berkeley levied a $0.01/oz excise tax on distributors of non-milk, non-alcoholic beverages containing caloric sweeteners (≥2 calories/oz). SSB consumption fell by 26% in Philadelphia, Pennsylvania 2 months after its beverage excise tax.\textsuperscript{6}

Determining longer-term SSB consumption changes is critical for determining the health effects of an SSB tax. Here, we estimated SSB consumption changes in demographically-diverse neighborhoods in Berkeley and in neighboring cities 3 years after Berkeley’s tax.

Methods

Using a repeated cross-sectional design, SSB consumption was measured annually through beverage frequency questionnaires (BFQs) administered in demographically-diverse neighborhoods in Berkeley, Oakland, and San Francisco (SF). Oakland and SF were chosen as comparators given shared exogenous but difficult-to-measure factors (e.g., culture, media, and retail environments) with Berkeley that might affect SSB consumption. In Berkeley and SF, 2010 Census data were used to identify two large, neighborhoods with the highest combined proportion of African-American and Hispanic residents. Two Oakland neighborhoods were selected to match the distribution of African-American and Hispanic residents in the Berkeley and SF neighborhoods.

Baseline consumption was assessed in April-July 2014, before SSB taxes were proposed on the Berkeley and SF November ballots. Only Berkeley’s tax passed in 2014. During the 3 post-tax years, data were collected between April and October. In 2016, Oakland and SF surveys
occurred within 1-3 months of their SSB-tax ballot measures passing. Oakland implemented its tax in July 2017 and SF in January 2018; thus, some 2017 surveys occurred 1-3 months after Oakland’s tax took effect.

BFQs were based on the previously validated BEVQ-15,7 asking “How many times per day, week, or month do you drink…?” each of regular (not diet) soda, energy drinks, sports drinks, fruit drinks, pre-sweetened coffee/tea, and unsweetened water. Responses were converted to daily frequencies (times/day). Total SSB consumption was determined by summing frequencies for regular soda energy, sports, and fruit drinks; and pre-sweetened coffee/tea.

Within each neighborhood, questionnaires were administered as anonymous, 3-10-minute surveys in English or Spanish near the highest foot-traffic intersection. Trained data collectors invited passersby to complete a survey; 20% of those approached (n=2,435) in Berkeley and 22% (n=5,141) in comparison neighborhoods agreed (eFigure 1). Of these, 79% were eligible (lived in the city in which the survey was conducted, spoke English or Spanish, were ≥18 years old, and could demonstrate understanding of questions, i.e. did not appear inebriated).

The primary outcome was the difference in SSB consumption pre- versus the first 3 years post-tax in Berkeley relative to that in the comparison cities. For each beverage, generalized linear models with a log link function and a gamma distribution (accounting for the non-negative and right-skewed nature of count data), modeled mean frequency of daily consumption, adjusting for age, sex, race/ethnicity, language, education, neighborhood, survey month, and ambient temperature.8 An indicator term for Berkeley and interaction terms between Berkeley and categorical year were included to adjust for time-invariant unmeasured confounders unique to Berkeley, and robust standard errors were calculated to correct for heteroskedasticity. Pre-post changes and 95% confidence intervals (CIs) in consumption frequency were computed within and between groups using nlcom commands in Stata (version MP-15, StataCorp; eTable 3).

Berkeley’s SSB tax was levied on distributors, who were expected to pass costs onto retailers who, in turn, were expected to raise shelf prices. In 2015, 3 months after implementation, roughly half of the full tax rate had been “passed through” or reflected in observed shelf prices.9 Therefore, consumption in 2015, measured when pass-through was incomplete, was given only half the weight compared to data from 2016 and 2017, when the tax was more fully passed-through in Berkeley.10 In robustness checks, un-weighted and pre-post (2014 versus 2017) models were estimated, as was a doubly robust modified-inverse probability weighted model (m-
and models with multiple imputation (MICE) for missing outcome or covariate data (12%).

**Results**

The primary analytic sample included 1,513 participants from Berkeley (91% of eligible) and 3,712 from the comparison cities (87% of eligible) who completed a BFQ. Berkeley participants were older, more likely to be white, and more highly educated (eTable 1) than comparison participants. Post-tax participants were older than those pre-tax for both groups, and within Berkeley, more likely to be white and more highly educated.

Adjusted SSB consumption, similar at baseline in the two groups, diverged post-tax (Figure 1). The initial reduction in Berkeley from 2014 to 2015 (-0.30 times/day [CI: -0.51, -0.08]) was amplified in 2016 and 2017 (2016: -0.66 times/day [CI: -0.87, -0.46]; 2017: -0.56 times/day [CI: -0.78, -0.35]). In the fully adjusted model, SSB consumption in Berkeley decreased by 0.55 (CI: 0.35, 0.75) times/day from 2014 to the weighted average of 2015-2017 (52.3% reduction), with significant declines in all categories of SSBs except energy drinks (eTable 2); water consumption increased by 1.02 (CI: 0.54, 1.50) times/day (29.3% increase). There were no significant consumption changes in the comparison group.

In the weighted model adjusted for all covariates, SSB consumption decreased 0.55 (CI: 0.30, 0.81) times/day more in Berkeley than in the comparison (a relative decline of 52.5%), with significant declines in regular soda, sports drinks, and sweetened teas and coffees (eTable 2). Water consumption increased 0.85 (CI: 0.29, 1.42) times/day (25.1%) more in Berkeley than in the comparison (eFigure2).

All between-group results were robust to sensitivity analyses (eTable 3 and eFigure 3).

**Discussion**

We observed sustained changes in SSB consumption after an SSB tax in the U.S. Similar to our findings, studies in Mexico (the only other geography documenting longer-term trends in post-tax consumption) revealed increased effects over time, with a 5.5% decrease in the volume of taxed beverage purchases in the first year and 9.7% decrease in the second year post-tax.\(^{11}\)
Our results reflect consumption changes in demographically-diverse neighborhoods, whose residents are more likely to consume SSBs. In the second year of Mexico’s tax, the volume of taxed beverage purchases declined more in low- than in high-SES households (14.3% versus 5.6%), providing some empirical evidence that low-income populations, who bear a disproportionate burden of cardiometabolic diseases, may be more responsive to taxes. If similar patterns manifest in other jurisdictions in the U.S., taxes could reduce health disparities.

This study has several limitations, including a convenience sample that may limit generalizability and unmeasured confounding, a concern in all non-experimental designs. Results from Berkeley, a small and highly educated city, may not translate to other geographic areas. Self-reported BFQ data are subject to bias; however, BFQs have been validated, and change estimates are less susceptible to bias than point estimates of consumption. In 2017, Oakland surveys occurred 1-3 months post tax-implementation, and both Oakland and SF had SSB tax ballot measures in 2017, which might lead to conservative estimates of relative declines in Berkeley.

**Public Health Implications**

The persistent declines in SSB consumption we demonstrate in Berkeley, 3 years into an SSB tax, could significantly reduce obesity, cardiovascular disease, and associated health care costs, particularly among populations with high initial SSB consumption.
Acknowledgments

The authors report no conflict of interest regarding this work. No results included have been published previously. Research reported in this publication was supported by the National Institute of Diabetes and Digestive and Kidney Diseases of the National Institutes of Health under Award Numbers R01DK116852 and K01DK113068, and by the California Endowment under Award Number 000533. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health or the California Endowment.

Human Participant Protection

This work was considered exempt by the UC Berkeley Committee for the Protection of Human Subjects.

2. Hu FB. Resolved: there is sufficient scientific evidence that decreasing sugar-sweetened beverage consumption will reduce the prevalence of obesity and obesity-related diseases. Obes Rev. 2013;14(8):606-619.


Figure 1: Adjusted within-group frequencies and between-group differences in sugar-sweetened beverage consumption, 2014-2017