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1 **Sugar-Sweetened Beverage Consumption Three Years After the Berkeley Sugar-Sweetened**
2 **Beverage Tax**

3

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9 Abstract

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

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

17 **Results:** At baseline, SSBs were consumed 1.25 times/day (95% CI: 1.00, 1.50) in Berkeley and
18 1.27 times/day (95% CI: 1.13, 1.42) in comparison city neighborhoods. Adjusting for covariates,
19 consumption in Berkeley declined by 0.55 times/day (95% CI: -0.75, -0.35) for SSBs and
20 increased by 1.02 times/day (95% CI: 0.54, 1.50) for water. Changes in consumption in Berkeley
21 were significantly different from those in the comparison group, which saw no significant
22 changes.

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

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

28

29 **Introduction**

30 SSB consumption, a major contributor to obesity, cardiometabolic disease, and dental caries,
31 carries significant health care costs.^{1,2} SSB consumption has declined but remains high in the
32 U.S. (50% of adults and 61% of children consume SSBs daily³) particularly among low-income
33 and racial/ethnic minority populations, who bear a disproportionate burden of diet-related
34 disease.⁴

35 SSB consumption fell in the short-term after SSB excise taxes were introduced into U.S. cities.
36 Consumption in demographically-diverse neighborhoods in Berkeley, California declined by
37 21%⁵ four months after Berkeley levied a \$0.01/oz excise tax on distributors of non-milk, non-
38 alcoholic beverages containing caloric sweeteners (≥ 2 calories/oz). SSB consumption fell by
39 26% in Philadelphia, Pennsylvania 2 months after its beverage excise tax.⁶

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

43 **Methods**

44 Using a repeated cross-sectional design, SSB consumption was measured annually through
45 beverage frequency questionnaires (BFQs) administered in demographically-diverse
46 neighborhoods in Berkeley, Oakland, and San Francisco (SF).

47 Oakland and SF were chosen as comparators given shared exogenous but difficult-to-measure
48 factors (e.g., culture, media, and retail environments) with Berkeley that might affect SSB
49 consumption. In Berkeley and SF, 2010 Census data were used to identify two large,
50 neighborhoods with the highest combined proportion of African-American and Hispanic
51 residents. Two Oakland neighborhoods were selected to match the distribution of African-
52 American and Hispanic residents in the Berkeley and SF neighborhoods.

53 Baseline consumption was assessed in April-July 2014, before SSB taxes were proposed on the
54 Berkeley and SF November ballots. Only Berkeley's tax passed in 2014. During the 3 post-tax
55 years, data were collected between April and October. In 2016, Oakland and SF surveys

56 occurred within 1-3 months of their SSB-tax ballot measures passing. Oakland implemented its
57 tax in July 2017 and SF in January 2018; thus, some 2017 surveys occurred 1-3 months after
58 Oakland's tax took effect.

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

64 Within each neighborhood, questionnaires were administered as anonymous, 3-10-minute
65 surveys in English or Spanish near the highest foot-traffic intersection. Trained data collectors
66 invited passersby to complete a survey; 20% of those approached (n=2,435) in Berkeley and
67 22% (n=5,141) in comparison neighborhoods agreed (eFigure 1). Of these, 79% were eligible
68 (lived in the city in which the survey was conducted, spoke English or Spanish, were ≥ 18 years
69 old, and could demonstrate understanding of questions, i.e. did not appear inebriated).

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

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

87 IPW),⁶ and models with multiple imputation (MICE) for missing outcome or covariate data
88 (12%).

89 **Results**

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

95 Adjusted SSB consumption, similar at baseline in the two groups, diverged post-tax (Figure 1).
96 The initial reduction in Berkeley from 2014 to 2015 (-0.30 times/day [CI: -0.51, -0.08]) was
97 amplified in 2016 and 2017 (2016: -0.66 times/day [CI: -0.87, -0.46]; 2017: -0.56 times/day [CI:
98 -0.78, -0.35]). In the fully adjusted model, SSB consumption in Berkeley decreased by 0.55 (CI:
99 0.35, 0.75) times/day from 2014 to the weighted average of 2015-2017 (52.3% reduction), with
100 significant declines in all categories of SSBs except energy drinks (eTable 2); water consumption
101 increased by 1.02 (CI: 0.54, 1.50) times/day (29.3% increase). There were no significant
102 consumption changes in the comparison group.

103 In the weighted model adjusted for all covariates, SSB consumption decreased 0.55 (CI: 0.30,
104 0.81) times/day more in Berkeley than in the comparison (a relative decline of 52.5%), with
105 significant declines in regular soda, sports drinks, and sweetened teas and coffees (eTable 2).
106 Water consumption increased 0.85 (CI: 0.29, 1.42) times/day (25.1%) more in Berkeley than in
107 the comparison (eFigure2).

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

109 **Discussion**

110 We observed sustained changes in SSB consumption after an SSB tax in the U.S. Similar to our
111 findings, studies in Mexico (the only other geography documenting longer-term trends in post-
112 tax consumption) revealed increased effects over time, with a 5.5% decrease in the volume of
113 taxed beverage purchases in the first year and 9.7% decrease in the second year post-tax.¹¹

114 Our results reflect consumption changes in demographically-diverse neighborhoods, whose
115 residents are more likely to consume SSBs. In the second year of Mexico’s tax, the volume of
116 taxed beverage purchases declined more in low- than in high-SES households (14.3% versus
117 5.6%), providing some empirical evidence that low-income populations, who bear a
118 disproportionate burden of cardiometabolic diseases, may be more responsive to taxes.¹¹ If
119 similar patterns manifest in other jurisdictions in the U.S., taxes could reduce health disparities.

120 This study has several limitations, including a convenience sample that may limit
121 generalizability and unmeasured confounding, a concern in all non-experimental designs. Results
122 from Berkeley, a small and highly educated city, may not translate to other geographic areas.
123 Self-reported BFQ data are subject to bias; however, BFQs have been validated, and change
124 estimates are less susceptible to bias than point estimates of consumption.¹² In 2017, Oakland
125 surveys occurred 1-3 months post tax-implementation, and both Oakland and SF had SSB tax
126 ballot measures in 2017, which might lead to conservative estimates of relative declines in
127 Berkeley.

128 **Public Health Implications**

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

132

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134

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143 **Human Participant Protection**

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

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

