Title

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Journal

American Journal of Preventive Medicine, 65(3)

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Publication Date

2023-09-01

DOI

10.1016/j.amepre.2023.03.016

Peer reviewed

HHS Public Access
Author manuscript
Am J Prev Med. Author manuscript; available in PMC 2024 September 01.

Published in final edited form as:
Am J Prev Med. 2023 September ; 65(3): 366–376. doi:10.1016/j.amepre.2023.03.016.

Sugar-sweetened beverage taxes and perinatal health: A quasi-experimental study

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Abstract

Introduction: One in five pregnant individuals report consuming sugar-sweetened beverages (SSBs) at least once per day. Excess sugar consumption during pregnancy is associated with several perinatal complications. As SSB taxes become increasingly common public health measures to reduce SSB consumption, evidence on the downstream effects of SSB taxes on perinatal health remains limited.

Methods: This longitudinal retrospective study examines whether SSB taxes in five US cities were associated with decreased risk of perinatal complications, leveraging 2013–2019 US national birth certificate data and a quasi-experimental difference-in-differences approach to estimate changes in perinatal outcomes. Analysis occurred from April 2021 through January 2023.

Results: The sample included 5,324,548 pregnant individuals and their live singleton births in the US from 2013 through 2019. SSB taxes were associated with a 41.4% decreased risk of GDM (−2.2 percentage points [pp]; 95%CI −4.2, −0.2), a −7.9% reduction in weight-gain-for-gestational-age *z*-score (−0.2 standard deviations; 95%CI −0.3, −0.01), and decreased risk of infants born small-for-gestational-age (−4.3 pp; 95%CI −6.5, −2.1). There were heterogenous effects across subgroups, particularly for weight-gain-for-gestational-age *z*-score.

Conclusions: SSB taxes levied in five US cities were associated with improvements in perinatal health. SSB taxes may be an effective policy instrument for improving health during pregnancy, a

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critical window during which short-term dietary exposures can have lifelong consequences for the birthing person and child.

INTRODUCTION

Birthing people and their children are vulnerable to acute and long-term health effects of poor diet quality and excess sugar consumption during pregnancy.[1, 2] Sugar-sweetened beverages (SSBs) are the largest source of added sugar for pregnant individuals, who on average consume 50% more calories from added sugar than recommended.[1] One in five pregnant individuals consumes SSBs at least once per day.[3] In the general population, SSB intake is associated with weight gain and risk of obesity, type 2 diabetes (T2D), and cardiovascular disease (CVD).[4–6] Growing evidence also supports the hypothesis that greater maternal SSB intake is associated with elevated risk for a range of perinatal complications, including gestational diabetes mellitus (GDM),[7, 8] gestational and post-partum weight gain,[9, 10] hypertensive disorders of pregnancy,[11, 12] preterm birth,[13, 14] and abnormal birthweight,[1, 15] conditions which increase the risk of CVD and T2D later in life.[16–18] Not only are pregnant individuals with GDM at elevated risk of excess gestational weight gain (GWG), but excess GWG also increases risk of neonatal complications, notably being small-for-gestational-age (SGA).[19, 20]

Population-wide interventions to reduce SSB intake and improve diet among pregnant individuals remain critical.[21] SSB taxation is one promising policy to reduce SSB consumption,[22–24] sugar intake, and chronic disease risk.[25] As of December 2019, seven US cities were levying an excise tax of $0.01-$0.02 per fluid ounce of SSBs. While modeling studies suggest that SSB taxes reduce chronic disease risk in the general population,[26, 27] empirical studies of the health impacts have proven difficult to conduct, because chronic diseases such as T2D develop over a long latency period. It also remains unclear whether SSB taxes improve the health of pregnant individuals and infants by reducing SSB consumption during pregnancy. Pregnancy is not only a critical period for later-life outcomes, but also a time-limited period during which nutrition policies can have observable health effects.[28–32] Thus, pregnancy is a uniquely valuable context for studying SSB taxes.

The present study examined whether SSB taxes were associated with a reduction in maternal and birth complications among pregnant individuals and offspring, using data from >5 million US births. Leveraging a quasi-experimental difference-in-differences design, this study compared before-after SSB tax changes in perinatal outcomes among pregnant individuals in five SSB-taxed US cities, while accounting for secular trends for pregnant individuals in untaxed comparator cities. This study also investigated subgroup effects of SSB taxes: by race and ethnicity motivated by the racial disparities in sugar intake and maternal and infant health outcomes,[33–38] and by pre-pregnancy body mass index (BMI), maternal age, and parity due to their modifying effects on perinatal risk.[39, 40] As SSB taxes become increasingly common across the US and globally,[25] evidence of their health impacts can inform policy making and community-level interventions targeting maternal and child nutrition and chronic disease.[41]

METHODS

Study Sample

Individual-level data were drawn from the National Center for Health Statistics Vital Statistics Birth Data Files of all live births in the US.[42] The data included 5,324,548 birthing individuals, and their live singleton births from January 1, 2013, through December 31, 2019, with identifiable city of maternal residence in metropolitan US counties (areas of ≥1 million population, which were expected to be a better comparator), within 22–44 weeks of gestation, and birthweight-for-gestational age within 3 standard deviations (SD) of the mean (Appendix Figure 1).[43] The study period included 8 to 20 quarters (24 to 60 months) before tax and 8 to 11 quarters (21 to 33 months) after tax, varying by city due to staggered policy adoption (Appendix Figure 1). The University of California San Francisco institutional review board approved the study procedures (Protocol #18–26719). Analysis occurred from April 2021 through January 2023.

Measures

The following five US cities with an SSB excise tax in effect as of December 31, 2019, were included as “intervention cities,” with date of tax implementation in parentheses: Berkeley, CA (March 1, 2015), Philadelphia, PA (January 1, 2017), Oakland, CA (July 1, 2017), San Francisco, CA (January 1, 2018), and Seattle, WA (January 1, 2018). Pregnant individuals residing in the intervention cities whose date of delivery fell on or after the quarter of SSB tax implementation in their city of residence were classified as exposed (eMethods). Pregnant individuals residing in all other cities (“comparator cities”) were classified as unexposed.

Primary outcomes were perinatal outcomes reported on birth certificates that, based on previous observational findings, could be affected by a pregnant individual’s SSB consumption.[7–9, 44–46] These included a binary variable for whether a pregnant individual was diagnosed as having GDM, and a continuous variable for the pregnant individual’s weight-gain-for-gestational-age *z*-score (GWG *z*-score), calculated using a previously validated weight-gain-for-gestational-age percentile and *z*-score chart generated from a cohort of US women.[47, 48]

Secondary outcomes included binary variables for hypertensive disorders of pregnancy (gestational hypertension and preeclampsia, available as a combined measure only[49]), whether the birthing individual was above, below, or within 2009 Institute of Medicine (IOM) GWG recommendations for BMI,[50] low birthweight (<2500 g, LBW), SGA, large-for-gestational-age (LGA),[43] preterm (born before 37 weeks gestation),[43] and continuous variables for birthweight (grams) and weeks of gestation at delivery. Although excess sugar consumption during pregnancy has been shown to increase the risk of several of these outcomes, including preeclampsia, gestational hypertension, preterm birth, and birthweight,[12, 14, 15, 51–54] evidence that SSB consumption during pregnancy causally influences these outcomes is lacking. Furthermore, these outcomes are more distal to SSB tax exposure, and often mediated by GDM and GWG.

Covariates included sociodemographic variables on the birth certificate that might confound the association between city of residence and perinatal outcomes: birthing individual's race and ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, Asian, other), age (<25, 25–29, 30–34, ≥35), education (some high school, high school diploma/GED, some college, college degree and beyond), parity (primiparous, multiparous, nulliparous), prepregnancy smoking status, and prepregnancy BMI (underweight, normal weight, overweight, obese). Models also included fixed effects (i.e., indicator variables) for city of residence to account for measured and unmeasured city-specific and time-invariant characteristics (e.g., retail environment, demographic composition) and birth quarter to adjust for secular trends (e.g., seasonality).

Statistical Analysis

The analysis first tabulated sample characteristics and the prevalence of outcomes stratified by exposure group before and after tax implementation in intervention cities.

For the main analysis, the study estimated the association of SSB taxes with perinatal outcomes using the Callaway-Sant'Anna (CS) difference-in-differences approach—a recently developed quasi-experimental approach that is unbiased by staggered policy adoption and includes "doubly robust" estimation with inverse probability weighting (eMethods).[55, 56] The study assessed changes in perinatal outcomes before versus after SSB tax implementation for pregnant individuals residing in intervention cities compared with those residing in comparator cities.

The study followed a standard approach used in difference-in-differences analyses to estimate linear regressions for binary and continuous outcomes due to differences in the interpretation of interaction terms in non-linear models and technical issues with implementing logistic models with fixed effects.[57–59] Binary outcomes may, therefore, be interpreted as percentage-point changes in risk. All regressions adjusted for the covariates listed above, with the exception of GWG-related outcomes, for which prepregnancy BMI was incorporated directly into the outcome measure. The inclusion of unit (city) and time fixed effects accounted for many measured and unmeasured sources of confounding. For ease of interpretation, estimates are expressed as the average percent change in outcomes, calculated as the difference-in-differences estimate divided by the average before-tax outcome value in tax-exposed cities, as done in several related studies.[23, 60, 61]

To examine dynamic policy effects, the study estimated event-study difference-in-differences analyses of the time-varying associations between tax exposure and each perinatal outcome of interest.[62, 63] An important assumption of difference-in-differences is that before-after differences in outcomes would be the same in the intervention and comparator groups in the absence of the intervention. While this "parallel trends" assumption is not directly testable, the study followed the literature to assess whether before-tax outcome trends were parallel between intervention and control groups by testing the significance of before-tax coefficients in the event studies (eMethods).[64, 65]

Subgroup analyses were conducted by birthing individual's race/ethnicity, education, age, prepregnancy BMI, and parity. Using stratified analyses, the study estimated the same CS difference-in-differences models as outlined above for each subgroup (eMethods).

To assess cohort effects by year-quarter of SSB tax implementation, the CS approach allowed for the identification of cohort-specific effects by tax implementation date (eMethods). Cohorts therefore included Berkeley, Oakland, Philadelphia, and Seattle and San Francisco combined.

To assess the robustness of estimates to different estimation approaches, the study implemented two alternate approaches: 1) the difference-in-differences approach developed by Borusyak and colleagues, also designed for staggered policy adoption,[64, 66] and 2) a generalized difference-in-differences approach that includes two-way fixed-effects (TWFE) for city and year-quarter (eMethods).

To assess the sensitivity of estimates to the choice of comparator, the study conducted the CS difference-in-differences analysis restricting the comparator group to large cities in Census Divisions where tax-exposed cities were located (eMethods).

To mitigate potential misclassification bias, the study conducted a sensitivity analysis for outcomes using imputed date of conception to define exposure status and excluding pregnant individuals exposed to SSB taxation for part of their pregnancy only (eMethods). The study also conducted a sensitivity analysis for GDM, excluding individuals in San Francisco, which changed its GDM testing procedures in 2016 (eMethods).[67]

Lastly, the study examined prepregnancy smoking status and marital status as placebo outcomes in CS models (eMethods).

RESULTS

Tax-exposed individuals were more likely than those in comparator cities to be non-Hispanic White or Black, older, educated, to have smoked prepregnancy, and have normal BMI, although these differences were modest (Table 1). Perinatal health was similar for individuals living in intervention and comparator cities prior to SSB tax implementation (Table 2), including GDM prevalence (5.4% in intervention cities vs. 5.5% in comparator cities) and GWG z-score (−1.8 vs. −1.9 SD).

SSB taxes were associated with a 41.4% reduction in GDM (−2.2 percentage points [pp]; 95%CI −4.2, −0.2) and 7.9% reduction in GWG z-score (−0.2 SD; 95%CI −0.3, −0.01) (Table 2). In addition, SSB taxes were associated with a 39.1% reduction in SGA risk (−4.4 pp; 95%CI −6.5, −2.1). There was no association between SSB taxes and other secondary outcomes (Table 2).

Event-study estimates revealed that before-tax differences for primary outcomes between tax-exposed and tax-unexposed individuals were small and not significant, suggesting roughly parallel before-tax outcome trends (Figure 1). Before-tax trends were also similar between tax-exposed and comparator individuals for most secondary outcomes, except birthweight, gestational age, and preterm birth (Appendix Figure 2).

Event-study estimates further highlighted that SSB taxes were associated with decreased GDM risk two to four quarters post-tax implementation, attenuated thereafter (Figure 2). For GWG *z*-score, the intervention-comparator difference particularly grew in later quarters. For SGA risk, there was a sustained decrease for five quarters post-tax implementation (Appendix Figure 2). Event-study plots for other secondary outcomes are provided in Appendix Figure 2 and discussed in the Appendix.

There were subgroup differences in the estimated associations between SSB taxes and outcomes (Figure 2, Appendix Figure 3). Event studies for some subgroups indicated pre-tax imbalance between intervention and control cities (Appendix Figure 8); results for those subgroups should be interpreted cautiously. Reductions in GDM risk and GWG *z*-score were more pronounced among Asian individuals. Reductions in GWG *z*-score were largest among those aged 25–29 and 35+, those with a high school diploma, as well as for multiparous and obese individuals. Subgroup findings are further discussed in the Appendix.

Cohort-specific analyses showed larger improvements in Philadelphia versus other cohorts for GWG *z*-score (Appendix Table 3, Appendix Figure 4). Philadelphia and Seattle/San Francisco also had larger declines in SGA risk (Appendix Table 1, Appendix Figure 5). All cohorts except Berkeley showed declines in GDM risk, yet none attained statistical significance. Results for other cohort-specific effects are provided in the Appendix (Appendix Figure 5).

Findings from additional sensitivity analyses were similar to the primary analysis but smaller in magnitude for GWG *z*-score and SGA, yet differed somewhat for GDM (Appendix Tables 1–2, Appendix Figures 6–7). Sensitivity estimates for GDM risk were also more muted and did not attain statistical significance for several models. Placebo analyses showed no significant association between prepregnancy smoking nor marital status and SSB taxes, suggesting time-varying confounding of the estimates is less likely (Appendix Table 2).

DISCUSSION

This study provides the first estimates, to the authors' knowledge, of the association between city-level SSB taxes and perinatal outcomes. Using quasi-experimental difference-in-differences methods, SSB taxes were associated with a 41.4% reduction in GDM risk and 7.9% decrease in GWG *z*-score. GDM and excess GWG are well-studied predictors of birthweight, preeclampsia, and preterm delivery, and even risk of CVD and T2D later in life for the birthing person and child,[18, 68, 69] highlighting these conditions as important mechanisms through which SSB taxes may affect longer-term health.[7–9, 53] SSB taxes were also associated with a 39.1% decrease in SGA risk, in line with the improvements in GDM and GWG *z*-score, which are predictors of SGA.[19, 20] Sensitivity and placebo analyses supported the robustness of our findings for GWG *z*-score and SGA, but conflicted somewhat with the GDM findings. Studies that leverage additional datasets with more information on mechanisms and less measurement error of maternal outcomes[70] may address this knowledge gap. Overall, our results suggest that SSB taxes induce clinically relevant changes that may translate into population-wide health improvements, although the findings should be interpreted with caution.

There were no consistent overall improvements in other maternal and neonatal health outcomes. Further research is needed to investigate the long-term health effects of SSB taxes as more post-period data become available. One plausible explanation for the null findings is that individuals undercut the health benefits of SSB taxes through compensatory caloric intake, although recent literature has tended to find such substitution effects to be limited.[24]

Given recent evidence that Philadelphia experienced among the largest behavioral effects on SSB purchasing and consumption due in part to its slightly higher SSB tax rate, it was hypothesized that Philadelphia would also see larger improvements in perinatal health, compared to other cities. [24, 60] Our cohort-specific findings support this hypothesis, strengthening the case for a causal link between SSB taxes and improvements in perinatal health. Nevertheless, further research leveraging individual-level SSB consumption data would help further test the causal relationship.

There were notable differences in the association of SSB taxes and perinatal health across subgroups. Growing evidence has similarly underscored the role of disparities in perinatal outcomes among these groups.[39, 71, 72] Differential exposure to SSBs has been driven partly by targeted marketing of SSBs to racial/ethnic minority and low-income communities,[33–38, 73] contributing to notably higher SSB consumption among Black and Hispanic vs. White women during pregnancy (28% and 33% vs. 15%).[3] This highlights the need to disaggregate results by subgroup. Our findings show larger declines in GDM and GWG *z*-score among non-Hispanic Asian pregnant people exposed to SSB taxes; violations of parallel trends for other racial subgroups precluded the study from inferring the impact of SSB taxes on racial disparities and perinatal health. There were large improvements in GWG *z*-score across other subgroups, including young (25–29), less educated (high school GED), and overweight individuals, indicating that SSB taxes could produce downstream health benefits, even among structurally disadvantaged subgroups. Additional years of follow-up data, along with larger sample sizes for subgroups of interest, might clarify the persistence of the perinatal effects, including among subgroups.

The present study provides the first quasi-experimental evidence suggesting that SSBs contribute to GDM, excess GWG risk, and SGA, and that policies to reduce excess sugar consumption among pregnant individuals may be an effective strategy to improve perinatal health. These findings are consistent with a recent federal commission suggesting that SSB taxes can reduce T2D risk,[74] and come at a critical time, as pregnancy complications in the US are highly prevalent and have grown in recent years. In population-based studies, the reported US prevalence for GDM is 6.2% (~230,000 births)[75] and 47.5% for excess GWG (~1,780,000 births),[76] GDM prevalence has increased by ≥4% over the last two decades, with a marked rise among non-White, overweight, and low-income groups.[77] Women with GDM also have a 7-fold increased risk of developing T2D and 43% increased risk of myocardial infarction or stroke post-pregnancy, with even higher rates among Black and Hispanic people.[16, 17, 78, 79] Our study also builds on previous findings that singular nutrition policies—e.g., healthy revisions to the food package offered through WIC—can improve perinatal health.[28–32] Tobacco taxation also provides a model of an effective policy intervention that has translated into population-wide improvements in perinatal health.[80]

Limitations

This study has several strengths. It used a large nationally representative sample of 5 million births and applied quasi-experimental difference-in-differences and fixed-effects techniques to evaluate the taxes independently of many potential measured and unmeasured confounders.[55] This study also has several limitations. First, data were not available for US cities with populations <100,000, including Boulder and Albany. Results may not apply to smaller or more rural counties and cities. Second, the study lacked data to define individual-level SSB exposure. Because not all pregnant people in intervention cities consumed SSBs during pregnancy, the study likely underestimated the magnitude of the population-wide association between SSB taxes and our outcomes of interest among those who actually changed their SSB intake. Third, an important assumption of difference-in-differences analysis is that no other exposures differentially influenced outcomes between intervention and control groups during the study period. The study cannot rule out the existence of co-occurring policies that would violate this assumption. Lastly, estimates were not adjusted for multiple comparisons.

CONCLUSIONS

A 2021 federal commission recommended a federal excise tax on SSBs as a strategy to control and prevent diabetes, yet empirical data regarding this relationship have been scant.[74] This study's results suggest that SSB taxes in five US cities were associated with declines in GDM, GWG *z*-score, and SGA at the population level, with cohort differences by city, and subgroup differences. These results provide critical evidence that SSB taxes may improve maternal outcomes, as well as some improvements to neonatal outcomes, strengthening the evidence base for improving maternal nutrition during pregnancy.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

Mrs. Jackson conducted the statistical analysis, drafted the initial manuscript, and reviewed and revised the manuscript. Dr. Hamad acquired the data and critically reviewed the manuscript for important intellectual content. Dr. Karasek conceptualized and designed the study and critically reviewed the manuscript for important intellectual content. Dr. White conceptualized and designed the study, provided supervision, conducted the statistical analysis, drafted the initial manuscript, reviewed, and revised the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work. This work is supported in part by Dr. Karasek's award from the UCSF-Kaiser Department of Research Building Interdisciplinary Research Careers in Women's Health (BIRCWH) Program from the National Institute of Child Health and Human Development (NICHD) and the Office of Research on Women's Health (ORWH) [K12 HD052163], as well as in part by Dr. Hamad's award from the National Institute on Diabetes and Digestive and Kidney Diseases (2P30 DK092924), and the National Institute of Health (NIH) and Centers for Disease Control grant U18 DP006526. No financial disclosures have been reported by the authors of this paper.

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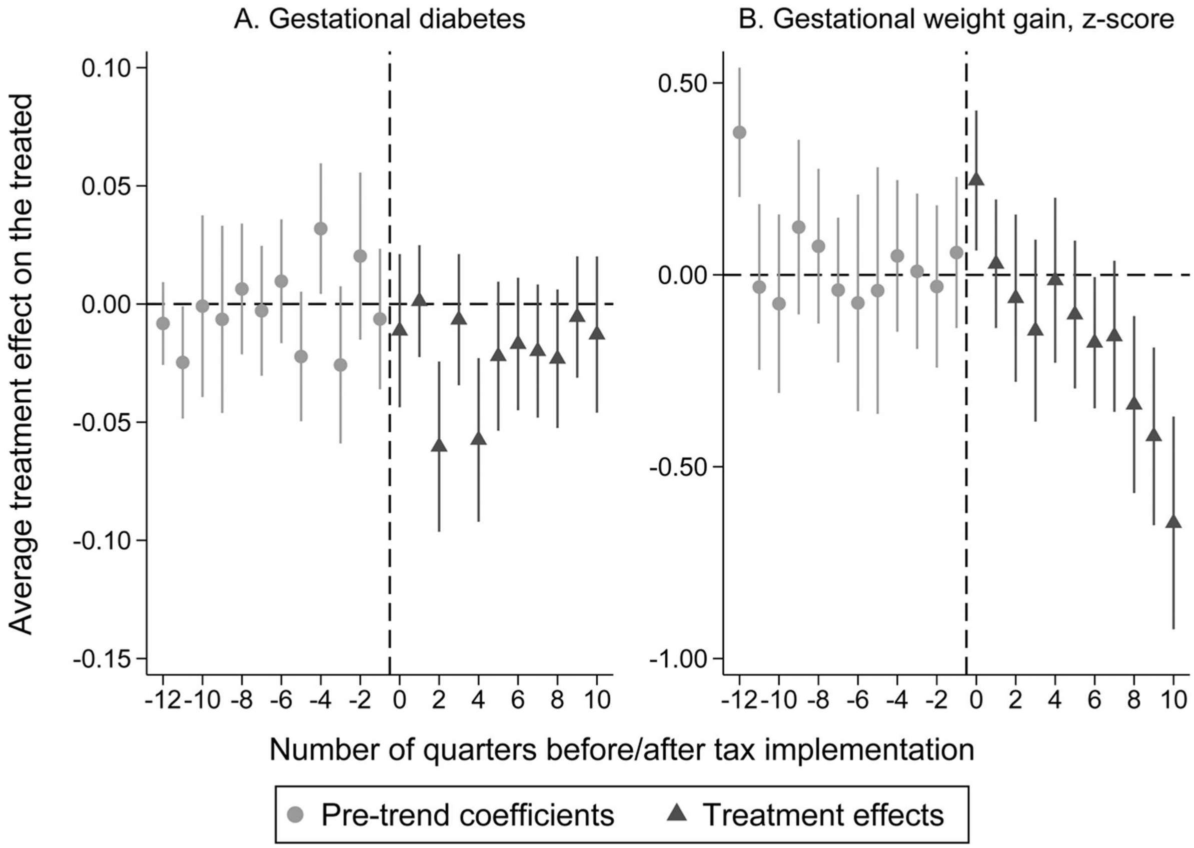

Figure 1.

Time-varying association between sugar-sweetened beverage taxes and primary health outcomes

Note: These plots of the time-varying differences in outcomes between those in SSB tax cities vs. comparator cities are estimated from Callaway-Sant' Anna event-study difference-in-differences regressions. Quarterly estimates are relative to the quarter just prior to SSB tax implementation (quarter −1, dotted line). 95% confidence intervals calculated from robust standard errors.

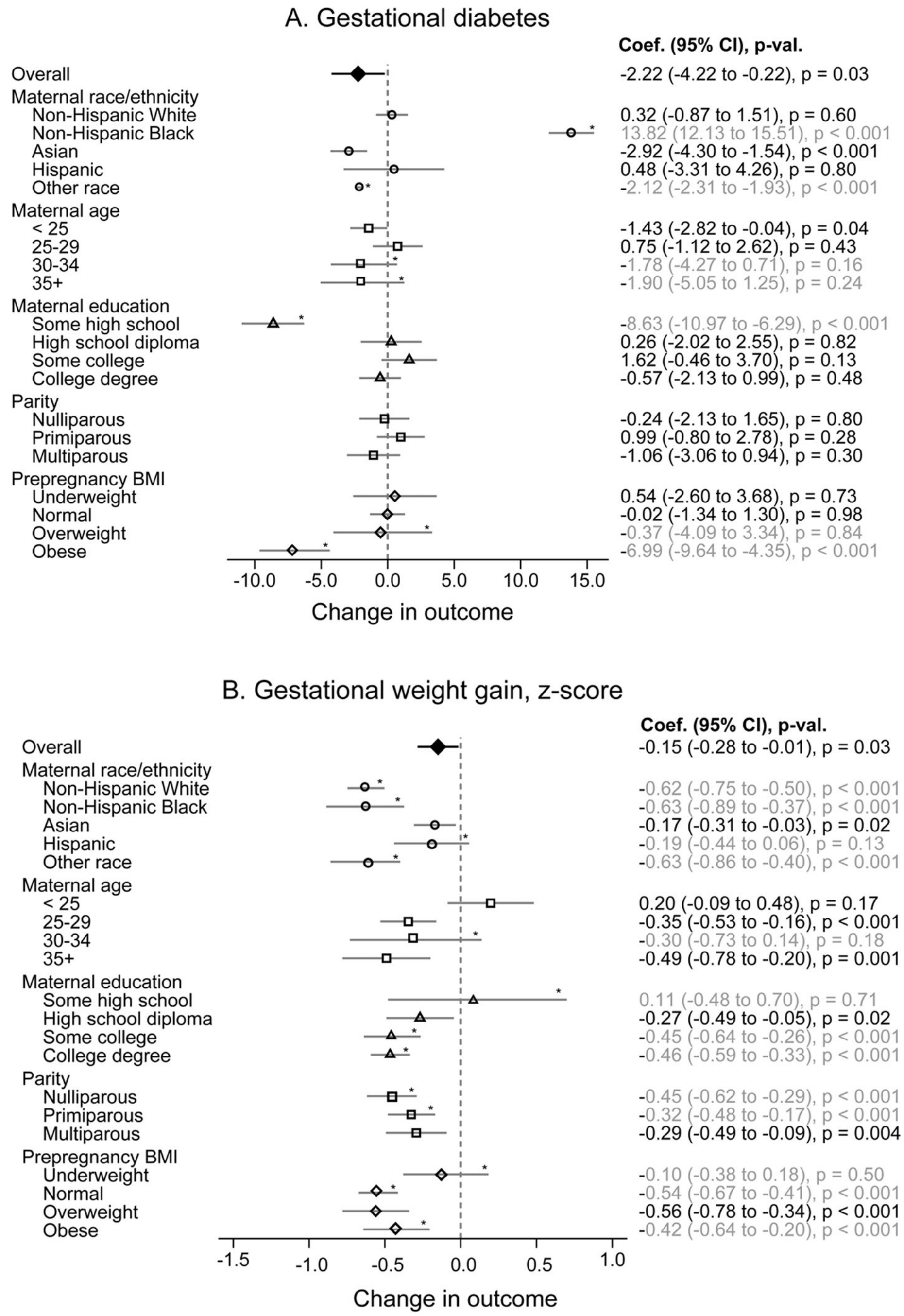

Figure 2.

Associations between sugar-sweetened beverage taxes and primary outcomes by population subgroup

Note: Each row represents a Callaway-Sant'Anna difference-in-differences estimate from a separate regression, either using the full sample or stratifying by a population subgroup and adjusting for race and ethnicity (NH-Black, NH-White, NH-Asian/NHOPI, Hispanic, NH-other race), maternal age (<25, 25–29, 30–34, 35+), education (some high school, diploma/GED, some college, college degree), parity (nulliparous, primiparous, multiparous), prepregnancy smoking status, and prepregnancy BMI (underweight, normal weight, overweight, obese), and fixed effects for maternal city of residence and quarter of birth. Estimated values written in light gray and with an asterisk (*) indicate imbalance during the pre-tax period (≥2 quarters with significant intervention-comparator differences at $p > 0.05$) and likely violate the "parallel trends assumption" required for valid inference.

Abbreviations: Body Mass Index (BMI); General Educational Development (GED); Non-Hispanic (NH), Native Hawaiians and Other Pacific Islanders (NHOPI).

Table 1.

Characteristics of pregnant individuals by tax exposure, before and after SSB tax implementation (2013–2019)

	SSB tax cities [c] (N= 267,952)		Comparator cities [b] (N= 5,056,596)	
Characteristics	**Pre (%)**	**Post (%)**	**Pre (%) [d]**	**Post (%) [d]**
Maternal race and ethnicity				
Non-Hispanic White	37.6	36.0	30.4	29.9
Non-Hispanic Black	24.5	26.6	20.3	20.5
Hispanic	18.6	19.9	36.9	36.4
Asian/Pacific Islander	16.6	14.5	10.7	10.9
Other race [a]	2.7	3.0	1.7	2.3
Age (years)				
<25	19.6	17.8	26.7	22.7
25–29	22.4	22.7	27.3	27.2
30–34	32.4	32.8	27.8	29.4
35+	25.6	26.6	18.2	20.8
Education				
Less than high school diploma	12.7	11.4	18.7	15.6
High school diploma or GED	21.0	22.2	25.5	26.3
Some college or associate degree	20.6	20.7	25.5	24.8
College degree or above	45.6	45.7	30.2	33.3
Prepregnancy BMI				
Underweight <18.5	5.5	3.6	4.9	3.6
Normal 18.5 – 24.9	52.7	49.6	47.1	44.7
Overweight 25.0 – 29.9	22.8	24.4	25.5	26.5
Obese >30	19.0	22.4	22.6	25.1
Parity				
Nulliparous	38.0	37.0	33.9	33.4
Primiparous	28.8	27.3	27.6	27.6
Multiparous	33.2	35.7	38.4	39.0
Prepregnancy smoking	5.9	5.1	4.7	3.6

[a] American Indian/Alaskan Native, multi-race, and other racial groups were combined into a single variable to avoid small cell sizes and unstable estimates.

[b] Women from 193 comparator US cities were included in this analysis. Total same size of pre- and post-comparator city residence varies by SSB tax implementation date.

[c] Birthdate cutoff for pregnant individuals before or after the SSB tax; Berkeley Q1 2015, Philadelphia Q1 2017, Oakland Q3 2017, San Francisco Q1 2018, and Seattle Q1 2018.

[d] Values are equal to the average sum of comparator cities pre- or post-SSB tax cutoff date (when SSB-taxes were enacted in each of the five SSB-taxed cities), divided by five.

Abbreviations: Body Mass Index (BMI), General Educational Development (GED).

Table 2.

Estimated association of SSB tax exposure and perinatal outcomes

	SSB tax cities		Comparator cities		Adjusted Difference-in-Differences Estimate [b]		
Outcomes	**Pre**	**Post**	**Pre**	**Post**	**Coef. (95% CI)**	***p*-value**	**Adjusted % change [c]**
Panel A. Primary outcomes							
Gestational diabetes, %	5.4	5.5	5.5	6.6	−2.22 (−4.22, −0.22)	**0.03**	−41.4
Weight-gain-for-gestational-age z-score [a]	−1.8	−1.8	−1.9	−1.9	−0.15 (−0.28, −0.01)	**0.03**	−7.9
Panel B. Secondary outcomes							
Hypertensive disorders of pregnancy,[d] %	5.8	8.5	4.8	6.4	−1.63 (−3.3, 0.05)	0.06	−28.5
GWG 2009 IOM recommendations, %							
Below recommendations	47.5	47.1	44.4	43.7	−2.21 (−5.07, 0.66)	0.13	−10.6
Above recommendations	31.7	31.6	32.9	33.2	−0.39 (−4.13, 3.36)	0.84	−0.8
Within recommendations	20.7	21.3	22.6	23.1	2.59 (−0.78, 5.97)	0.13	8.1
Birthweight, grams [a]	3315.0	3290.0	3291.4	3286.8	17.17 (−26.06, 60.4)	0.44	0.5
Low birthweight, %	6.5	7.1	6.5	6.9	0.61 (−1.46, 2.68)	0.57	9.4
Gestational age, weeks [a]	39.0	39.0	39.0	39.0	17.17 (−26.06, 60.40)	0.44	0.5
Small for gestational age, %	11.0	11.0	8.3	7.8	−4.28 (−6.49, −2.06)	**<0.001**	−39.1
Large for gestational age, %	8.3	7.9	7.1	6.8	0.47 (−1.52, 2.45)	0.65	5.6
Preterm birth, %	6.7	6.7	4.8	6.4	0.59 (−1.60, 2.77)	0.60	8.8

Note: Boldface indicates statistical significance $p<0.05$).

[a] Mean values were calculated for continuous variables.

[b] Estimates, expressed as percentage points for binary outcomes, from Callaway-Sant'Anna difference-in-difference models adjusted for race and ethnicity (non-Hispanic Black, non-Hispanic White, Hispanic, non-Hispanic Asian/Native Hawaiian and Other Pacific Islander, non-Hispanic other race), maternal age (<25, 25–29, 30–34, 35+), education (some high school, diploma/GED, some college, college degree), parity (nulliparous, primiparous, multiparous), prepregnancy smoking status, and prepregnancy BMI (underweight, normal weight, overweight, obese), and fixed effects for maternal city of residence and quarter of birth. Gestational weight gain-related outcomes incorporated prepregnancy BMI into the outcome measure.

[c] Adjusted percent changes are calculated by dividing the difference-in-differences estimate by the average pre-tax outcome in the intervention city.

[d] Gestational hypertension and preeclampsia, which are combined in national birth certificate data.

Abbreviations: Body Mass Index (BMI); Gestational Weight Gain (GWG); Institute of Medicine (IOM).