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RESEARCH ARTICLE

Impact of Restricting Sugar-Sweetened Beverages From the Supplemental Nutrition Assistance Program on Children's Health

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Introduction: Children enrolled in the Supplemental Nutrition Assistance Program are at higher risk of poor diet, including higher intake of sugar-sweetened beverages than non−Supplemental Nutrition Assistance Program participants. This study aims to identify the impact of restricting sugar-sweetened beverage purchases with Supplemental Nutrition Assistance Program benefits on children's consumption and health.

Methods: Using Supplemental Nutrition Assistance Program participation and dietary data of children (aged 2−19 years) in the National Health and Nutrition Examination Survey (2009−2016), a microsimulation model was constructed to assess expected changes in daily sugar-sweetened beverage consumption, total calorie intake, BMI, incidence of dental caries, and obesity prevalence of 2019 U.S. children over a 10-year period, incorporating differences in food consumption and disease risks between the Supplemental Nutrition Assistance Program and the general U.S. populations. Sensitivity analyses were conducted with various food substitution patterns and Supplemental Nutrition Assistance Program participation characteristics. Analysis was performed in 2019.

Results: Sugar-sweetened beverage restriction in the Supplemental Nutrition Assistance Program was estimated to reduce daily sugar-sweetened beverage intake by 112.5 g/person (95% CI= −115.9, −109.2), which was estimated to decrease the number of decayed teeth by 0.53/person (95% CI= −0.55, −0.51), an 8.0% decline from the baseline. If sugar-sweetened beverages were substituted with fruit juice and milk, the restriction would be expected to reduce daily total calorie intake by 39.2 kcal/person (95% CI= −39.8, −38.7), resulting 2.6 kg/m^2 (95% CI= −2.9, −2.4) decrease in BMI and a 6.2 percentage point (95% CI= −6.5, −5.8) decrease in obesity prevalence among Supplemental Nutrition Assistance Program participants. Estimated changes in total calorie intake and obesity were subject to food substitution patterns.

Conclusions: Restricting sugar-sweetened beverage purchases in Supplemental Nutrition Assistance Program could promote a healthier diet and significantly lower the incidence of dental caries and potentially obesity prevalence in children.
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INTRODUCTION

Sugar-sweetened beverage (SSB) consumption (e.g., drinks with added sugar such as soda, sweetened juices, and sport drinks) has declined among the U.S. children between 2003 and 2014 but still remains high.[1] Currently, 6 of 10 children consume ≥1 SSB on a typical day, equivalent to about 125 calories/day.[1−3] Lower-income children have higher odds of heavy SSB consumption (defined as ≥500 kcal/day) than higher-

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income children.[4] Strong evidence links SSBs with increased risk of childhood dental caries and obesity—conditions that disproportionately occur among lower-income children.[5−8]

One controversial strategy to reduce SSB consumption among lower-income children is to restrict the ability to use benefits from the Supplemental Nutrition Assistance Program (SNAP),[9] formerly the Food Stamp Program, for the purchase of SSBs. SNAP is the largest nutrition assistance program in the U.S., serving approximately 40 million low-income Americans each month, half of whom are children.[10,11] Currently, SNAP benefits can be used at >240,000 authorized retailers across the country,[12] with few restrictions on what can be purchased.

Available evidence suggests that restricting the ability to purchase SSBs with SNAP benefits might have a significant impact on reduced SSB consumption.[10,13] SNAP households allot a higher proportion of their grocery bills to SSBs than any other food items (approximately $0.05/dollar compared with $0.04/dollar among non-SNAP households), resulting in SNAP benefits being used to buy an estimated 20 million servings of SSBs daily, at an annual cost of about $4 billion.[14] A prior study suggests that an excising tax on SSBs may be cost effective and reduces childhood obesity in the general U. S. population.[15] Moreover, simulation studies of adult SNAP enrollees show that SNAP restrictions on SSBs could lower chronic disease morbidity and mortality.[12,13]

To date, no studies have explored the impact of restricting SSB purchases with SNAP benefits on childhood obesity and dental caries. When studying the impact of restricting SSB purchases, several issues need to be addressed, including how differences between the national population and the SNAP-participating population in food consumption patterns affect the effectiveness of the SSB restriction and how complex patterns of food substitution could alter the effectiveness of the SSB restriction in terms of reducing obesity. Thus, a simulation approach is an ideal way to study this issue because all state waivers requesting permission from the U.S. Department of Agriculture (USDA, the agency that administers SNAP) have been denied.[16] To fill this important gap in the literature, this study uses nationally representative data and a newly developed microsimulation model to estimate the impact of restricting SSB purchases with SNAP benefits on children's consumption and health.

METHODS

The authors constructed and validated a microsimulation model to examine how restricting SSB purchases in SNAP would be expected to affect consumption across food groups and the risk of the health outcomes (obesity and dental caries) that are significantly associated with SSB intake according to comprehensive meta-analysis and systematic review (Figure 1).[5,8,17] Dental caries and obesity share multiple common risk factors (modifiable and nonmodifiable),[8] and a microsimulation model was used to account for complex co-variations in key traits that may critically impact the effectiveness of the SSB restriction in SNAP (Appendix Text 1, available online).

Table 1 summarizes the key model parameters and data sources, which are further detailed in the Appendix (available online). Demographic, biometric, food security, and dietary data were obtained from the National Health and Nutrition Examination Survey (NHANES, 2009−2016, N=13,004, age <20 years). Rates and duration of SNAP participation by demographic group were obtained from the USDA.[18] Food price data were obtained from the USDA Quarterly Food-at-Home Price Database (Appendix Text 2, available online).[19]

Modeling Framework

The risk of SSB-related outcomes (obesity, defined as BMI in the 95th percentile of the same age and sex for children [Appendix Table 1, available online] and >30 kg/m^2 for adults, and dental caries, defined as the number of decayed, filled on the crown or enamel surface of a tooth, or missing teeth with the missing component excluded for primary teeth) was estimated for each individual. To ensure internal validity, the model was calibrated against obesity and dental caries prevalence from NHANES by age and sex (Appendix Figure 1, available online).[20,21] BMI trajectories were validated externally against Medical Expenditure Panel Survey data.[22]

This study simulated a nationally representative sample of 10,000 Americans aged 2−19 years starting in 2019 and estimated the impact of the SSB restriction on daily SSB consumption and total calorie intake, BMI, obesity prevalence, and dental caries incidence given observed SSB consumption rates and differences in disease risks within the SNAP population compared with the general U.S. population. The model was simulated over a10-year period to be consistent with policy planning horizons and to minimize longitudinal uncertainty in the estimates. The simulated individuals were stratified by cohorts defined by SNAP participation status (given typical rates of entry/exit by demographics and income), age (2−5, 6−12, 13−19 years), sex, race/ethnicity (NHANES categories of Mexican American; non-Hispanic White; non-Hispanic Black), and income (low [≤130% federal poverty level], middle [130%−300% federal poverty level], and high [>300% federal poverty level]). Starting-year enrollment status in SNAP was assigned to each individual on the basis of demographic-specific probabilities of participation.[23] Length and frequency of participation was modeled using rates of entry and exit to define single-spell versus multiple-spell participants, and among multiple-spell participants, the median completed spell length was assumed to be 96 months with 16 months median time off between spells (Appendix Table 2, available online).[24]

Health-related risk factors for obesity and dental caries were assigned to each simulated individual to match the distribution of risk factors among each demographic group according to NHANES: weight and height and daily food intake in each of 16 USDA food categories per 24-hour dietary recalls corrected for within-person variations in consumption (Appendix Tables 3–7,

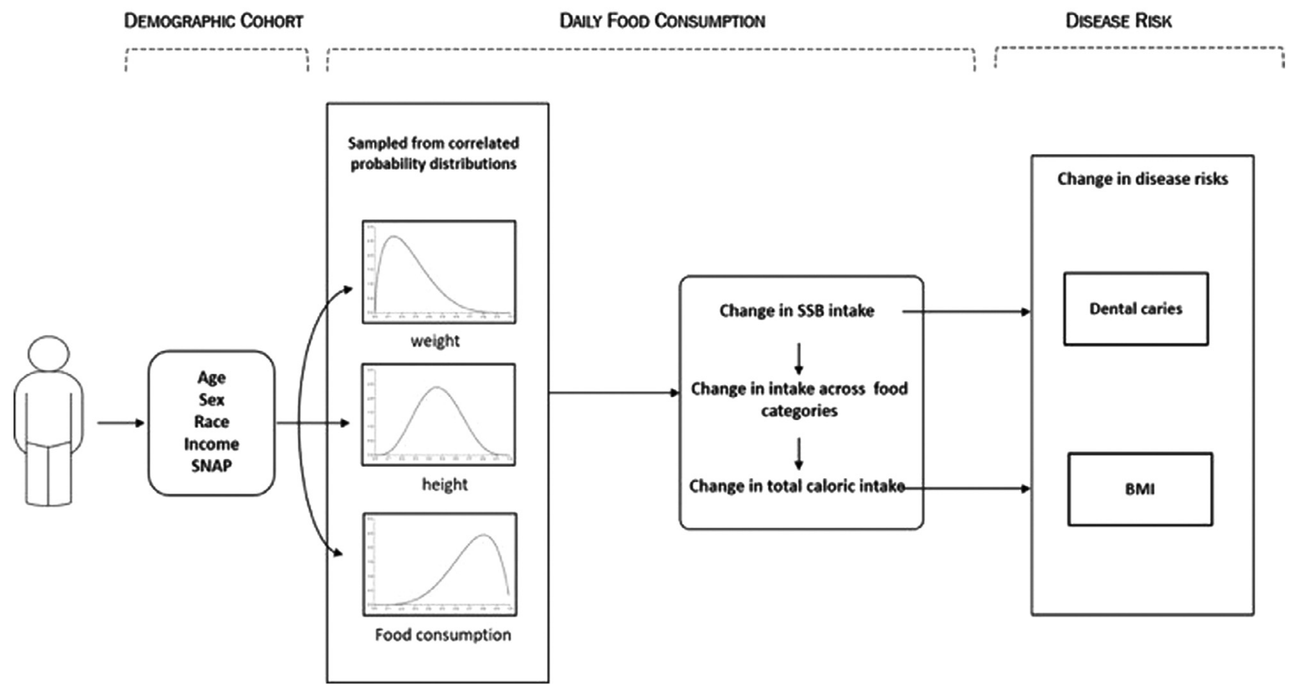

Figure 1. Model schematic. SNAP, Supplemental Nutrition Assistance Program; SSB, sugar-sweetened beverage.

Table 1. Model Parameters and Sources

Parameters	Source
Population size of demographic cohorts	NHANES 2009–2016
Effects of SSB purchase restriction on food consumption (Appendix Text 2)	[13,15,17]
Weight changes associated with caloric intake (Appendix Text 3)	NIH models[27–29]
SNAP enrollment dynamics (Appendix Table 2)	USDA[18]
Baseline tooth decay (Appendix Table 3)	NHANES 2009–2016
Baseline weight and height (Appendix Tables 4 and 5)	NHANES 2009–2016
Baseline SNAP participation (Appendix Table 6)	NHANES 2009–2016
Baseline food consumption (Appendix Table 7)	NHANES 2009–2016
Relationship between dental caries with increased SSB consumption (Appendix Table 8)	[31–33]
All-cause mortality rate	CDC

CDC, Center for Disease Control and Prevention; NHANES, National Health and Nutrition Examination Survey; SNAP, Supplemental Nutrition Assistance Program; SSB, sugar-sweetened beverage; USDA, U.S. Department of Agriculture.

available online).[23,24] Weights and heights were updated annually in the model to reflect age and secular trends, as well as changes in dietary consumption patterns when people are participating versus not participating in SNAP. Survey sample weights were used to correct for differential sampling and nonresponse in NHANES.[25,26]

Assessment of Benefit

This study simulated 2 scenarios: (1) status quo (no SSB restriction in SNAP) and (2) base case scenario with SSB restriction among SNAP participants (substituting SSB with milk and fruit juice). Investigators simulated 2 effects of restricting SSB purchases on consumption of SNAP participants. First, SSB consumption among SNAP participants was lowered based on the marginal propensity to consume (MPC) such beverages, accounting for both reduced purchases using SNAP dollars and compensatory increased purchases using disposable income.[13] Second, the SNAP dollars no longer spent on SSBs were distributed among other food groups based on the price-induced own- and cross-elasticities (identifying how food price changes affect food consumption) between such beverages and other foods (substitution): milk and 100% fruit juice identified in a recent review (change in calories for unsweetened coffee/tea and water was not incorporated because of their minimal caloric contribution).[17] The portion of overall SSB consumption paid with SNAP dollars was estimated as the ratio of SNAP benefits to total food expenditures. The restriction covered all SSBs, including sodas, sweetened juice, and sport drinks, but not 100% fruit juice.[6,7] Then, changes in total calorie intake were estimated to change individual weight based on NIH equations (Appendix Text 3, available online).[27–30] More details are available in Appendix Text 2 (available online). The relationship between the amount of sugar consumed and caries incidence was informed by 3 studies.[31–33] Risk of dental caries was dependent on changes in sugar consumption (from changes in SSB intake and food substitutions) at different rates by age groups (Appendix Table 8, available online).

Sensitivity and Uncertainty Analyses

Three different scenarios of modeling the impact of SSB restriction on obesity were evaluated: (1) impact on weight when distributing the SNAP dollars no longer spent on SSBs to purchasing food items that were typically purchased by SNAP participants (i.e., meat, poultry, and seafood) proportional to the rates currently spent on food items (Appendix Table 9, available online),[34] (2) impact on BMI per change in SSB serving based on randomized trials and cohort studies (Appendix Table 10, available online),[35−39] and (3) impact on total energy intake according to crossover feeding trials and observational studies of diet and energy intake (Appendix Table 10, available online).[15,40]

Next, the MPC estimates were varied from 14% to 47%, the range estimated for overall SNAP participant households by a prior independent study,[41] to assess the impact of lower or higher SSB reduction from SSB purchase restriction. In addition, how lower length and frequency of SNAP participation affect the outcomes was examined by varying the median completed spell length to 24 and 48 months, the lowest length in the past 20 years.

Finally, the percentage of the U.S. population enrolled in SNAP was varied. The base case used the 2017 estimate in which 16.7% of all children were living in households with SNAP benefits.[42] The participation rate was varied from 5% to 25%, the lowest and highest rates of participation in the last 3 decades, with participation within each demographic group proportional to the rate of participation during those prior years.

All analyses were performed in 2019 using R, version 3.6.1. In each scenario, the model was rerun 10,000 times while repeatedly Monte Carlo sampling from the probability distributions of all input parameters to capture uncertainties in the estimates, generating 95% CIs around all outcomes. Modeling assumptions are listed in Appendix Table 11 (available online). The Appendix (available online) details all input data, equations, and complete technical details consistent with international model reporting guidelines.[43]

RESULTS

If there were no changes to the current SNAP participation, food consumption, and health risk factor profiles, the model estimated that the obesity prevalence would be 14.9% (95% CI=14.6, 15.2) among children aged 2−5 years, 19.6% (95% CI=19.1, 20.1) among children aged 6−12 years, and 20.5% (95% CI=19.9, 30.0) among those aged 13−19 years (Appendix Figure 1, available online). Dental caries prevalence was estimated to be 21.3% (95% CI=19.4, 22.2), 49.5% (95% CI=44.0, 50.1), and 52.9% (95% CI=47.2, 58.3) in the respective age groups. These model-predicted values matched outcomes from the observed data within <5% absolute error. External validation results of BMI changes are given in Appendix Figure 2 (available online).

Currently, daily SSB consumption among SNAP participants was 102.6 g/person (95% CI=98.6, 106.6) higher than non-SNAP participants, and the difference in SSB consumption was highest among non-Hispanic Black male SNAP participants, consuming 123.7 g/person more (95% CI=119.5, 127.9) than non-SNAP participants (current daily SSB consumption levels available in Appendix Figure 3, available online). Restricting SSB purchases in SNAP would reduce daily SSB intake by 112.5 g/person (95% CI= −115.90, −109.17), approximately 4 fluid ounces on average, with the largest reduction among non-Hispanic Black participants (Table 2 and Figure 2).

If SSBs were substituted with 100% fruit juice and milk based on cross-price elasticity estimates,[18] the SSB restriction would be expected to reduce total calorie intake by a net average of −39.2 kcal/person (95% CI= −39.8, −38.7) among SNAP participants, resulting in a 2.6 kg/m^2 (95% CI= −2.9, −2.4) decrease in BMI (Table 2). The largest reduction in BMI was also experienced by non-Hispanic Black participants owing to their high baseline SSB consumption. Based on this change in BMI, obesity prevalence would be expected to decrease by 6.2 percentage points (95% CI= −6.5, −5.9). The anticipated decrease in the number of decayed teeth averaged 0.53/person (95% CI= −0.55, −0.51), an 8.0% decline from the baseline.

When SSBs were substituted with most typically purchased food items by SNAP participants, such as meat, vegetables, and frozen prepared foods (Appendix Table 9, available online), the participants consumed 4.4 more daily kcal/person (95% CI=4.3, 4.5) owing to higher caloric density in food items that were substituted with (Table 2). BMI and obesity prevalence among the participants were expected to increase by 0.3 kg/m^2 (95% CI=0.0, 0.6) and 1.1 percentage points (95% CI=0.7, 1.4); however, these increases were not translated into statistically significant changes in BMI (0.04 kg/m^2, 95% CI= −0.2, 0.1) or obesity prevalence (0.17 percentage points, 95% CI= −0.4, 0.0) from an overall population perspective (Appendix Table 12, available online). In a scenario in which SSB restriction affects BMI based on randomized trials and cohort studies, BMI and obesity prevalence were estimated to decrease by 1.1 kg/m^2 (95% CI= −1.4, −0.9) and 3.27 percentage points (95% CI= −3.6, −3.0). When changes in total energy intake were modeled based on crossover feeding trials and observational studies of diet and energy intake, greater reductions in BMI and obesity prevalence were estimated compared with the base case: 5.5 kg/m^2 (95% CI= −5.8, −5.1) reduction in BMI and 9.5 percentage point (95% CI= −9.8, −9.2) decrease in obesity prevalence.

When participants maintained SNAP enrollment for 24 months compared with 96 months in the base case,

Table 2. Impact of a Simulated Restriction on Using SNAP Dollars to Purchase Sugar-Sweetened Beverages (versus Status Quo) Among SNAP Participants

Sensitivity analyses	Change in SSB (grams/day per person)	Change in calorie intake (kcal/day per person)	Change in BMI (per person)	Change in obesity prevalence (percentage point)	Change in number of decayed teeth (per person)
Base case (substitute with milk and fruit juice)	−112.54 (−115.90, −109.17)	−39.24 (−39.78, −38.70)	−2.64 (−2.86, −2.41)	−6.16 (−6.46, −5.84)	−0.53 (−0.55, −0.51)
Effects of SSB restriction on obesity					
Substitute with typically purchased items	−112.54 (−115.90, −109.17)	4.38 (4.34, 4.42)	0.29 (0.01, 0.60)	1.05 (0.73, 1.37)	−0.52 (−0.54, −0.50)
Model changes in BMI (based on trials and cohort study)	−112.54 (−115.90, −109.17)	—	−1.11 (−1.35, −0.87)	−3.27 (−3.59, −2.96)	−0.53 (−0.55, −0.51)
Model changes in TEI (based on cohort study)	−112.54 (−115.90, −109.17)	−83.67 (−84.60, −82.75)	−5.46 (−5.80, −5.11)	−9.54 (−9.84, −9.23)	−0.53 (−0.55, −0.51)
SNAP enrollment					
5% enrolled	−112.54 (−115.90, −109.17)	39.24 (−39.78, −38.70)	−2.64 (−2.86, −2.41)	−6.16 (−6.46, −5.84)	−0.53 (−0.55, −0.51)
10% enrolled	−112.54 (−115.90, −109.17)	39.24 (−39.78, −38.70)	−2.64 (−2.86, −2.41)	−6.16 (−6.46, −5.84)	−0.53 (−0.55, −0.51)
25% enrolled	−112.54 (−115.90, −109.17)	39.24 (−39.78, −38.70)	−2.64 (−2.86, −2.41)	−6.16 (−6.46, −5.84)	−0.53 (−0.55, −0.51)
SNAP duration					
24 months	−112.54 (−115.90, −109.17)	39.24 (−39.78, −38.70)	−1.39 (−1.56, −1.22)	−3.68 (−3.99, −3.37)	−0.28 (−0.30, −0.26)
48 months	−112.54 (−115.90, −109.17)	39.24 (−39.78, −38.70)	−1.88 (−2.19, −1.58)	−4.80 (−5.11, −4.48)	−0.39 (−0.36, −0.41)
MPC (SSB reduction per dollar reduction in SNAP benefit)					
$0.17	−59.11 (−62.72, −55.51)	−20.71 (−20.99, −20.42)	−1.39 (−1.67, −1.11)	−3.82 (−4.14, −3.50)	−0.28 (−0.30, −0.26)
$0.47	−163.53 (−166.67, −160.38)	−57.29 (−58.08, −56.51)	−3.84 (−4.18, −3.50)	−7.77 (−8.08, −7.46)	−0.78 (−0.80, −0.75)

MPC, marginal propensity to consume; SNAP, Supplemental Nutrition Assistance Program; SSB, sugar-sweetened beverage; TEI, total energy intake.

they would still be expected to experience significant decreases in all outcomes evaluated per participant; obesity prevalence decreased by 3.7 percentage points (95% CI= −4.0, −3.4), and the number of decayed teeth were reduced by 0.28/person (95% CI= −0.30, −0.26). With the lowest MPC estimate of $0.17/dollar, participants still experienced significant reduction in daily SSB intake (−59.1 g/person, 95% CI= −62.7, −55.5), as well as in obesity prevalence and dental caries (Table 2 and Appendix Table 12, available online).

When SNAP enrollment rates were varied from 5% to 25%, the SSB restriction would significantly reduce obesity prevalence and incidence of dental caries from an overall population perspective when the enrollment rate is >5% (Appendix Table 12, available online). From an overall population perspective, the SSB restriction would be expected to result in significant reduced obesity prevalence and dental caries even at low SNAP participation rates: a reduction of −0.4 percentage points (95% CI= −0.6, −0.1) in obesity prevalence and 0.03 (95% CI= −0.05, −0.01) decrease in the number of decayed teeth.

DISCUSSION

Restricting SSB purchases with SNAP benefits would likely have meaningful public health benefits among children by significantly reducing risk of dental caries, one of the most common chronic diseases of childhood in the U.S., and obesity, depending on the food substitution behaviors. The health benefits from SSB purchase restriction would likely hold even at lower SNAP participation rates and with shorter duration of receiving SNAP benefits. However, with a likely impending recession and currently high unemployment, an increasing number of households would become eligible for SNAP,[44] and the benefits of SSB restriction in SNAP would be likely to be greater from an overall population perspective.

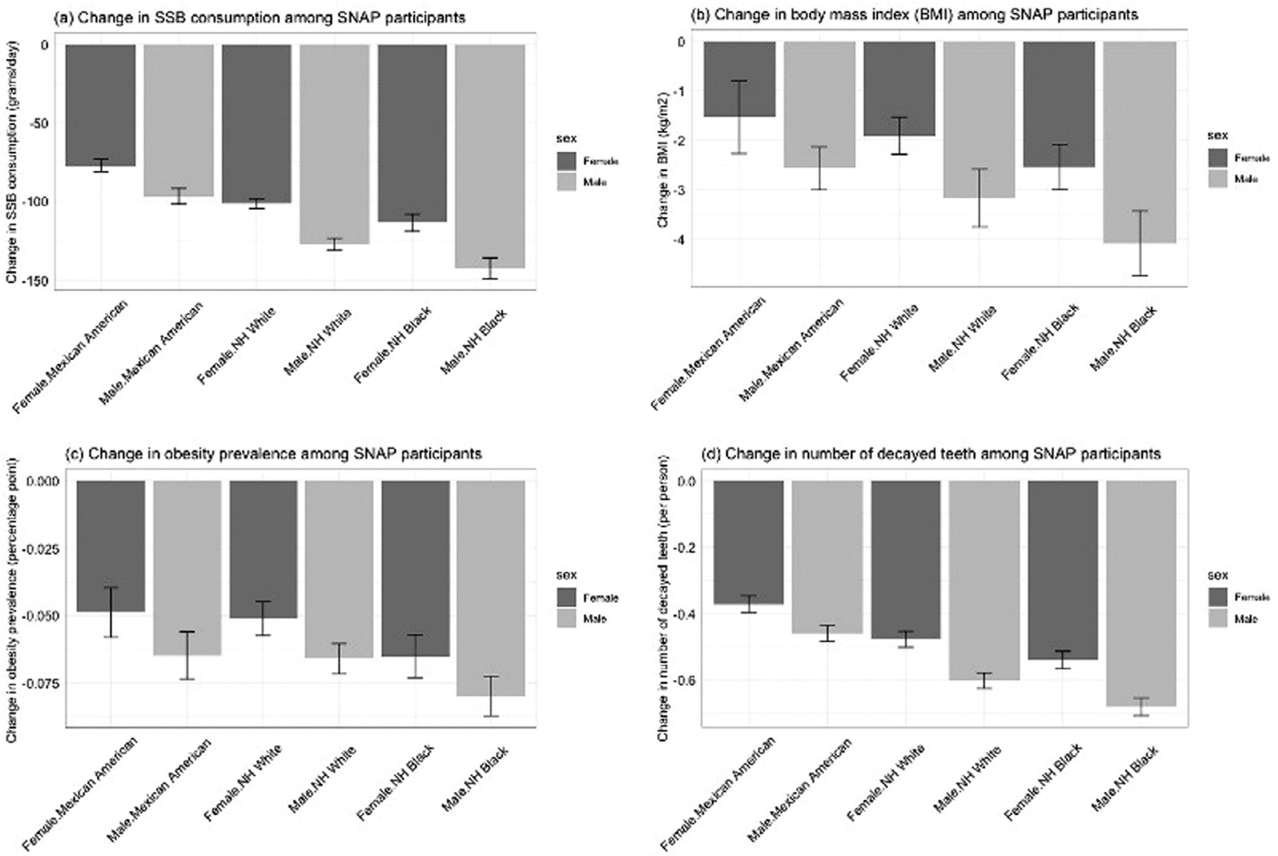

Figure 2. Estimated changes in SSB intake, BMI, and risks of obesity and dental caries. NH, non-Hispanic; SNAP, Supplemental Nutrition Assistance Program; SSB, sugar-sweetened beverage.

A prior 4-week randomized trial among low-income individuals found that SSB restriction would be expected to significantly reduce SSB purchases but not SSB intake among the trial participants. This disparity may result from the fact that trial participants were primarily middle-aged and female and are the purchasers, but not representative of the consumers of SSBs.[45,46] SNAP participants reported that they are in favor of policies that facilitate purchases of healthful foods and limit purchases of unhealthful foods, specifically SSBs.[47] Currently, in the absence of all state waivers to empirically test SSB restrictions in SNAP,[16] results from this simulation model can provide valuable insights by providing potential benefits of SSB restriction on childhood dental caries and obesity. Although prior simulation studies that evaluated the impact of SSB restriction on adult SNAP participants show that the restriction could lower chronic disease morbidity and mortality,[12,13] the potential impact of SSB restriction on children's consumption and health has not been evaluated. This study accounted for the fact that reduced SSB consumption would only be expected during periods of SNAP participation among SNAP household members who cycle in and out of SNAP and found that SSB restriction is likely to significantly reduce caries incidence and potentially obesity prevalence from an overall children population perspective. Accounting for the complex variations in SNAP participation among different demographic groups and the associated correlated risk factors among SNAP participants, the SSB restriction particularly would be expected to reduce daily SSB intake among non-Hispanic Black male participants, the group that has been at a higher risk of obesity and dental caries.[48,49]

Limitations

This study has limitations inherent to modeling based on secondary data. In the absence of stronger direct evidence, especially without all state waivers to empirically test the SSB restriction, the effects of SSB purchase restriction on weights were modeled based on MPC and a review of beverage demand elasticity in the base case,[15,17] resulting in lower dental caries incidence and obesity prevalence by substituting SSB with fruit juice and milk. Because there is limited evidence to estimate the effect of the SSB restriction, such as predicting how consumers would respond to the restriction, future research on SNAP benefit restrictions should address how consumption behaviors differ among groups within the SNAP population. It is likely that there are complex interactions among location, accessibility of food choices, and consumption behaviors, not just the price variations. When the authors assessed the impact of a different substitution pattern, participants substituting SSB with food items that are most typically purchased by SNAP participants, obesity prevalence slightly increased from substituting with food items with higher caloric density. Weight changes in this study were mainly modeled through changes in calorie intake; however, added sugars in SSBs are devoid of nutrients and in fact deplete energy from the body.[50] Because calories consumed in liquid form have weak satiety properties and elicit poor energy compensation compared with calories from solid food,[38] leading to excess weight gain, this study provides conservative results. Next, this study used data from NHANES, which are subject to the limitations of survey studies, including recall biases, acceptability biases, and under-reporting, which may lead to underestimation of SNAP participation.[51] This bias would also cause the impact estimates to be conservative. Finally, although uncertainty analyses were performed by sampling from distributions around the input parameter data sources, all possible uncertainties in a simulation model cannot be captured; hence, the results are inevitably subject to the assumptions inherent in modeling. In addition to the limitations, it is important to note that there are potential indirect effects of SSB restriction that may discourage eligible beneficiaries from participating in SNAP.

CONCLUSIONS

Children enrolled in SNAP are at a higher risk of poor diet, including higher SSB consumption, than non-SNAP participants. This proposed policy could potentially promote a healthier diet and significantly reduce dental caries. These benefits would likely accumulate among demographic groups that have remained at high risk of obesity and dental caries, thus addressing social and economic determinants of nutritional disparities.

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SUPPLEMENTAL MATERIAL

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