Simulation Modeling of Policies Directed at Youth Sugar-Sweetened Beverage Consumption

David T. Levy · Karen B. Friend

© Society for Community Research and Action 2012

Abstract  Childhood obesity is a significant public health problem requiring innovative solutions. While recent reviews indicate that some policies show promise, there is a lack of information regarding which policies, and policy combinations, work best. Low-nutrition, energy-dense foods and beverages such as sugar-sweetened beverages (SSBs) have been identified as a major contributor to the problem. The purpose of this paper is to use simulation modeling to show how changes in three categories of SSB policies—school nutrition, school-based education, and taxes—impact SSB and other food consumption. The model shows that policies directed at SSBs, particularly tax hikes, could lead to substantial reductions in the number of calories consumed by youth. The estimates, however, are subject to a high degree of uncertainty. Estimates from school-based nutrition and school-based education policies, while also helping to reduce caloric intake, generally show smaller effects than tax policies and considerable variation around parameter estimates for individual and combined policies. We conclude with a discussion of the limits of the model, and suggest where additional information is needed. Limitations notwithstanding, simulation modeling is a promising methodology that can help advance our understanding of policy effects, thereby helping policymakers to better formulate effective policies to reduce obesity prevalence and the associated social harms.

Keywords  Simulation modeling · Obesity · Policies · School programs · Youth · Sugar-sweetened beverages

Introduction

Obesity and its associated health consequences are widely recognized as significant public health issues facing today’s youth. While recent reviews indicate that some policies directed at the problem show promise (Andreyeva et al. 2010; Brown and Summerbell 2009; Doak et al. 2006; Flodmark et al. 2006; Levy et al. 2011; Matson-Koffman et al. 2005; Seymour et al. 2004), there is a lack of information regarding which policies and policy combinations work best to reduce this major health threat. The difficulty with policy selections lies in part with the fact that nutrition involves a complex interaction of individual and genetic components, coupled with environmental issues related to food intake and energy output (Gortmaker et al. 2011). Low-nutrition, energy-dense foods and beverages (LNED) have been identified as a major contributor. They are broad in number, however, making it challenging to develop and implement interventions to target all such offenders. Further, the role of specific LNED foods in promoting weight gain is generally difficult to distinguish.

Despite this difficulty, one specific subset of LNED beverages has been identified as a target for public health interventions: sugar-sweetened beverages (SSBs). SSBs lack nutritional value, increase overall appetite, and are not only associated with weight gain (Malik et al. 2006; Vartanian et al. 2007), but have also been directly linked to diabetes (Malik et al. 2010), heart disease (Brown et al. 2011) and dental decay. These effects may be attributed in part to their displacing healthier options such as milk (Malik et al. 2006; Vartanian et al. 2007). SSB consumption doubled in the US...
between 1977 and 2002 (Duffey and Popkin 2007). Children and adolescents now derive 10–15% of their total kilocalories per day (kcal/day) from SSBs (Wang et al. 2008).

Three types of policies have received considerable attention as ways to reduce youth SSB consumption. First are policies that limit access. One popular option in this category is limiting the availability of SSBs in schools, where youth are a “captive audience.” Access in schools, however, only contributes to a portion of youth SSB consumption, and, unless schools can educate youth not to drink SSBs at home, school policies will have limited effects. Second are school education policies that aim to change consumption habits. Third are policies that affect all SSB prices inside and outside of school. Policies in this category can reduce SSB consumption not only among youth, but also adults, which, in turn, can help promote better role models for youth. Adults also serve as gatekeepers for youth SSB access, since they purchase most of the SSBs consumed by youth, including beverages for lunches brought to school. A compelling body of evidence shows that cigarette tax hikes are consistently associated with reduced tobacco use (Chaloupka and Powell 2009; Levy et al. 2000), especially among youth.

While the immediate aim of SSB policies is to reduce SSB consumption, the ultimate goal from a public health perspective is to lower the trajectory of the youth body mass index (BMI) and improve health. Some models and statistical analyses have examined the impact of policies on BMI, but they examine a single policy or limited set of policies. Many studies do not report the effect of policies on BMI or are inconclusive. In addition, reduced SSB consumption in schools may be compensated by increased intake of other LNED or high calorie foods and beverages inside or outside of schools. In general, past studies do not yet provide sufficient information to isolate the linkages from policies to SSB consumption to BMI. This is especially likely where policies affect only a portion of consumption, such as in schools. The effects may also take time to develop, and studies often last short periods of time (Gortmaker et al. 2011; Hall et al. 2011; Levy et al. 2011).

As emphasized in a recently released Institute of Medicine report (Institute of Medicine 2010) simulation models (SMs) can be especially useful for considering the potential impact of an array of policies that will be required to tackle the obesity problem. Simulation models (SMs) are now widely used to understand and predict behavior in complex systems. The use of these models in public health is at a nascent stage, but has tremendous potential to bridge the gap between research and practice (Homer and Hirsch 2006; Levy et al. 2006; Sterman 2006). SMs combine information from different sources to provide a useful tool for examining how the effects of public health policies unfold over time in complex systems and impact population health (Homer and Hirsch 2006; Levy et al. 2006).

SMs can be particularly useful in understanding the complex interaction of the relationships between public policy, diet and exercise, measures of overweight and obesity, and reduced health and other outcomes associated with overweight and obesity. As shown in Fig. 1, obesity depends on the energy balance equation, which in turns depends on caloric intake through food consumption and calories burnt through physical activity, growth, and other processes that influence metabolism. Separate public and private policies may affect nutrition and physical activity. In this study, we only consider policies affecting nutrition, focusing on SSB consumption and how SSB policies may affect the consumption of other foods.

In this paper, we develop a simulation model of the pathways of policy effects of school-based access to nutrition, school-based education and SSB tax policies on the consumption of SSBs by youth, and the resulting effects on caloric intake. The model will embody a systematic approach that considers the effect of various school nutrition policies on the number of SSB calories consumed inside and outside of school, and how changes in SSB consumption affect the consumption of other foods (more specifically, their associated caloric intake). We also consider how a range of price changes through tax increases influence SSB and non-SSB consumption, so that the different policies can be compared. Because a range of effect sizes are associated with each of the pathways to final caloric intake, sensitivity analysis is used to indicate the uncertainty surrounding the relevant parameters and
highlight priority areas for future research. Thereby, modeling provides an important tool for researchers, as well as a guide to policymakers.

Methods

In a previous article (Levy et al. 2011), we reviewed the literature on the direct effects of school nutrition policies on SSB consumption, the effect of price on SSB consumption (with a focus on youth), the effects of reduced consumption of SSBs in school on the consumption of other foods in school (LNEGs or otherwise), the effects of SSB consumption in school on the consumption of SSBs and other foods outside of school, and the effects of SSB consumption on caloric intake (both through direct reductions in the amount consumed and the effect on the consumption of other foods). We apply those estimates where feasible in our current modeling approach and incorporate new studies conducted since that review.

In gauging the effect of caloric intake on BMI, evaluations sometimes apply the equation that a 3,500 yearly calorie reduction (roughly 10 kcal/day) reduces weight by 1 pound (Hall et al. 2011). However, Butte and Ellis (2003) argued that the energy gap is higher for children, due to greater energy expenditures. Studies indicate that the required calorie reductions to prevent weight gain vary from as little as 100–140 kcal/day at younger ages (Plachta-Danielzak et al. 2008; Wang et al. 2006) to 300–500 kcal/day at slightly higher ages (Butte et al. 2007; Butte and Ellis 2003; Swinburn et al. 2006) and to 600–1,100 kcal/day (Wang et al. 2006) for those who became overweight adolescents over 10 years. At present, in the absence of a well-accepted model (Hall et al. 2011), considerable uncertainty surrounds the changes in caloric intake needed to prevent abnormal weight gain in youth. For that reason, we stop short of estimating the effects of SSB policies on BMI and limit the analysis to the effect of SSB policies on overall caloric intake.

In-School Nutrition SSB Policy Effect Sizes

As shown in Fig. 2, in-school policies to reduce SSB may involve (1) limits on access in school, (2) school education policies, and (3) price policies. Studies that do not include specific outcome measures useful for modeling, such as the quantity of SSBs consumed or caloric intake, were excluded.

School Access Policies

Overall, published research has found that limiting access to SSBs in school is associated with decreased SSB consumption. Three studies (Cullen et al. 2008; 2006; Cullen and Zakeri 2004) examined the effect of a variety of different school nutrition policies in a Texas middle school with high Hispanic and lower income populations. Cullen et al. (2007) and Hartstein et al. (2008) conducted a pilot study in three states that examined serving size limits. Johnson et al. (2009) conducted a study in Washington that examined limits in a variety of venues (vending machines, snack bars and lunch); and Woodward-Lopez et al. (2010) examined a variety of venues; Shi (2010) focused on vending machines. A study of Boston schools (Cradock et al. 2011) examined a general policy of reducing SSB availability. The most comprehensive study (Briefel et al. 2009) considered a range of access and education policies across a broad range of schools.

Blum et al. (2008) found no difference in the effect in the intervention and control groups from reduced a la carte and vending machines, and Forshee et al. (2004) and? Fletcher et al. (2010a, b) found little or no effect on weight of reducing SSB vending machine availability. Because these studies did not obtain significant effects, they were excluded from this study. However, they suggest uncertainty regarding the effect of policies, especially on BMI.

School Education Policies

In 2006, 70 % of states required nutrition and dietary behavior to be taught at the elementary, middle, and high school levels as part of the health education curriculum but did not necessarily emphasize SSBs (Kann et al. 2007). For example, Briefel et al. (2009) found nearly significant effects of school education policies on SSB consumption in 9–12th grades. Because their study did not distinguish programs targeting SSB consumption, it may be premature to draw strict conclusions. Another study of education programs (Lo et al. 2008) failed to find significant effects, indicating uncertainty surrounding the effect of education programs.
policies. In contrast, two randomized control trials of school education programs targeted at SSB consumption showed encouraging results: one (James et al. 2004) in England with elementary school students and another (Sichieri et al. 2009) in Brazil with students aged 9–12.

School Pricing Policies

No studies were found that directly examined in-school SSB price policies. However, reducing the price of lower fat snacks, fruits and vegetables in school has been found to increase sales (French 2003), suggesting that students may also be sensitive to SSB prices. We consider the effect of price assuming that the same elasticities apply inside school as outside of school, but confining the direct effects to SSBs purchased in school.

SSB Tax Policy Effect Sizes

A tax on SSBs leads to higher prices, which in turn affects consumer purchases and SSB consumption. Therefore, the effects of tax policies occur through differences in the price paid by the consumer, and statistical studies that consider prices are likely to provide more direct estimates of their effect on consumers.

Demand Studies

Demand studies generally estimate the effects of price in terms of price elasticity, defined as the percentage change in quantity consumed relative to a specific percentage change in price. A recent meta-analysis by Andreyeva et al. (2010) estimated a price elasticity for soft drinks of −0.79, with a 95 % confidence interval of −0.33 to −1.24. However, the studies varied in their classifications of SSBs, with some narrowly confining their analyses to sodas and others considering a broader spectrum of SSBs, such as fruit and sports drinks. In studies conducted since Andreyeva’s review, Finkelstein et al. (2010) and Duffey et al. (2010) obtained elasticities in the range of −0.7 and −0.9. More extreme elasticities were obtained by Zheng and Kaiser (2008) of −0.15 and for soft drinks of −1.9 (Dharmasena and Capps 2011). Smith et al. (2010) obtained a price elasticity of −1.3 for all SSBs. Using narrowly defined categories, Zhen et al. (2011) obtained roughly comparable price elasticities, with less price responsiveness among low-income than high-income consumers.

For our model, based on the cluster of recent analyses between −0.3 and −1.4, we use a midpoint of −0.9, with bounds of −0.4 to −1.4 to estimate the SSB price elasticity. We use a slightly broader estimate of −0.3 to −1.5, with a best estimate of −0.9, for the narrower category of carbonated SSBs, i.e., sugar-sweetened sodas, but allow for substitution of other SSBs, non-SSBs and other foods, as described below. Price elasticities are assumed constant over the range of prices considered.

None of the price studies explicitly examine youth, but SSBs consumed at home or in restaurants or brought from home to school are often purchased by adults. Some studies have found that youth and individuals with high BMIs are particularly sensitive to food prices (Auld and Powell 2009; Epstein et al. 2006; Powell et al. 2007; Sturm and Datar 2005, 2008). To be conservative, we apply the estimates developed above for adults to youth, since adults purchase much of the food for youth.

The Effect of SSB Taxes

Currently, there are differences in the taxes that states apply and differences in the beverages to which they are applied, such as carbonated sodas versus sports drinks (Chriqui et al. 2008; Powell et al. 2009). Possibly because the form of a sales tax levied at the counter is small, past studies that consider tax rates (Powell and Chaloupka 2009) have generally found small or weak effects. These studies are subject to limitations, including that soda taxes tend to show limited variance and thus are unable to distinguish effects; are often imposed on a restricted set of SSBs (e.g., carbonated sodas only); and are taken at the checkout counter rather than viewed as posted prices.

We assume a common per unit tax across the selected SSB beverages sold at all locations. While we recognize that prices and thus the percentage effect of a tax will differ depending on location (e.g., SSB prices are generally higher at restaurants than convenience stores), we do not distinguish the source of purchase due to the lack of sufficiently detailed data.

The tax is assumed to directly affect the price. Besley and Rosen (1999) found a 129 % pass through of SSB taxes to price. We consider a range of tax shifting from 80 to 130 %, with our best estimate as 100 % shifting. We note, however, that while a per unit tax is more likely to be passed along to consumers than an ad valorem (percentage) tax (Brownell et al. 2009), a constant per unit tax per ounce will be applied at different percentages for beverages at different prices (e.g., SSBs in restaurants are generally priced the same size SSBs bought at supermarkets). We consider a tax of $0.01/ounce of soda, which translates to a 20 % increase in price (Andreyeva et al. 2011) with 100 % shifting. We also consider $0.005/ounce and $0.02/ounce tax increases.

Consumption Parameters

In order to operationalize the above effect sizes, we apply the effect sizes to measures of average SSB consumption in
terms of kcals/day (kcal/day). The effect of decreased SSB consumption on BMI will depend further on how this reduction is affected by the consumption of other foods and beverages and their associated calories. We adjust the estimates of reduced consumption of SSBs to incorporate the consumption of other beverages and solid foods.

**Levels of US SSB Consumption**

For the price analysis, the percentage change in price is multiplied by the average SSB consumption. Using nationally representative data from the National Health and Nutrition Examination Survey (NHANES), Wang et al. (2008) found average daily consumption was 184 kcal/day (9 % of total caloric intake) for ages 6–11 years and 301 kcal/day (13 % of total intake) for ages 12–19 years. For policies that target a subset of SSBs, such as carbonated beverages, carbonated drinks contributed 55 % (53 % for individuals ages 6–11 years and 66 % for those ages 12–19 years) and fruit drinks 33 % of all SSB kcal/day (13 % of total intake) for ages 6–11 years and 20 % for ages 12–19 years. For the price analysis, the percentage change in price is multiplied by the average SSB consumption. Using the 3rd School Nutrition Dietary Assessment Study (SNDAS, 2004–2005), Briefel et al. (2009) found that school children consumed an average of 159 kcal/day on school days (with 209 kcal/day by secondary school students), of which 93 were at home, 36 were at school and 31 were at other locations. Another study by Briefel et al. (2009) found that SSBs were consumed by 17 % of students in the elementary school, 32 % in middle school and 36 % in high school, of which only a portion were actually purchased at schools (27, 67 and 74 %, respectively). Students purchased and consumed, on average, 3, 29 and 46 kcal/day in elementary, middle and high school, respectively.

School studies sometimes report the results in terms of the absolute change in calories consumed in school and other times in terms of the percentage change in calories consumed. We use an estimate of SSBs consumed and purchased in school to convert the percentage change to an absolute change. We converted the results to average daily consumption by multiplying the average reduction per school day by the percent of school days in the year (=180/365). The only exception is for Sichiari et al. (2009), where results were reported in terms of all SSB consumption.

**Substitution to Other Beverages Inside and Outside of School**

The most direct effect of a change in the consumption of SSBs is to replace other beverages. In the context of demand studies, these effects are measured in terms of substituting other products in reaction to price changes. Many of the demand analyses are confined to soda, so that there may be substitution to other SSBs, such as sport drinks and fruit drinks.

Examining all SSBs, Smith et al. (2010) estimated that a 20 % SSB price increase reduced SSB caloric intake by 38.8 % for adults and 48.8 % for youth. They found offsets from juices and milk of 1.9 % for adults and 6.1 % for youth, thus suggesting little offset. Zhen et al. (2011) also found limited substitution and that, as the price of sugar-sweetened sodas increased, consumption of other beverages such as diet soda fell, especially among low-income consumers. For low-income consumers, Yen et al. (2004) found a small effect of soda prices on the consumption of other beverages. Finkelstein et al. (2010) obtained relatively large substitution effects of a tax on all SSBs, but the overall reduction in calories was still only about 30 % lower when other non-SSBs were considered. Calories were, however, reduced another 40 % if the tax was confined to carbonated sodas. Dharmasena and Capps (2009, 2011) found substantial substitution, but examined a limited set of beverages (e.g., milk) Fletcher et al. (2010a, b) obtained a nearly 100 % offset of SSB consumption through increased milk consumption, but other studies have found substantially less substitution toward milk (Vartanian et al. 2007). Brownell et al. (2009) estimated a 25 % offset in calories. Wang (2011) estimated a 39 % offset, assuming that, upon reducing SSB consumption, a third each switched to water, diet soda and milk or juice.

The studies above demonstrate that substitution effects are highly dependent on the products considered and specification of the empirical model. Based on these results, our best estimate is a 20 % substitution for a tax on all SSBs, with estimates ranging from 0 to 60 %. Substitution of calories from other beverages. If the tax is confined to carbonated SSBs, we estimate an additional 15 % offset with a range of 5–40 %. The 40 % estimate reflects the potential that, in reaction to the tax, beverage manufacturers may develop new non-carbonated SSBs whose costs are favorable to consumers.

As shown in Fig. 3, the effect of SSB school policies on SSB caloric intake involves multiple pathways. When SSB access is limited in schools, youth may bring SSBs from home. For non-price policies, we use the estimated substitution effects from price studies, i.e., an estimated 20 % reduction per 18 % increase in price, with a range of 0–60 % around that estimate.

The effects of school nutrition access policies on overall caloric intake also depend on how consumption in school affects consumption outside of school. Even if SSB purchases are reduced in school, youth may compensate with
increased consumption at home. However, studies that have considered overall consumption (Briefel et al. 2009; Cullen et al. 2008; Fernandes 2008; Schwartz et al. 2009; Woodward-Lopez et al. 2010) have not found increased SSB consumption at home in response to reduced SSB consumption in schools. Indeed, youth may further reduce consumption at home if drinking SSBs becomes less of a habit. We estimate no effect of reduced in-school SSB consumption on SSB consumption outside of school, but increase the variability of our estimates by 25% to incorporate the increased uncertainty.

**SSB Consumption and Substitution to Solid Foods**

Besides substituting for other beverages, reduced consumption of SSBs may be replaced by the consumption of solid foods. However, it has also been suggested that SSB consumption may instead increase the appetite for other foods (Bellisle and Rolland-Cachera 2001; Drewnowski and Bellisle 2007; Hattersley et al. 2009; Mattes 1996; Yamada et al. 2008), especially high fat and high salt items (e.g., French fries). Thus, reduced SSB consumption may reduce or increase the intake of solid foods.

Some studies have considered how SSB consumption affects foods consumed and overall caloric intake. Lack of compensation is supported by a recent meta-analysis by Vartanian et al. (2007), but an alternative view is presented in DiMeglio and Mattes (2000). In addition, Wang et al. (2009) found that each additional 8 oz. serving of SSBs was associated with a net increased intake of 106 kcal/day on that day \((p < .001)\), similar to the 100 kcal/day from an 8-oz serving of sodas, indicating limited substitution to other foods and beverages.

In general, even while some research reports that SSB consumption may affect the calories consumed from solid foods, but the effects appear limited and may be in either direction. Overall, we estimate no effect of changes in SSB consumption on caloric intake from solid foods, but increase the uncertainty of the estimates to allow for an added 25% variability in overall caloric intake.

**Results**

The parameters used in our analysis are listed in Table 1. In conducting our analysis, we present best estimates, as well as upper and lower bounds.

### School Access Policies

Table 2 reports the results from studies of school access studies, followed by the effects calculated in terms of caloric changes in SSBs. It then incorporates the effect of reduced caloric intake due to consumption outside of school, substitution to non-SSBs, and compensation/reduced consumption of non-liquids, and finally reports the net effect with bounds after incorporating all substitution and compensation.

Cullen and Zakeri (2004) found that, when SSBs became more available to 6th graders, consumption increased 1.3 ozs/day (from 2.1 to 3.4 ozs), and fell only slightly in the next year. Upon converting to kcal/day, we calculate a net increase in SSB consumption averaging 7.1 kcal/day over the entire year, ultimately yielding a net increase in caloric intake of 5.6 (with bounds of 3.2–8.8) kcal/day. Allowing for consumption outside of school, substitution to non-SSBs reduced, and finally compensation/reduced consumption of non-liquids, the simulation model estimates a net increase in overall caloric intake of 5.6 (with bounds of 2.4–11.0) kcal/day due to the increased availability of SSBs.

Upon removing LNEDs from snack bars and in cafeteria vending machines, Cullen et al. (2006) found that mean SSB intake declined by 1.9 oz. in lunch and snack bars, ultimately yielding a 4.9 (2.1–9.5) kcal/day reduction in overall caloric intake. Of three Texas middle school studies, the largest effect was in schools limiting portion size and vending machine availability (Cullen et al. 2008), whereby overall SSB fell 1.9 oz leading to 7.4 (3.1–14.5) kcal/day reduction in net caloric intake. Results from Hartstein et al. (2008) indicate that net caloric intake is reduced by 1.3 (0.6–2.5) kcal/day if all 6 schools in their sample are included and by 2.6 (1.1–5.0) kcal/day if the 2 outlier North Carolina schools are excluded.

A large scale Washington study (Johnson et al. 2009) yielded a net decline of 2.9 (1.2–5.6) kcal/day. Two studies examined California policies, one (Shi 2010) of which yielded a reduction of 4.9 (2.1–9.6) kcal/day and the other yielded a reduction of 1.4 (0.6–2.8) kcal/day. (Woodward-Lopez et al. 2010). Another large scale study for Boston (Cradock et al. 2011) yielded a net reduction of 9.2 (4.3–18) kcal/day.

Incorporating a vast array of policies, Briefel et al. (2009) obtained a wide range of effect sizes for the different policies, many of which were not significant. Estimates for
specific policies ranged from 6.3 kcal/day (lack of pouring rights in middle school) to 16.2 kcal/day (not offering French fries in high schools). Some of these reductions, however, were larger than the average SSB consumption of students, which may reflect the large differences in consumption between schools with and without restrictive practices and collinearity between the policy variables. Most relevant may be the results for their composite measures, where the model estimated that stricter availability policies (e.g., limits on vending machines and snack bars) reduces net caloric intake by 18.9 (8.0–37.0) kcal/day in middle schools and by 22.1 (9.3–43.2) kcal/day in high schools. Stricter school lunch policies have the potential to reduce overall caloric intake by 30.4 (12.8–59.3) kcal/day.

### School Education Policies

Briefel et al. (2009) found that having school nutrition education in all grades had the potential to reduce SSB consumption by 6.3 (2.7–12.3) kcal/day, although the effect did not quite reach statistical significance ($p = 0.51$). In elementary schools in England, James and Kerr (2004) reported that carbonated SSB consumption over 3 days decreased by 0.3 servings (0.4 oz.), implying the potential to reduce net caloric intake by 0.8 kcal/day (0.3–1.5) kcal/day. For an education program aimed at Brazilian students aged 9 to 12, results from Sichieri et al. (2009) a reduced net caloric intake of 14.5 (6.3–28.4) kcal/day.

### Table 1  Estimates and parameters used to determine effects from studies

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Population</th>
<th>Best estimate</th>
<th>Lower bound(^a)</th>
<th>Upper bound(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSBs in kcals</td>
<td>Ages 2–19 years</td>
<td>224</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ages 2–5 years</td>
<td>24</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ages 6–11 years</td>
<td>184</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ages 12–19 years</td>
<td>301</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbonated SSBs in kcals</td>
<td>Ages 2–19 years</td>
<td>123.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ages 2–5 years</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ages 6–11 years</td>
<td>98</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ages 12–19 years</td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSB consumption in kcals</td>
<td>Elementary schools</td>
<td>19</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Secondary schools</td>
<td>52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSB consumption in kcals</td>
<td>Elementary school</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purchase and consumed</td>
<td>Middle school</td>
<td>29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In school</td>
<td>High school</td>
<td>46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tax policy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of tax/price increase</td>
<td>$0.01/oz tax = 20 % price increase</td>
<td>$0.005 = 10 % price increase</td>
<td>$0.02 = 40 % price increase</td>
<td></td>
</tr>
<tr>
<td>Shifting of the tax to price</td>
<td>100 %</td>
<td>80 %</td>
<td>130 %</td>
<td></td>
</tr>
<tr>
<td>Price elasticity</td>
<td>All ages</td>
<td>-0.9</td>
<td>-0.3</td>
<td>-1.5</td>
</tr>
<tr>
<td>Substitution to other beverages (in terms of the reduction in the effect on kcals)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soda to other SSBs</td>
<td>All ages</td>
<td>20 %</td>
<td>40 %</td>
<td>5 %</td>
</tr>
<tr>
<td>SSBs to other beverages</td>
<td>All ages</td>
<td>20 %</td>
<td>60 %</td>
<td>0 %</td>
</tr>
<tr>
<td>Compensation (other foods)</td>
<td>Youth</td>
<td>0.0 %</td>
<td>25 %</td>
<td>-25 %</td>
</tr>
<tr>
<td>In-school policies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effect size (by individual study—see Table 1)</td>
<td>0</td>
<td>25 %</td>
<td>-25 %</td>
<td></td>
</tr>
<tr>
<td>Substitute SSB consumption outside of school</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Substitution (same as for tax policy)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soda to other SSBs</td>
<td>All ages</td>
<td>20 %</td>
<td>40 %</td>
<td>5 %</td>
</tr>
<tr>
<td>SSBs to other beverages</td>
<td>All ages</td>
<td>20 %</td>
<td>60 %</td>
<td>0 %</td>
</tr>
<tr>
<td>Compensation (other foods)</td>
<td>Youth</td>
<td>0.0 %</td>
<td>25 %</td>
<td>-25 %</td>
</tr>
</tbody>
</table>

\(^a\) 95 % confidence interval
<table>
<thead>
<tr>
<th>Study location (year)</th>
<th>Setting year grades</th>
<th>Major findings</th>
<th>Reduced kcal consumption/day</th>
<th>With compensation outside of school (lower bound)</th>
<th>With compensation outside of school (upper bound)</th>
<th>With compensation of non-SSB drinks (best estimate)</th>
<th>With compensation of non-SSB drinks (upper bound)</th>
<th>With compensation of non-SSB drinks (lower bound)</th>
<th>With compensation of non-liquids (best estimate)</th>
<th>With compensation of non-liquids (upper bound)</th>
<th>With compensation of non-liquids (lower bound)</th>
</tr>
</thead>
<tbody>
<tr>
<td>School nutrition policies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cullen and Zakeri (2004)</td>
<td>TX 1988–1989 ES &amp; early MS</td>
<td>SSBs increased 2.1–3.4 oz in first year, decreased from 4.9 to 4.3 oz in second year</td>
<td>7.1</td>
<td>5.3</td>
<td>8.8</td>
<td>5.6</td>
<td>3.2</td>
<td>8.8</td>
<td>5.6</td>
<td>2.4</td>
<td>11.0</td>
</tr>
<tr>
<td>Cullen et al. (2006)</td>
<td>TX 2001–2003 MS</td>
<td>Mean SSB intake declined from 5.4 oz to 3.5 oz and sweetened soft drink consumption declined from 5.2 oz to 2.6 oz</td>
<td>6.1</td>
<td>4.6</td>
<td>7.6</td>
<td>4.9</td>
<td>2.7</td>
<td>7.6</td>
<td>4.9</td>
<td>2.1</td>
<td>9.5</td>
</tr>
<tr>
<td>Cullen et al. (2008)</td>
<td>TX 2001–2003 MS</td>
<td>Year 1–3 from 5.4 to 3.5 to 1.5 ozs for all SSBs</td>
<td>9.3</td>
<td>7.0</td>
<td>11.6</td>
<td>7.4</td>
<td>4.2</td>
<td>11.6</td>
<td>7.4</td>
<td>3.1</td>
<td>14.5</td>
</tr>
<tr>
<td>Hartstein et al. (2008)</td>
<td>TX, CA, &amp; NC 2003 MS</td>
<td>SSBs reductions across the 6 schools of −1 oz. If the 2 schools with increases are excluded = 0.5 oz</td>
<td>1.6, 3.2 (eliminating outliers)</td>
<td>1.2, 2.4 (eliminating outliers)</td>
<td>2, 4 (eliminating outliers)</td>
<td>1.28, 6 (eliminating outliers)</td>
<td>0.72, 1.4 (eliminating outliers)</td>
<td>2, 4 (eliminating outliers)</td>
<td>1.28, 2.6 (eliminating outliers)</td>
<td>0.54, 1.1 (eliminating outliers)</td>
<td>2.5, 5 (eliminating outliers)</td>
</tr>
<tr>
<td>Johnson et al. (2009)</td>
<td>WA 2007–2008 MS</td>
<td>Net effect of 25% reduction in SSB consumption</td>
<td>3.6</td>
<td>2.7</td>
<td>4.5</td>
<td>2.9</td>
<td>1.6</td>
<td>4.5</td>
<td>2.9</td>
<td>1.2</td>
<td>5.6</td>
</tr>
<tr>
<td>Shi (2010)</td>
<td>CA 2005 MS &amp; HS</td>
<td>.181 fewer drinks in schools, and 0.16 fewer drinks using a Kernel-based propensity score</td>
<td>6.2</td>
<td>4.6</td>
<td>7.7</td>
<td>4.9</td>
<td>2.8</td>
<td>7.7</td>
<td>4.9</td>
<td>2.1</td>
<td>9.6</td>
</tr>
<tr>
<td>Woodwad-Lopez et al. (2010)</td>
<td>CA 2005–2008 ES, MS &amp; HS</td>
<td>Soda consumption at school fell by 7% &amp; sport drinks fell by about 5% (NS) with non-significant increases at home</td>
<td>1.8</td>
<td>1.3</td>
<td>2.2</td>
<td>1.4</td>
<td>0.8</td>
<td>2.2</td>
<td>1.4</td>
<td>0.6</td>
<td>2.8</td>
</tr>
<tr>
<td>Craddock et al. (2011)</td>
<td>Boston, MA 2004–2005 HS</td>
<td>Soda consumption fell 0.16 and other SSBs by −0.14 servings/day Yielding −0.30 servings/day</td>
<td>11.5</td>
<td>8.7</td>
<td>14.4</td>
<td>9.2</td>
<td>5.2</td>
<td>14.4</td>
<td>9.2</td>
<td>3.9</td>
<td>18.0</td>
</tr>
<tr>
<td>Briefel et al. (2009)</td>
<td>US 2004–2005 HS</td>
<td>Attending a school without snack bars −22 kcal</td>
<td>10.8</td>
<td>8.1</td>
<td>13.6</td>
<td>8.7</td>
<td>4.9</td>
<td>13.6</td>
<td>8.7</td>
<td>3.7</td>
<td>17.0</td>
</tr>
<tr>
<td></td>
<td>MS</td>
<td>Lack of pouring rights −16 kcal</td>
<td>7.9</td>
<td>5.9</td>
<td>9.9</td>
<td>6.3</td>
<td>3.6</td>
<td>9.9</td>
<td>6.3</td>
<td>2.7</td>
<td>12.3</td>
</tr>
<tr>
<td></td>
<td>MS</td>
<td>High ala’ carte offerings −52 kcal</td>
<td>25.6</td>
<td>19.2</td>
<td>32.1</td>
<td>20.5</td>
<td>11.5</td>
<td>32.1</td>
<td>20.5</td>
<td>8.7</td>
<td>40.1</td>
</tr>
<tr>
<td></td>
<td>HS</td>
<td>Attending a school without snack bars −28 kcal</td>
<td>13.8</td>
<td>10.4</td>
<td>17.3</td>
<td>11.0</td>
<td>6.2</td>
<td>17.3</td>
<td>11.0</td>
<td>4.7</td>
<td>21.6</td>
</tr>
<tr>
<td></td>
<td>HS</td>
<td>Stricter rules against VMs −40 kcals</td>
<td>19.7</td>
<td>14.8</td>
<td>24.7</td>
<td>15.8</td>
<td>8.9</td>
<td>24.7</td>
<td>15.8</td>
<td>6.7</td>
<td>30.8</td>
</tr>
<tr>
<td></td>
<td>HS</td>
<td>Not offering french fries −41 kcal</td>
<td>20.2</td>
<td>15.2</td>
<td>25.3</td>
<td>16.2</td>
<td>9.1</td>
<td>25.3</td>
<td>16.2</td>
<td>6.8</td>
<td>31.6</td>
</tr>
<tr>
<td>Study location (year)</td>
<td>Setting year grades</td>
<td>Major findings</td>
<td>Reduced kcal consumption/day</td>
<td>With compensation outside of school (lower bound)</td>
<td>With compensation outside of school (upper bound)</td>
<td>With compensation of non-SSB drinks (best estimate)</td>
<td>With compensation of non-SSB drinks (lower bound)</td>
<td>With compensation of non-SSB drinks (upper bound)</td>
<td>With compensation of non-liquids (best estimate)</td>
<td>With compensation of non-liquids (lower bound)</td>
<td>With compensation of non-liquids (upper bound)</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------------</td>
<td>----------------</td>
<td>-------------------------------</td>
<td>-------------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>------------------------------------------------</td>
<td>------------------------------------------------</td>
<td>------------------------------------------------</td>
<td>------------------------------------------------</td>
<td>------------------------------------------------</td>
</tr>
<tr>
<td>MS, composite</td>
<td></td>
<td></td>
<td>23.7</td>
<td>17.8</td>
<td>29.6</td>
<td>18.9</td>
<td>10.7</td>
<td>18.9</td>
<td>8.0</td>
<td>37.0</td>
<td></td>
</tr>
<tr>
<td>HS, composite</td>
<td></td>
<td></td>
<td>27.6</td>
<td>20.7</td>
<td>34.5</td>
<td>22.1</td>
<td>12.4</td>
<td>34.5</td>
<td>22.1</td>
<td>9.3</td>
<td>43.2</td>
</tr>
<tr>
<td>HS, composite</td>
<td></td>
<td></td>
<td>38.0</td>
<td>28.5</td>
<td>47.5</td>
<td>30.4</td>
<td>17.1</td>
<td>47.5</td>
<td>30.4</td>
<td>12.8</td>
<td>59.3</td>
</tr>
<tr>
<td>School education policies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Briefel et al. (2009)</td>
<td>HS</td>
<td>School offering nutrition education in every grade-16 kcal, but ( p = 0.055 )</td>
<td>7.9</td>
<td>5.9</td>
<td>9.9</td>
<td>6.3</td>
<td>3.6</td>
<td>9.9</td>
<td>6.3</td>
<td>2.7</td>
<td>12.3</td>
</tr>
<tr>
<td>James et al. (2004)</td>
<td>England 2001–2002 ES</td>
<td>Carbonated SSBs, change for controls = 0.0 (95 % CI = -0.3-0.4) and for intervention group = -0.3 (95 % CI = -0.6-0.1). The difference was 0.3 (95 % CI = -0.4-0.5).</td>
<td>1.0</td>
<td>0.7</td>
<td>1.2</td>
<td>0.8</td>
<td>0.4</td>
<td>1.2</td>
<td>0.8</td>
<td>0.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Sichieri et al. (2009)</td>
<td>Brazil 2005 Ages 9–12</td>
<td>A decrease in the daily consumption of carbonated SSBs in the intervention compared to control group (mean difference = -56 ml; 95 % CI = -119, -7 ml) a 20 % reduction.</td>
<td>18.1</td>
<td>13.6</td>
<td>22.7</td>
<td>14.5</td>
<td>8.2</td>
<td>22.7</td>
<td>14.5</td>
<td>6.1</td>
<td>28.4</td>
</tr>
</tbody>
</table>

Table 2 continued...
Effects of an SSB Tax

Table 3 reports results for the effect of a tax increase using best estimates of elasticities. We first consider the effects of the same percentage tax applied to all SSBs. A tax increase of $0.01 ($0.005, $0.02) per ounce is predicted to increase price by 20 % (10 %, 40 %) with 100 % tax shifting. This price increase in turn is predicted to reduce SSB consumption by 18 % (9 %, 36 %), with lower bounds of 6 % (3 %, 12 %) and upper bounds of 30 % (15 %, 60 %). In terms of SSB kcal/day, the $0.01 tax per ounce is predicted to ultimately reduce SSB consumption by 40.3 (13.4–67.2) kcal/day. The effects are greater for those ages 12–19 years, a 54.2 kcal/day reduction, but less for those ages 6–11 years, a 33.1 kcal/day reduction. Under the assumption of constant elasticity, the effects increase directly with the size of the tax; kcal/day reductions are half as much with a $0.005 tax/oz. and twice as much with a $0.02 tax/oz. compared to a $0.01 tax/oz.

The effects also depend on tax shifting, where we assumed 100 % shifting of the tax to price. The effects are reduced by 20 % (to 32.3 kcal/day) with 80 % tax shifting, or increased by 30 % (to 52.4 kcal/day) with 130 % tax shifting. With substitution into other beverages and incorporating the consumption of non-liquid food, the kcal/day reduction falls from 40 to 32.3, with the bounds from 4.0 to 84.0 kcal/day.

If the tax were limited to carbonated soda rather than all SSBs, the tax would directly affect only the consumption of carbonated SSBs. With the consumption of carbonated beverages at 123 kcal/day and the same elasticity, the consumption of carbonated beverages is reduced to 22.2 (7.4–37.0) kcal/day. Much larger effects are observed for those ages 12–19 years, with initial consumption of 200 kcal/day, yielding a 36 kcal/day reduction. With a 20 % reduction from substituting toward non-carbonated SSBs, substitution to other non-SSB drinks and incorporating the consumption of non-liquid foods, the estimate declines to 14.2 kcal/day with the bounds expanded by 25 % to 4.0 kcal/day and 84 kcal/day.

We also calculated the effect of higher prices imposed in all secondary school purchases. With average consumption of 37.5 kcal/day of SSBs bought and consumed in middle and high schools, a 3.4 (1.1–5.6) kcal/day reduction in SSB consumption is estimated with a 10 % price increase, a 4.1 (2.3–11.3) kcal/day reduction is estimated with a 20 % price increase, and a 8.3 (4.5–22.5) kcal/day reduction is estimated with a 40 % price increase. Allowing for substitution to non-SSB beverages and solid foods, a 20 % price increase yields a 3.3 (0.7–14.1) kcal/day reduction.

Table 4 summarizes other studies simulating the effect of an SSB tax. These studies, except Smith et al. (2010), do not specifically consider youth. In addition, none of the studies consider substitution to non-liquid foods. The estimates in Table 4 for a 0.01 tax/oz. on all SSBs range from 6.5 to 56 kcal/day. While we have assumed the same price elasticities for youth as adults in our analyses, the results in Table 4 reflect similar ranges to our analysis. The tax impacts, however, vary according to study methodologies and subjects investigated (e.g., entire population vs. subgroups who may be more price sensitive, individuals with lower vs. higher incomes, etc.).

Discussion

Our models predict that that policies directed at SSBs could lead to substantial reductions in calories consumed. A tax of $0.01 per ounce on all SSBs is predicted to reduce consumption by 32 kcal/day. However, we estimate a variation of 4–84 kcal/day around that estimate, due to uncertainty about the effects of SSB prices on SSB consumption and their effect on the consumption of non-SSB beverages and foods. Estimates from school access and education policies generally indicate smaller effects than our estimates of tax policies, again with considerable variation around the effect for each policy and also for the estimated effects of different policies.

Our estimates are subject to important limitations. More recent data is needed on SSB consumption. Parameters estimates will also be improved as more evaluation studies are conducted. Detailed information is needed on diet at home as well as in school. For policies in school, it is important to understand how out-of-school consumption is related to in-school consumption and how policy-related changes in SSB consumption affect the consumption of non-SSBs, especially LNED foods. The mathematical representation of the effects merits further consideration. We have used absolute changes or percentage changes in consumption based on the way that authors reported their results, but the effect on consumption may depend on the initial level of consumption (i.e., dependent on relative effect sizes). In examining the effect of tax increases on SSB consumption, the reaction of consumers purchasing at different locations (e.g., restaurants versus school, where prices and elasticities may differ) merits further study.

The analysis above assumed the same elasticities for youth as for adults, because adults purchase much of the SSBs consumed by youth. However, based on the results for other types of food, especially for low income consumers (Auld and Powell 2009; Epstein et al. 2006; Powell et al. 2007; Sturm and Datar 2005, 2008), elasticities may be much higher for SSBs consumed at school and purchased by teens outside of school. In that case, the effects on SSB consumption will substantially increase, especially for in-school consumption.
Table 3  Simulation of the effects of a $0.005, $0.01 and $0.02 per oz. tax increase on caloric intake

<table>
<thead>
<tr>
<th>Effect of a tax on all SSBs on SSB consumption*</th>
<th>0.005 Tax/ounce</th>
<th>0.01 Tax/ounce</th>
<th>0.02 Tax/ounce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price increase assuming 100% tax shifting</td>
<td>10%</td>
<td>20%</td>
<td>40%</td>
</tr>
<tr>
<td>Percent reduction in SSB consumption (best estimate)</td>
<td>9.0% (3.0%, 15.0%)</td>
<td>18.0% (6.0%, 30.0%)</td>
<td>36.0% (12.0%, 60.0%)</td>
</tr>
<tr>
<td>Change in SSB kcal/day for those ages 2–19 (best estimate)</td>
<td>20.1 (6.7, 33.6)</td>
<td>40.3 (13.4, 67.2)</td>
<td>80.6 (26.9, 134.4)</td>
</tr>
<tr>
<td>Change in SSB kcal/day for those ages 6–11 (best estimate)</td>
<td>16.6 (5.5, 27.6)</td>
<td>33.1 (11.0, 55.2)</td>
<td>66.2 (22.1, 110.4)</td>
</tr>
<tr>
<td>Change in SSB kcal/day for those ages 12–19 (best estimate)</td>
<td>27.1 (9.0, 45.15)</td>
<td>54.2 (18.1, 90.3)</td>
<td>108.4 (36.1, 180.6)</td>
</tr>
</tbody>
</table>

Tax shifting of 80% and 130% 

| Change in price with 80% tax shifting | 8% | 16% | 32% |
| Change in SSB kcals with 80% tax shifting (best estimate) | 16.1 (5.4, 26.9) | 32.2 (10.8, 53.8) | 64.5 (21.5, 107.5) |
| Change in price with 130% tax shifting (best estimate) | 13% | 26% | 52% |
| Change in SSB kcals with 130% tax shifting (best estimate) | 26.2 (8.7, 43.9) | 52.4 (17.5, 87.4) | 104.8 (34.9, 174.7) |

Effect on overall caloric intake of ages 2–19 with 100% tax shifting 

| Best estimate with substitution to other non-SSB beverages, ages 2–19 | 16.1 (5.4, 67.2) | 32.3 (10.8, 134.4) | 64.5 (21.5, 107.5) |
| Best estimate with substitution to liquid and non-liquid consumption | 16.1 (2.0, 42.0) | 32.3 (4.0, 84.0) | 64.5 (8.1, 168.0) |

The effect of a tax on carbonated SSBs on carbonated SSB consumption w/100% tax shifting 

| Price increase assuming 100% tax shifting | 10% | 20% | 40% |
| Percent reduction in carbonated SSB consumption (best estimate) | 9.0% (3.0%, 15.0%) | 18.0% (6.0%, 30.0%) | 36.0% (12.0%, 60.0%) |
| Change in carbonated SSB kcal/day for those ages 2–19 (best estimate) | 11.1 (3.7, 18.5) | 22.2 (7.4, 37.0) | 44.4 (14.8, 73.9) |
| Best estimate with substitution to other SSB beverages, ages 2–19 | 7.1 (1.3, 16.7) | 14.2 (2.7, 33.4) | 28.4 (5.3, 66.7) |
| Best estimate with substitution to other non-SSB foods, ages 2–19 | 7.1 (1.0, 20.8) | 14.2 (2.0, 41.7) | 28.4 (4.0, 83.4) |

Effect on overall caloric intake of high school students of a price increase only in schools 

| Change in carbonated SSB kcal/day for those ages 12–19 (best estimate) | 3.4 (1.1, 5.6) | 4.1 (2.3, 11.3) | 8.3 (4.5, 22.5) |
| Overall variation with substitution to home, liquid and non-liquid consumption | 2.7 (0.3, 7.0) | 3.3 (0.7, 14.1) | 6.6 (1.4, 28.1) |

* 95% confidence intervals shown in parentheses

Table 4  Summary of projected effects from other simulations of the effects of a tax on SSBs

<table>
<thead>
<tr>
<th>Study</th>
<th>Price increase</th>
<th>Assumptions</th>
<th>Population</th>
<th>Kcal reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andreyeva et al. (2010, 2011)</td>
<td>20%</td>
<td>Tax on all SSBs, w/out substitution</td>
<td>All</td>
<td>50</td>
</tr>
<tr>
<td>Finkelstein et al. (2010)</td>
<td>20%</td>
<td>Tax on carbonated SSBs, w/substitution</td>
<td>All</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>Tax on all SSBs, w/substitution</td>
<td>All</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>Tax on carbonated SSBs, w/substitution</td>
<td>All</td>
<td>7.8</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>Tax on all SSBs, w/substitution</td>
<td>All</td>
<td>12.4</td>
</tr>
<tr>
<td>Smith et al. 2010</td>
<td>20%</td>
<td>Tax on all SSBs, w/substitution</td>
<td>Adults</td>
<td>34.2</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>Tax on all SSBs, w/substitution</td>
<td>Adults, low income</td>
<td>36.8</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>Tax on all SSBs, w/substitution</td>
<td>Adults, high income</td>
<td>33.3</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>Tax on all SSBs, w/substitution</td>
<td>Children</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>Tax on all SSBs, w/substitution</td>
<td>Children, low income</td>
<td>33.1</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>Tax on all SSBs, w/substitution</td>
<td>Children, high income</td>
<td>44.7</td>
</tr>
<tr>
<td>Sturm et al. (2008, 2010)</td>
<td>20% tax</td>
<td>Tax on all SSBs, w/out substitution</td>
<td>3rd to 5th graders</td>
<td>15.2</td>
</tr>
<tr>
<td>Duffey et al. 2010</td>
<td>20%</td>
<td>Tax on all SSBs, w/out substitution</td>
<td></td>
<td>56</td>
</tr>
<tr>
<td>Dharmasena and Capps (2009, 2011)</td>
<td>20%</td>
<td>Tax on all SSBs, w/out substitution</td>
<td></td>
<td>19.6, 31.2</td>
</tr>
</tbody>
</table>
In the above analyses, we used average consumption data, and conservatively assumed that the impacts were distributed over the entire population. The effects, however, would be centered on those who already consume beverages. Of individuals ages 12–19 years, Wang et al. (2008) found that males consumed more than females (357 kcal/day vs. 242 kcal/day), and found little difference in intake between those overweight or obese and those normal weight (e.g., for 12–19 year olds, 297 kcal/day for those less than the 85th percentile, 304 kcal/day by those between the 85 and 95th percentile, 320 kcal/day by those above the 95th percentile). Nevertheless, those overweight may still be disproportionately affected through greater reductions in consumption. In addition, those at low income might be expected to be most affected by tax policies, since they are most likely to be sensitive to price. For example, Sturm et al. (2010) found limited effects of taxes on soda consumption by young school children, but greater effects were observed in schools, and for those who are lower income, African American and higher BMI.

The effect of school policies at a national level will be less if other nutrition policies are already in place. Briefel et al. (2009) and the 2006 SHPPS data (O’Toole et al. 2006). Results from Ebbeling et al. (2006) imply a comparable reduction in BMI of 0.26 kg/m² for every SSB serving (12 oz.) per day displaced by adolescents, and Chen et al. (2009) found about twice that effect for adults. However, Fletcher et al. (2010a, b) found no effect of SSB taxes on BMI. Powell et al. (2009) also found no effect of state-level soda taxes on adolescent BMI, but found a weak, though insignificant effect of vending machine soda tax rates on BMI of teens at risk for overweight. Assuming a linear relationship, Sturm et al. (2010) found that an 18 percent differential soda tax would correspond to 0.23 fewer BMI units, or a 1 % reduction in average BMI. At 12 months, James et al. (2007) found that the percent of overweight youth showed a net increase of 7.3 % relative to the control group, but the difference disappeared within 2 years after the program ended, and Sichieri et al. (2009) found that overweight girls showed a reduction in BMI.

A widely-used metric is that each 3500 calorie reduction is associated with a one pound weight loss. This relationship was formalized (Hall 2008) to predict an approximate 10 kcal/day reduction in food energy results in one pound of weight loss at steady state, but the reduction must be maintained. Larger reductions, as much as three times as great, would be needed for older youth and as much as six times as great for youth at higher weight levels (Butte et al. 2007; Jordan and Hall 2008). As indicated above, there is not yet a well-accepted model for youth to enable us to make those predictions. Initial weight and food consumption patterns as well changing patterns over time will need to be considered. Relatively modest behavioral modifications are required to prevent weight gain at younger ages, but larger reductions may be required for older youth and for those at higher weights (Wang et al. 2006).

Generally, simulation models that examine patterns in consumption and BMI over time as individuals’ age will be needed to fully understand the effects of the different obesity policies over time. Information will be needed on current and past levels of BMI and about how policies might be anticipated to affect future BMI. Policy effects may be strengthened over time as attitudes change, or unanticipated reactions by the individual or industry may counteract the effects of a policy. The effect of BMI on disease outcomes is also complex. In addition to their effect on BMI, SSB consumption may have a direct effect on diabetes, heart disease and cancers (Jones et al. 2006; Lightwood et al. 2009; Milstein et al. 2007; Van Meijgaard et al. 2009). Finally, in making policy choices, the costs associated with each policy, as well as the feasibility, sustainability and equity should be considered (Gortmaker et al. 2011; Swinburn 2008).

The bottom line message of this paper is that the type of policy analysis needed to tackle the obesity problem involves dealing with complexity, and admitting the uncertainty involved in any analysis. Does this mean that we should throw up our hands and await further study or just move on to other problems? In our opinion, the answer is no. The analysis above suggests that, while there is a wide range of possible outcomes, there is considerable scope for improving the current consumption habits. We expect that a multiplicity of policies will be needed, targeting different populations, such as in tobacco control policy (Levy et al. 2004). As we attempt various policies, outcomes must be evaluated at the various levels in the chain from the initial policy impact on behavior to population-level changes in BMI. Simulation modeling provides a framework for systematically piecing together that information in order to summarize the best information and provide direction on
the information still needed to better understand the problem and its solution.

Acknowledgments This study was funded by the Academy for Educational Development, Project #4245-01 and the Robert Wood Johnson Foundation Healthy Eating Research Program, Contract #63048.

References


Jordan, P. N., & Hall, K. D. (2008). Dynamic coordination of
Jones, A. P., Homer, J. B., Murphy, D. L., Essien, J. D., Milstein, B.,
Institute of Medicine (2010). Bridging the evidence gap in obesity
Hartstein, J., Cullen, K. W., Reynolds, K. D., Harrell, J., Resnicow,
Hall, K. D., Sacks, G., Chandramohan, D., Chow, C. C., Wang, Y. C.,
Hall, K. D. (2008). What is the required energy deficit per unit weight
demographics and beverage consumption with dental caries.
Food and Chemical Toxicology, 42(11), 1805–1816.
Nutrition, 133(3), 8415–8435.
Gortmaker, S. L., Swinburn, B. A., Levy, D., Carter, R., Mabry, P. L.,
10.1016/S0140-6736(11)60681-5.
Hall, K. D. (2008). What is the required energy deficit per unit weight
Hall, K. D., Sacks, G., Chandramohan, D., Chow, C. C., Wang, Y. C.,
Gortmaker, S. L., et al. (2011). Quantification of the effect of
Hartstein, J., Cullen, K. W., Reynolds, K. D., Harrell, J., Resnicow,
K., & Kennel, P. (2008). Impact of portion-size control for school a la carte items: Changes in kilocalories and macronu-
trients purchased by middle school students. Journal of Amer-
ican Diet Association, 108(1), 140–144.
Determinants and patterns of soft drink consumption in young adults: A qualitative analysis. Public Health Nutrition, 12(10),
1816–1822.
public health: Background and opportunities. American Journal of
Institute of Medicine (2010). Bridging the evidence gap in obesity
prevention: A framework to inform decision making.
drinks: Cluster randomized controlled trial. BMJ, 328(7450),
1237–1239.
obesity: Two year follow-up results from the Christchurch obesity prevention programme in schools (CHOPPS). BMJ, 335(7623),
762–765.
Johnson, D. B., Bruemmer, B., Lund, A. E., Evans, C. C., & Mar, C.
M. (2009). Impact of school district sugar-sweetened beverage
policies on student beverage exposure and consumption in middle schools. The Journal of Adolescent Health, 45(3 Suppl),
S30–S37.
Jones, A. P., Homer, J. B., Murphy, D. L., Essien, J. D., Milstein, B.,
 dynamics through simulation modeling and experimentation. 
Jordan, P. N., & Hall, K. D. (2008). Dynamic coordination of
macronutrient balance during infant growth: Insights from a mathematical model. American Journal of Clinical Nutrition,
87(3), 692–703.
education: Results from the school health policies and programs study 2006. The Journal of School Health, 77(8), 408–434.
and tobacco control: Creating more robust public health policies. 
as a strategy to reduce cigarette use and deaths: Results of a simulation model. Preventive Medicine, 31(3), 279–286.
literature on policies directed at the youth consumption of sugar
tobacco control policies on smoking rates: A tobacco control
scorecard. Journal of Public Health Management & Practice, 
10, 338–351.
Levy, D. T., Mabry, P. L., Wang, Y. C., Gortmaker, S., Huang, T. T.,
Marsh, T., et al. (2011b). Simulation models of obesity: A
review of the literature and implications for research and policy. 
Lightwood, J., Bibbins-Domingo, K., Coxson, P., Wang, Y. C.,
Williams, L., & Goldman, L. (2009). Forecasting the future
economic burden of current adolescent overweight: An estimate
of the coronary heart disease policy model. American Journal of
Lo, E., Coles, R., Hambert, M. L., Polowski, J., Henry, C. J., &
Whiting, S. J. (2008). Beverage intake improvement by high
school students in Saskatchewan, Canada. Nutrition Research,
28(3), 144–150.
between consumption of sugar-sweetened drinks and childhood
obesity: A prospective, observational analysis. Lancet, 357(9255),
505–508.
(2010). Sugar-sweetened beverages, obesity, type 2 diabetes mellitus, and cardiovascular disease risk. Circulation, 121(11),
1356–1364.
sweetened beverages and weight gain: A systematic review. 
[Review]. American Journal of Clinical Nutrition, 84(2), 
274–288.
Mattes, R. D. (1996). Dietary compensation by humans for supple-
mental energy provided as ethanol or carbohydrate in fluids. 
Milstein, B., Jones, A., Homer, J. B., Murphy, D., Essien, J., &
prevalence in the United States: A role for system dynamics
simulation modeling. Preventing Chronic Disease, 4(3), A52.
Nutrition services and foods and beverages available at school:
Results from the school health policies and programs study 2006. 
gap in normal-weight children: Longitudinal data of the KOPS. 
Obesity (Silver Spring), 16(4), 777–783.
Powell, L. M., Auld, M. C., Chaloupka, F. J., O’Malley, P. M., &
Johnston, L. D. (2007). Access to fast food and food prices: Relationship with fruit and vegetable consumption and


