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Reducing Sugar-Sweetened Beverage Consumption: Evidence, Policies, and Economics

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Abstract Sugar-sweetened beverages (SSBs) are the largest source of added sugar in the US diet and have contributed to the obesity and diabetes epidemics. This review article describes the health consequences of overconsumption of SSB over the past decades, and its potential implications on economic costs and population health. Policy-based strategies to discourage SSB consumption are discussed, with particular emphasis on their economic rationales. Though there is evidence of the need to curb SSB consumption at the population level, several important evidence gaps remain regarding potential unintended consequences, and the comparative and cost effectiveness of policy interventions.

Keywords Obesity · Diet · Sugar · Health care costs/expenditures · Beverage consumption

Introduction

Sugar-sweetened beverages (SSBs), including sodas, sports drinks, energy drinks, fruit drinks and punches, sweetened teas, and other sweetened beverages, are the largest source of added sugar and calories in the US population, especially among youth [1–3]. Rather than consumed as an occasional treat, SSBs have become an essential part of the American diet. In 1999–2004, 84 % of adolescents and 63 % of adults consumed SSBs on any given day [1, 4]. Compared to just a decade earlier, the per capita consumption increased by 46 kcal/day in adults and 20 kcal/day in children—largely due to increases in the amount consumed, rather than an increase in the proportion of the population consuming them [1, 4]. Despite recent declines in added sugar consumption, mean SSB intakes still considerably exceed recommended intakes [5, 6]—an average American consumed 45 gallons of SSBs in 2009, averaging 15.8-oz servings per day [7••], with nearly 7 teaspoons of sugar per serving.

Studies have found that diets high in SSBs are associated with long-term excess weight gain and nutritional inadequacy [8–11, 12••]. Calories derived from energy-dense, nutrient-poor beverages are usually not accompanied by a reduction of energy intake elsewhere. On the contrary, SSBs often displace healthier options, such as milk, which has substantially declined in consumption alongside the rise in SSBs, especially in children [13]. Calories in liquid form are particularly poorly compensated [14, 15]—the majority of these "discretionary calories" has led to a net increase in caloric intake and, ultimately, weight gain.

In addition to displacing healthier beverages and increasing caloric intake, long-term follow-up studies have established that high SSB intake increases several health risks [16]. Unlike naturally-occurring sugars in foods (e.g., apples), the rapid spikes in glycemic load from habitual consumption of large amounts of SSBs results in insulin resistance, hypertension, atherogenic dyslipidemia, and visceral adiposity, possibly through a pro-inflammatory mechanism [17]. As a result, these disruptions at the cellular level lead to increased risk of development of chronic conditions, including overweight/obesity, metabolic syndrome, type 2 diabetes, hypercholesterolemia, cardiovascular disease, cancer, dental disease, and osteoporosis [16, 18••, 19, 20].

Overweight and Obesity One of the clearest links is between increased SSB consumption and risk of obesity [12••, 16, 21–23]. Following 120,877 US men and women, Mozaffarian et al. found that each additional SSB serving per day was associated with 1 lb of weight gain over 4 years [12••]. In adults with a genetic predisposition to weight gain (based on a score composed of 32 genetic sequences known to be associated with BMI), SSB consumption has been shown to nearly double the

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risk of obesity [24]. In an intervention trial of 118 overweight women, Stookey et al. found that replacing SSBs with plain water led to significant decreases in total energy intake of 200 kcal/day over a year [25]. Similar results have been replicated in prospective cohort and experimental studies, though some studies did not find statistically significant correlations [16].

Correlations between high SSB intake and overweight/obesity have been observed in children and adolescents as well. In a randomized control trial in which non-caloric beverages were delivered to homes, adolescents in the intervention arm decreased overall SSB consumption by 82 % (P=.002); for those in the upper tertile of baseline-BMI (BMI≥25.7), the intervention group had significantly better weight outcomes (BMI: –0.63±0.23 kg/m^2 vs control +0.12±0.26 kg/m^2; net effect of –0.75±0.34 kg/m^2 (P=.03)) [26]. In a Dutch trial, children given sugar-free, artificially-sweetened beverages in place of regular sugary beverages gained less weight (6.35± 3.07 kg) than children in the control arm who continued to consume sugary beverages (7.37±3.35 kg, P<.001) over 18-months [27••]. Whether reducing or avoiding sweetened beverages early in life can produce changes in lifetime taste preferences is an area of active research [27••, 28].

Type 2 Diabetes According to the longest longitudinal cohort data to date, women who consumed ≥1 SSBs per day were 1.83 (95 % CI: 1.42, 2.35) times more likely to develop type 2 diabetes, compared to those who drank <1 per month [22]. The association may not be surprising to many as high body mass index is strongly associated with incidence of type 2 diabetes. Nevertheless, this study also showed that only about half of the increased diabetes risk was explained by the participants' higher BMI levels (the relative risk of consuming ≥1 SSBs per day attenuated from 1.83 to 1.39 after controlling for BMI). Similar findings have been reported elsewhere [18••]. The effect of additional diabetes risk from high SSB intake independent of weight gain is likely explained by the large quantity of easily-digestible sugar in liquid form and its impact on glycemic load and insulin production [29, 30].

Hypertension and Heart Disease Even after controlling for body weight, reducing SSB consumption is shown to reduce systolic blood pressure [31••], possibly through a pathway involving serum uric acid levels and the activation of renin angiotensin system [32]. Others postulate that the SSB-hypertension link is mediated through habitual caffeine intake through both diet and regular soda [33]. SSB intake also appears to increase long-term risks of coronary heart disease (CHD) beyond what is expected from elevated blood pressure, diabetes, and body weight. For example, among SSB drinkers in the Nurses' Health Study who consumed ≥2 servings per day, there was an 18 % increase in CHD incidence compared to those who drank <1 serving per month [34].

Other Health Consequences Excess SSB consumption has also been shown to reduce bone mineral stores and lead to osteoporosis [35], though the mechanisms are not well understood. One hypothesis is that SSBs displace milk consumption [13], though soft drinks are correlated with decreased bone mass density even after adjusting for milk and calcium intake [36]. It is also unclear whether caffeine in SSBs plays a role in the absorption and regulation of calcium storage in the bone [37]. Some studies note the possible contribution of SSB consumption in the doubling incidence of hyperuricemia and gout since the 1970s [38]. Frequent soft drink consumption can also lead to dental erosion in children [39].

Sugar Types There is emerging evidence that the body may metabolize various types of sugar differently. In the United States, SSBs are typically sweetened using high-fructose corn syrup, and the higher proportion of fructose (55 % compared to table sugar made up of 50 % fructose, 50 % glucose) makes it poorly absorbed by the gastrointestinal tract. Preferentially cleared by the liver, fructose increases the amount of lipids in the bloodstream and reduces the secretion of insulin (unlike glucose that stimulates its release) that is necessary to remove sugars from the bloodstream and convert them to energy for use by the body [40–42]. This may exacerbate the risk of diabetes and high cholesterol [40, 42, 43].

Economic Arguments for Curbing Population-Level SSB Consumption

Decades of nutrition research have clearly established that poor diets undermine population health—and nutritionally-sound diets are as essential as preventive medicine [44]. Given their ubiquitous presence in the American diet and the established and emerging links between excess SSB intake and health, curbing added sugars—particularly in the form of SSBs—has been a recommended strategy to improve diet quality and health outcomes [6, 19, 45]. For example, the American Academy of Pediatrics recommends that SSBs and naturally-sweet beverages (e.g. fruit juice) be limited to 4–6 oz/day for ages 1–6, and 8–12 oz/day for ages 7–18 [46]. Meanwhile, despite challenges in data quality and the need for long-term empirical studies with sufficient follow-up, researchers have started to quantify the potential healthcare and economic costs due to the elevated diseases attributable to excess SSB intake, and subsequently, the potential savings in costs if SSB intake were reduced.

Quantifying Healthcare Costs Attributable to Excess Intake of SSB

To date, most studies attempting to quantify the cost burden of excess SSB consumption on society relied on indirect

(usually model-based) approaches. These approaches typically make inferences based on the increased health risks of SSB intake, notably obesity and type 2 diabetes, two major drivers of US healthcare costs [47–49]. For instance, Finkelstein et al. found that an obese adult spent an average of $1,429 more per year in medical costs than a normal weight adult [48]. Using an instrumental variable approach, Cawley et al. estimated that obesity costs the US healthcare system $224.3 billion (adjusted for inflation, 2012 dollars), or 29.6 % of US health expenditures [50••], and an additional $5.23 billion forgone in work productivity, predominantly from absenteeism among professional and managerial ranks [51]. Broken down by insurance type, each obese adult patient (compared to non-obese) with private insurance spends $3674 more on medical care; those on Medicaid spend $2568 more, and those uninsured spend $3153 more [50••]. These additional costs are borne by third parties, including private insurance enrollees in the form of higher premiums, or taxpayer money that funds Medicaid and Medicare. These same cost differentials are also apparent in youth—the cumulative excess attributable total costs of obesity, diabetes, and CHD in overweight adolescents are estimated at $208 billion from lost productivity due to death or morbidity, and $46 billion in direct medical costs [52]. While Medicaid pays a large burden of obesity-attributable hospitalizations, private payers shoulder a greater proportion of the costs of obesity treatments [49].

Type 2 diabetes has been estimated to cost the US $174 billion in 2007—$116 billion in medical costs and $58.2 billion due to reduced productivity, worker absenteeism, and unemployment from disability or premature mortality [53]. In 2007, approximately 12 %, or 24.3 million hospital admissions were attributable to type 2 diabetes [54]—and for the most part preventable. Using a validated model that includes diabetes, obesity, heart disease, and stroke, Wang et al. estimated that over 10 years, $82 billion in medical costs was attributable to excess SSB consumption nationwide (defined as consuming >1 SSB per week) [55••].

In addition to its likely contribution to the cost burden of obesity and type 2 diabetes, SSBs may increase healthcare spending through other conditions, such as osteoarthritis, dental decay, and gout. The magnitude of these pathways, however, has not been well studied. Many researchers also cite the less tangible societal costs of obesity. For instance, obese children are more likely to be bullied [56], have lower academic performance [57], and are less likely to pursue higher education [58]. While weight status is clearly correlated in these studies, causal inferences are difficult to establish. Obesity has also become a concern for military recruitment and veteran healthcare costs [59, 60], maintaining a globally competitive workforce [61], and capital investments in localities with healthier workers [62].

Policies to Curb Consumption of SSBs

Given the evidence on the negative effects of SSBs on children's diets and health, public schools have been an active arena for policy action. In 1983, the US Department of Agriculture (USDA) attempted to change the diets of schoolchildren by barring the sale of competitive foods on school premises until after lunch, but the National Soft Drink Association successfully sued the USDA on the grounds that the Secretary of Agriculture exceeded his authority in regulating competitive foods [63]. Since then, there has been a proliferation of school soda sales by as much as 1100 % from 1985 to 1997 [64].

Following several congressional reports on the effect of marketing to children in schools, in 2001 the USDA issued a summary report on how competitive foods may have undermined the nutritional integrity of the School Lunch Program [65]. In the past, schools were somewhat reluctant to limit competitive foods, as "pouring rights" contracts from the industry could bring in as much as $1.5 million per year for a school district [66]. But with more stringent policies surrounding school foods gaining support over the past decade, a number of states have passed legislation to eliminate the sale of sodas in schools [67, 68]. Such bills have been shown to reduce SSB consumption in school, and even overall daily intake—Boston Public School students affect by SSB restrictions did not increase their out-of-school SSB intake to compensate for in-school restrictions [67, 69]. On February 8, 2013, the USDA proposed new school beverage guidelines that would set calorie limits on sport drinks (40–50 kcal per 8 oz), and remove all regular sodas from schools, as well as no- or low-calorie beverages from elementary and middle schools [70]. While legislation has been successful in limiting SSBs, there have also been changes not driven by regulations: for example, the Alliance for a Healthier Generation partnered with the American Beverage Association (ABA) to voluntarily reduce shipments of full-calorie soft drinks to schools [71].

Although providing healthier beverages in schools has been a key driver for change, one analysis found that only 1–5 % of SSBs consumed on a typical weekday were from vending machines and school cafeterias [4]. Children (as well as adults) consume the majority of their SSBs in the home [1, 4]. Because reducing SSBs has been established as a key strategy to counter the obesity-diabetes dual epidemic [72•], municipalities and states are increasingly considering legislation to curb consumption using supply-side strategies. The public has also shown support through willingness to pay higher taxes to address the consequences of SSB intake through anti-obesity policies [73]. Among the policy instruments to curb SSB consumption more broadly, taxes are the most debated of all.

True Costs of SSBs: The Case for Taxing SSBs

Based on recent studies, the average price of carbonated beverages is 4.5 cents per ounce, or $0.90 per 20-oz bottle [7••, 74]. While the prices of fruits and vegetables have gone up over the past decades, the inflation-adjusted price of "liquid candies" has gone down [75••]. Considering its negative health impact, the low purchase price of SSBs likely does not reflect its full costs from a societal standpoint. Drawing parallels from the history of tobacco and alcohol 'sin taxes', a seminal article by Manning et al. asked the question, "Do smokers and drinkers pay their way?" Accounting for not only medical costs but also costs associated with sick leave, insurance premiums, pensions, fires, and motor-vehicle accidents, they found that smokers appeared to have "paid their way" via higher taxes on cigarettes and shorter life expectancy; on the other hand, heavy drinkers imposed roughly half their societal costs (externalities) onto non-drinkers [76]. It is important to note that the Manning framework argued for taxing tobacco and alcohol because the associated externalities, including second-hand smoking and drunk driving, are much better documented and understood. In comparison, quantifying the full externalities from excess SSB intake is still in its infancy. More research will be necessary before one can make the same economic judgment about what the 'just' level of taxes on SSBs is that fully internalizes the externalities. Whether such a level of taxation is politically feasible or sufficient to change consumption behaviors is an entirely different policy question.

The rationales presently cited for imposing a tax on SSBs are manifold. Sales taxes on soft drinks have been used as a revenue-generating vehicle for states since the 1990s. As of 2011, 34 states and DC had a sales tax on SSBs. Many argue that the existing taxes are too insignificant to affect consumption [77, 78]. As a proportion of price, a sales tax applied at checkout when consumers have already decided to buy the item is ineffective in discouraging purchases, and in fact may encourage a shift toward larger container sizes that are cheaper on the per-ounce basis. Since 2009, 24 states and six cities have attempted to pass legislation to impose special taxes on SSBs, usually at a rate of penny-per-ounce (20–30 % increase in price) [77], aiming to not only raise revenue but to discourage consumption. Based on the published price elasticity estimate of –1.21 [75••], a 10 % SSB tax increase could lead to a 12.1 % decrease in SSB consumption [72•]. Industry reports are consistent with these estimates—a Coca-Cola price increase of 12 % would result in a 14.6 % drop in sales [79].

These tax proposals spurred fierce outcries from the beverage industry, who argued that SSBs are unfairly targeted as the sole culprit of obesity [80] and that SSB consumption had already declined in recent years [5]. In 2009, as Congress discussed a federal tax on SSBs to help finance the Patient Protection and Affordable Care Act, the soft drink industry spent $40.7 million in lobbying, a dramatic increase from $2.8 million in 2006 [80], that in part led to the proposal being dropped. In Washington state, a temporary excise tax of 2 cents for every 12-oz soda was passed in 2010, but was repealed after the ABA spent approximately $16.5 million to defeat it [81]. Most recently in California, the ABA similarly spent an estimated $3.8 million defeating the SSB tax referendums proposed in El Monte and Richmond. Because there are no states or cities to date that have succeeded in levying substantial excise tax on SSBs, no empirical studies exist to directly measure the effect of a new tax on population-level purchases and its net impact on caloric intake and body weight.

Nevertheless, a number of studies used simulation models to predict that a tax at the level of penny-per-ounce could result in a net reduction in calories consumed [82••], body weight [83], and downstream prevalence of diabetes and cardiovascular diseases [55••]. Based on the Nielsen Homescan data that tracks household food and beverage purchases, Finkelstein et al. estimated that a 20 % tax on SSBs would lead to a mean reduction of 4.2 kcal/day per person [82••]. Along the same lines, using a dynamic model that accounts for the non-linear calorie-to-weight relationship, Lin et al. estimate that a 20 % tax would reduce consumption by 34–47 kcal among adults (and result in 1.84 kg lower mean body weight over 10 years) and 40–51 kcal in children [83]. Using a validated simulation model of CHD and stroke, Wang et al. estimated that a nationwide penny-per-ounce tax would reduce consumption by 15 %, averting 95,000 coronary heart events, 8000 strokes, and 26,000 premature deaths over a decade—amounting to healthcare cost savings of $17.1 billion over 10 years [55••]. Although the estimated healthcare cost savings from reducing downstream diseases could be substantial, even greater gains could be realized by the potential societal gains if the estimated $13 billion in tax revenues generated by such a tax went to prevention, healthcare, or nutrition education programs [77].

Uncertainties and Potential Unintended Consequences

Many researchers agree that the evidence base linking excess SSB intake and weight gain is strong [16], and that reducing SSB consumption is a key weight management and weight gain prevention strategy. However, regardless of political ideology, several researchers have voiced skepticism about whether a tax on SSBs would produce the desired reduction in obesity. This is mainly because, unlike tobacco, one can substitute other calorie-laden beverages in place of SSBs, rendering no net benefit on energy balance. Using a cross-price elasticity approach, several studies estimated that an

increase in SSB price would lead to a small increase in the purchases of milk and juice [84, 85]. Finkelstein et al. estimated that a 20 % tax on SSBs would reduce mean caloric intake by 10 kcal/day, of which 3 kcal (30 %) would be compensated by increases in other beverages [82••]. In contrast, combining cross-sectional NHANES data with state-level soda tax rates, Fletcher et al. suggested that a tax-induced reduction in SSB calories may be fully compensated by increased whole milk and juice intake in children [86]. However, the effect of compensation and the type of beverages substituted depend on a range of factors, particularly age. As young children consume more milk and juice (and fewer diet beverages), they may be more likely to substitute SSBs with these beverages [4], though the potential offsetting effect from milk and juice may decline with age [87]. Nevertheless, others suggested that increases in foods or beverages not examined in these studies, such as beer [88], could conceivably result in unintended consequences of a tax on SSBs.

Cap on Portion Size In addition to taxation, state and local legislatures have explored a number of other options to reduce population-level SSB consumption. In September 2012, New York City passed a sugary drinks size cap of 16 oz for beverages sold in food service establishments that are under the jurisdiction of the Department of Health and Mental Hygiene [89]. In a study examining receipts from NYC fast food patrons, Elbel et al. estimated that consumers affected by the law could be expected to reduce intake by 75 kcal/day [90]. Though recently struck down by the State Supreme Court of Manhattan as placing "arbitrary and capricious" limits on sugary drinks, the law is grounded in the behavioral psychology of 'defaults': individuals consume more when offered a larger portion size irrespective of appetite or taste [91]. Given that the increases in SSB consumption over the past two decades are largely driven by portion size [1, 4], this regulation holds promise in nudging consumers to choose a smaller SSB portion size, resulting in lower calories consumed. The City has appealed the ruling.

Restrictions on SNAP-Eligible Items Another highly-debated policy proposal to reduce SSB consumption is through the restructuring of the federal Supplemental Nutritional Assistance Program's (SNAP) eligible items. In fiscal year 2012, SNAP served over 46 million people in an average month [92]. While the program has been successful in reducing food insecurity among low-income Americans, some critics believe that SNAP may encourage unhealthy eating habits or even increase the risk of obesity [93], in part because the allowable foods for purchase are not restricted as with the Women, Infants, and Children program. In 2004, Minnesota was the first state to apply for a waiver to prohibit the purchase of candy and soft drinks with SNAP benefits, followed by a New York City proposal in 2010 that sought to prohibit the purchase of SSBs. In both cases, the USDA rejected the waiver requests, citing the lack of clear nutritional standards and substantial administrative burdens [94]. South Carolina is the latest state to consider a similar proposal [95].

Low-income adults and children have greater odds of being heavy consumers of SSBs [96]. Among only low-income adults (≤130 % federal poverty level), SNAP participants consume more SSBs than nonparticipants [97], and it is estimated that the SNAP program spends between $1.7–$4 billion on SSBs each year [98, 99]. Proponents of excluding SSBs from the SNAP program highlight the need for more transparency and accountability for how taxpayer-financed SNAP funds are spent within a program designed to promote nutrition. Some also argue that the elevated risks of metabolic syndrome, diabetes, and cardiovascular diseases among SNAP participants could be mitigated by an allowable foods list that is better aligned with the Dietary Guidelines for Americans [97]. Opponents note, however, that the evidence is insufficient to support that the proposed restriction would result in substantial consumption changes. Moreover, it may further stigmatize SNAP recipients. Yet others argue that a subsidy for healthier items (e.g., fruit and vegetables) is a better alternative. Nonetheless, it is clear that both the public health and anti-hunger community would benefit from better data to illuminate the consumption patterns of SNAP-receiving households and determinants of purchasing decisions.

Conclusions

There is clear evidence that SSBs contribute to excess calorie intake, weight gain, and other chronic health conditions, and reducing SSB intake at both individual and population levels could produce favorable health outcomes. However, significant knowledge gaps remain in determining the most effective policy or economic vehicle. The arguments for or against certain policies rely on cross-sectional studies; the lack of repeated measures, natural experiments, or small-scale pilot studies, as well as the paucity of evidence focused on racial-ethnic or socioeconomic sub-populations are challenges for policymakers.

Nevertheless, it is clear that a combination of programs and policies, as well as meticulous evaluation and data tracking, are necessary to understand the impacts (including unintended consequences) of specific policies and the key mechanisms for success. There is evidence that we are moving in the right direction with childhood obesity rates dropping for the first time in decades, especially in localities that have actively implemented policies to promote healthy eating and active living [100–105]. While the focus of this

review is to examine these issues from a regulatory and policy perspective, industry initiatives such as the Healthy Weight Commitment and the food and beverage industry's voluntary agreements for healthier school meals may also improve health. As with tobacco prevention policies, decreases in smoking rates were achieved chiefly through clean air policies, tobacco excise taxes, and restrictions in tobacco marketing, even if it took decades to realize the benefits from these upfront societal investments. The policy-driven efforts to date have sparked much debate about the role of government, society, and individuals in tackling public health issues. As the evidence continues to accumulate, policymakers have an unprecedented opportunity to improve dietary consumption and the health and well-being of the population.

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Compliance with Ethics Guidelines

Conflict of Interest Amber Hsiao declares that she has no conflict of interest.

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- • Of importance
- •• Of major importance

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