The Associations Between Sugar-Sweetened Beverage Consumption and Children's Health: An Updated Review of the Literature

Healthy Eating Research
Building evidence to prevent childhood obesity

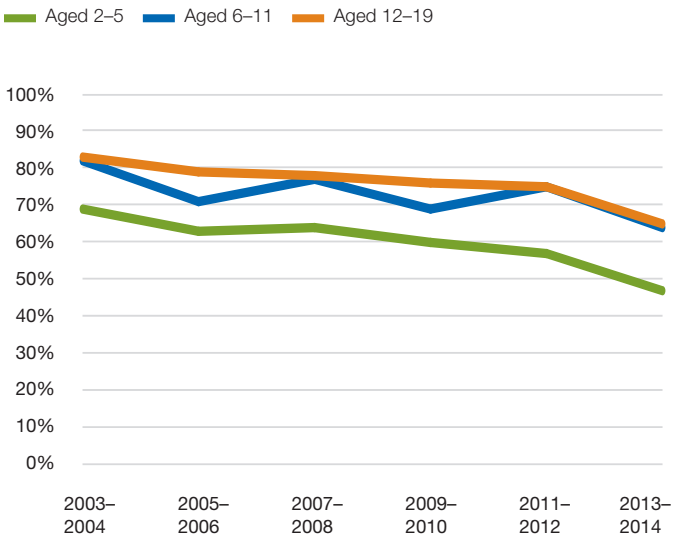
Research Review, February 2018

Introduction

Childhood obesity* affects roughly one in six (13 million) children in the United States, disproportionately impacting children who are low-income and racial and ethnic minorities.[1] From 1976 to 2016, the prevalence of childhood obesity has more than doubled in children aged 2 to 5 (from 5 percent to 13.9 percent), nearly tripled in children aged 6 to 11 (from 6.5 percent to 18.4 percent) and quadrupled in adolescents aged 12 to 19 (from 5 percent to 20.6 percent).[2-4] Since 2003, obesity rates appear to be declining among children aged 2 to 5, stable among children aged 6 to 11, and increasing among children aged 12 to 19.[3] Overall, obesity prevalence (18.5 percent) is higher than the Healthy People 2020[5] goal of 14.5 percent. Given that obese children and youth are likely to remain so as adults,[6] obesity and its adverse health consequences create a serious threat to children's current and future health.[7]

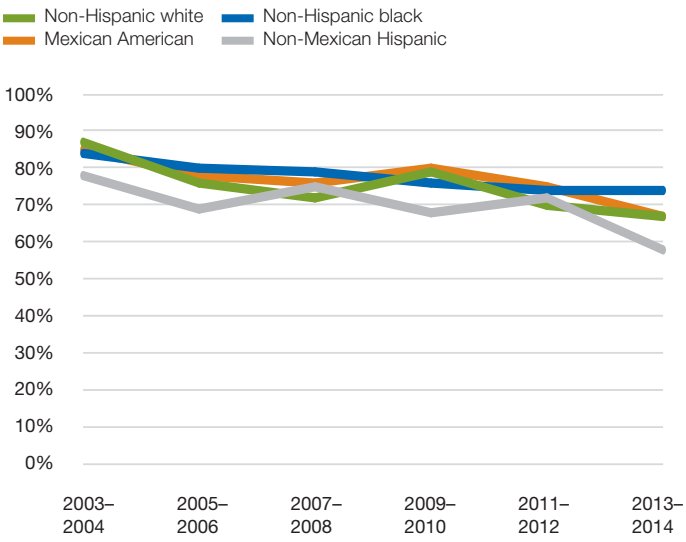
Consumption of sugar sweetened beverages (SSBs) is strongly linked to obesity and a number of other negative health consequences.[8] In parallel with recent obesity trends, consumption of SSBs (drinks with added sugar such as soda, fruit drinks, and sports drinks) has begun to decline.[9] From 2003 to 2014 in the National Health and Nutrition Examination Survey (NHANES), the percentage of children consuming at least one SSB on a typical day declined significantly† from 80 percent to 61 percent (See Figure 1).[10] Much of the decline over this period was driven by a decrease in the percentage of young children aged 2 to 5 consuming SSBs, although the decline was significant across all age groups.

Figure 1. Percentage of children/adolescents aged 2 to 19 who consumed at least one SSB on a given day, by age group and year



Source: National Health and Nutrition Examination Survey, 2003-2014, based on Bleich et al., 2017[10]

Figure 2. Percentage of children/adolescents aged 2 to 19 who consumed SSBs on a given day, by race/ethnic group and year



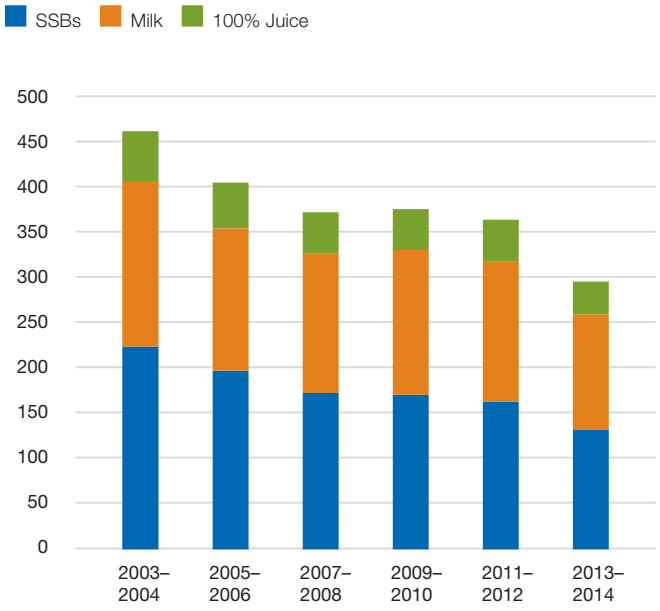
Source: National Health and Nutrition Examination Survey, 2003-2014, based on Bleich et al., 2017[10]

* Defined as a body mass index of greater than or equal to the age- and sex-specific 95th percentile of the 2000 CDC growth charts.

† Defined as $p<0.01$ to account for multiple comparisons.

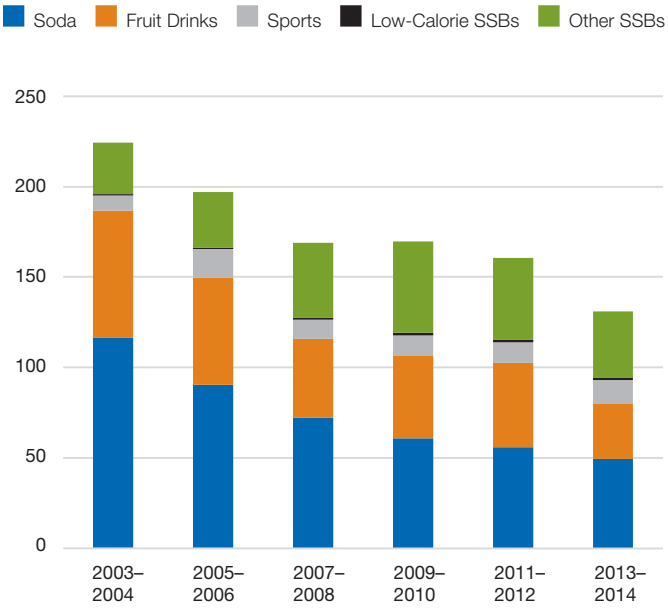
Robert Wood Johnson Foundation

Figure 3: Trends in beverage consumption of children/ adolescents aged 2 to 19: Daily caloric intake by beverage type and year



Source: National Health and Nutrition Examination Survey, 2003-2014, author calculations.

Figure 4. Trends in SSB consumption of children/ adolescents aged 2 to 19: Daily caloric intake by SSB type and year†



Source: National Health and Nutrition Examination Survey, 2003-2014, author calculations.

From 2003 to 2014, there was a decrease in the prevalence of SSB consumption for each race/ethnic group, with the prevalence of SSB consumption declining from 78 percent to 58 percent for non-Hispanic white children, from 84 percent to 74 percent for non-Hispanic black children, from 85 percent to 67 percent for Mexican-American children, and from 86 percent to 67 percent for non-Mexican Hispanic children (See Figure 2).*

These decreases were significant for all age groups of non-Hispanic white children, among non-Hispanic black 12- to 19-year-olds and among Mexican-American 2- to 5-year-olds and 12- to 19-year-olds.[10] With respect to income, the percentage of children consuming SSBs declined significantly from 81 percent to 64 percent among low-income children and from 79 percent to 59 percent among higher-income children.* Despite the important declines in SSB consumption across race/ethnic minorities and low-income children, these groups are still experiencing a higher prevalence of consumption compared to non-Hispanic white and higher-income children, reflecting the need for targeted policies and interventions.

Over the same period (2003-2014), consumption from caloric beverages (SSBs, milk, and 100 percent juice) declined significantly from 463 to 296 daily calories per day (Figure 3). Significant decreases in milk and SSB calories were seen for each age group, while per capita 100 percent juice consumption declined significantly only among 2- to 5-year-olds and 12- to 19-year-olds.[10]

Consumption of all SSBs (soda, fruit drinks, sport drinks, low-caloric SSBs, and other SSBs) declined significantly from 224 to 131 calories from 2003 to 2014. The number of calories from soda and fruit drinks declined from 116 kcal to 49 kcal and 70 kcal to 31 kcal, respectively (Figure 4). At the same time, calorie intake from sports drinks increased from 8 kcal to 13 kcal, but that increase was smaller than the decrease from soda and fruit drinks. Despite significant declines in per capita soda and fruit drink consumption over the past 15 years, calories from SSBs still represent a significant portion of total dietary intake for children and adolescents. As a result, there is still a necessity for continued research and implementation of strategies to reduce consumption of SSBs.

The relationship between SSB consumption and obesity is complicated by corresponding trends in total calorie consumption and energy expenditure. In particular, because total calorie consumption has also declined significantly in recent years,* the relative intake of SSBs in the diet of children and adolescents may not have shifted as meaningfully as consumption trends suggest. From 2003 to 2014, total daily calorie consumption among children and adolescents declined significantly from 2127 to 1879 calories per day,* although these estimates of dietary data are limited by day-to-day

* Author calculations.

† Coding definitions for beverage categories (NHANES 2003-2010): Low-caloric SSB refers to any beverage described as "low-calorie," including items such as fruit juices, teas, and some fruit drinks. "Other SSB" refers to any beverage that does not fit into the previous four categories, including items such as sweetened tea, rice drinks, bean beverages, sugar cane beverages, horchata, non-alcoholic wines/malt beverages, etc.

variation, biases in recall and reporting, and errors associated with nutrient databases and coding.[11,12] Additionally, in the past decade, physical activity among children has remained low, with fewer than half of U.S. children meeting the current recommended standard of at least 60 minutes of moderate- or vigorous-intensity physical activity each day.[13,14] However, current surveillance systems of physical activity have significant weaknesses, including a reliance on self-reported data, failure to assess all relevant types of physical activity (e.g., commuting to school), and lack of standardized definitions of physical activity.[15,16] The limitations of physical activity and dietary data make it challenging to fully capture the energy balance equation associated with excess weight gain.

This research synthesis updates a prior review[17] on this topic and examines the evidence regarding the various health impacts of sugary beverages on children's health (obesity, insulin resistance, dental caries, and caffeine-related effects), the health impact of substituting SSBs with other drinks, and the role of taste preferences in SSB consumption patterns. For each health impact, we present the literature by the type of study design. A summary of key strengths and weaknesses of the study designs included in this review can be found in Appendix A.

Methodology

For each of the health impacts (obesity, insulin resistance, dental caries, and caffeine-related effects), separate searches were conducted of PubMed, Web of Science and PAIS International. For all searches, a search hedge was created in three parts: 1) terms relevant to SSBs, including "beverage" and "sodas," 2) terms restricting to children and adolescents including "teens" and "pediatric," and 3) terms specific to the outcome being examined such as "body mass index" and "body weight" for the search on overweight and obesity risk (see Appendix B for full list of search terms). These search terms were chosen to retrieve the most relevant results using an iterative process in consultation with a medical librarian. For searches of PubMed, MeSH subject headings were used. In addition to database searches, reference lists of SSB literature reviews and articles were searched. Following the removal of duplicate studies, one author (K.V.) screened titles, abstracts, and full-texts, and another author (S.B.) confirmed the inclusion of these studies. Included studies had to be peer-reviewed articles examining the effects of SSBs on a specific health outcome, be limited to children and adolescents, and be published after January 1, 2007. Studies were excluded if they were not published in English, were conducted in non-Organisation for Economic Co-operation and Development (OECD) countries, were not presenting new data, or were grey literature (i.e., non-academic or unpublished sources). This narrative review is meant to reflect the current state of evidence for SSBs and children's health and is not intended to be an exhaustive review of all available studies.

Key Research Results

- **Overweight and Obesity Risk:** The review found a strong, positive relationship between SSB consumption and overweight and obesity risk in children, meaning that increased consumption of SSBs was associated with higher risk of overweight or obesity. This was true for cross-sectional studies, which provide a snapshot of a single moment in time (15 of 19 found a positive association in all or some part of the study population);[18-32] longitudinal studies, which track the same children over time (13 of 19 found a positive association in all or some part of the study population);[33-45] and intervention studies, which randomly assign children to a "treatment" or "control" group and examine relative changes in SSB consumption before and after the intervention (three of three found a positive association for at least one follow-up point).[46-48]

- **Insulin Resistance:** All seven studies found a positive association between SSB consumption and insulin resistance, measured using the homeostasis model assessment of insulin resistance (HOMA-IR). All six cross-sectional studies found a positive association in the whole or a subset of their study population.[19,49-53] One longitudinal study was conducted to examine this association, and it also reported a positive association between SSB consumption and insulin resistance.[54] No intervention studies have been conducted to assess the association between SSB consumption and Type 2 diabetes among children and adolescents.

- **Dental Caries:** Twenty-three studies have examined the relationship between SSB consumption and dental caries (cavities or tooth decay) among children and adolescents, with all but one study reporting a positive association in at least some part of the study population. Fifteen of the 16 cross-sectional studies[55-69] and six of the six longitudinal studies found a positive association between SSB consumption and dental caries.[70-75] One intervention study also found a positive association.[76]

- **Caffeine-Related Effects:** Eight cross-sectional studies examined the caffeine-related effects of SSBs, with seven focusing on energy drinks,[77-83] and three analyzing the effects of other caffeinated SSBs such as colas.[82-84] In general, the literature pointed to an association between energy drinks and a wide range of health issues, including poor quality or reduced sleep,[79,81,82] headaches,[78,79,82] risk-seeking behavior,[77,78] and depressive symptoms.[77,81] One longitudinal study was conducted and found that energy drink consumption was associated with attention deficit/hyperactivity disorder, inattention, and hyperactivity.[80]

- **Substitution:** A growing body of research broadly examined the health effects associated with substituting SSBs for artificially sweetened beverages, plain water, and milk among children and adolescents. The literature on substitution was quite heterogeneous, with considerable variation in study design, the beverage being substituted, and the outcomes being examined. Most often, research assessed the effect of artificially sweetened beverage substitution on total caloric intake and weight-related outcomes, such as Body Mass Index (BMI) and body composition. While the results are limited by a small number of studies, two cross-sectional studies found an association between substitution of SSBs and lower caloric intake,[85,86] and two longitudinal studies found an association between substitution of SSBs and lower BMI, [87,88] although the results varied by which beverage was being used for substitution. Four intervention studies have examined the effects of replacing SSBs on weight-related outcomes, [46,47,89,90] with the studies finding a mixture of positive and null results depending on outcome being examined and follow-up time.

- **Taste Preferences:** Early childhood (ages 0-5) is a critical period for the development of food preferences that will carry over into adulthood and have serious implications for health over the life course.[91-93] No research has been conducted to assess the effect of SSB consumption during early childhood on taste preferences, with the literature instead examining sugar and sweetness more generally.[94-96] The majority of research indicated that preference for sweetness is an inborn trait, while some evidence suggested that repeated exposure to sweet foods or drinks may result in an infant preferring that level of sweetness in the future.

Studies Supporting Key Research Results

Overweight and Obesity Risk

The exact mechanism through which SSBs impact childhood obesity is not entirely understood. Generally, the research points to the low satiety of SSBs and incomplete compensation.[97,98] In other words, drinking calories in liquid form does not decrease hunger in the same way as solid food, and people do not sufficiently reduce their total energy intake to make up for the excess calories from SSBs. There is also a lively debate about whether the effect of calories from SSBs on body weight is worse than some other foods or nutrients.[99,100] Specifically, the notion that "a calorie is a calorie" has been challenged. While the American Heart Association, the American College of Cardiology, and the Obesity Society issued a joint statement urging people to focus on reducing overall calories for weight loss,[101] some research suggests that the type of calories consumed matters for losing weight (i.e., a diet with a low-glycemic index has been shown to burn more calories than a low-fat diet).[102]

Cross-sectional Studies

Most cross-sectional studies found significant positive associations between SSB intake and obesity risk among children and adolescents. Of the 19 cross-sectional studies included in this review,[18,20-32,103-107] 15 found positive associations.[18-32] For example, among 12- to 19-year-olds in the combined 1999-2004 NHANES, each additional SSB serving (250g) consumed per day was associated with a 0.93-percentile increase in BMI for age.[107] These positive findings were well-replicated across a range of OECD countries, including Canada, Spain, Greece, and in Australia, where those who consumed more than one SSB serving (≥250g) per day were 26 percent more likely to be overweight or obese compared to those who consumed less than one serving per day.[27] This was also consistent with results focused on specific sub-groups, such as among Mexican-American children aged 8 to 10, where each additional SSB serving (240mL) per week was associated with a 1.3 greater odds of obesity,[18] and among toddlers living in low-income families where no SSB intake was associated with a 31 percent lower obesity prevalence compared to households where toddlers consumed two or more SSB servings (355mL) per day.[24]

Some of these cross-sectional studies found positive associations only within subsets of the sample, including specific age, gender, or racial/ethnic groups. Of the 15 studies that found positive associations between SSB intake and obesity risk, 10 reported this finding for the whole study population[18,19,21,23-27,30,31] and five found positive associations only within a subset of the population: boys,[28,32] boys aged 6 to 11,[22] children aged 9 to 11,[29] and Mexican-American and non-Hispanic white adolescents.[20]

Three cross-sectional studies reported null findings,[103,104,106] and one study conducted in South Korea among 9- to 14-year-olds reported an inverse association among boys, although the association was not statistically significantly.[105] Possible reasons for these results include: different instruments used to assess SSB consumption, alternate measures of weight gain, and systematic underreporting of weight and SSB consumption among participants.

Longitudinal Studies

Like the cross-sectional analyses, longitudinal studies generally demonstrated that increased SSB consumption was associated with excess weight gain among children and adolescents. Of the 19 longitudinal studies included in this report,[33-45,108-113] 13 found positive association in at least part of the study population.[33-45] For example, in a nationally representative survey of parents of 2- to 5-year-olds in the United States, the authors found that children who consumed more than one SSB serving (8 ounces) per day at 2 years old had a significantly greater increase in BMI z-score over the next two years compared to infrequent/non SSB drinkers.[33] Two of the studies that identified positive relationships between SSBs and weight gain examined longitudinal associations between SSB consumption and obesity risk among minority populations,

with one finding that high SSB intake (defined as greater than median intake in study population) among Latino toddlers was significantly associated with a 0.46 higher weight-for-height z-score at six-month follow-up[40] and the other finding that SSB consumption was significantly associated with two-year risk of being overweight among African-American preschool children.[36]

Of the 13 longitudinal studies that found positive associations, three reported this only among females,[42-44] and one reported differing results depending on follow-up time.[45] For example, one study found high SSB intake (≥15 servings/week) at 13 months old was significantly associated with an increased BMI among girls at ages 2, 3, 4, and 6.[43] Another study found that girls who moved to the top tertile of SSB consumption (>335g/day) between 14 and 17 years of age had increased BMI and nearly a five-fold greater odds of overweight or obesity risk compared to girls who remained in the lowest tertile of SSB consumption.[42] One study found a positive association when using SSB consumption at 15 years to predict change in BMI from ages 15 to 21 and found null results when using SSB consumption at 9 years as a predictor.[45]

Six of the 19 longitudinal studies found no association between SSBs and BMI or BMI z-scores[108-114] and most of these six studies received neutral quality ratings for methodological quality in a recent systematic review.[115] None of the six studies reporting null results examined obesity or overweight risk and instead reported BMI or zBMI scores.

Intervention Studies

Several intervention studies have examined SSB consumption and overweight and obesity risk among children. Three recent randomized controlled trials found a reduction in BMI or obesity risk in the intervention group compared to the control.[46-48] De Ruyter and colleagues conducted a double-blinded placebo-controlled trial wherein 641 normal weight Dutch children were randomized to receive either 250mL of an SSB or a sugar-free beverage each day for 18 months.[46] The children in the study were recruited from urban elementary schools in the Netherlands and over half of participants had a parent with a college or university degree. At the end of the trial, the difference in BMI z-score was significantly different between the two groups, with the SSB group increasing on average by 0.15 units (compared to 0.02 units in the sugar-free group).

The second study randomized 224 overweight and obese American adolescents who regularly consumed SSBs to either participate in a program to reduce SSB consumption or receive no intervention.[47] The study population was relatively heterogeneous, capturing a number of different race/ethnic groups, household incomes, and parental education levels. At the end of the one-year intervention, those in the intervention group had beneficial changes in BMI and weight compared to those who did not receive the intervention, but these differences in BMI were no longer significant when participants were followed-up for an additional year after the end of the intervention. However, in a subgroup analysis of Hispanic participants, there were significant differences in BMI between groups at both follow-up periods.

The third study was a cluster randomized trial in which schools in the United Kingdom were randomized to either an intervention discouraging consumption of SSBs/health education classes or no intervention for one year.[48,116] Details on study population demographics (e.g., race/ethnicity, household income) were not reported. A significant difference in BMI z-scores and overweight/obesity prevalence between groups was observed at the end of the first year, supporting a positive association between SSBs and obesity risk.[116] Two years after the intervention had been discontinued, the researchers completed a follow-up assessment and reported the differences in BMI between the groups were no longer significant.[48]

Insulin Resistance

While strong and consistent evidence has shown a positive relationship between SSB consumption and Type 2 diabetes among adults,[8,117,118] the available literature among children and adolescents was limited. In addition, the majority of studies among children and adolescents did not directly examine the link between SSB consumption and Type 2 diabetes. Instead, studies primarily used measures of insulin resistance such as HOMA-IR, which is calculated using fasting glucose and fasting insulin levels. The studies among children and adolescents generally found a strong positive relationship between SSB consumption and HOMA-IR, although most were cross-sectional in design, which limited their utility in making causal inferences. Several studies examined other measures associated with insulin resistance and metabolic syndrome, such as blood pressure, body composition, and lipid profiles, generally finding evidence for an association between SSB consumption and these measures.

Cross-sectional Studies

All six cross-sectional studies found a positive association in the whole or a subset of their study population.[19,49-53] For example, among 12- to 19-year-olds in 1999-2004 NHANES, each additional SSB serving (250g) consumed per day was associated with a 5 percent increase in HOMA-IR, a 0.16mmHg increase in systolic blood pressure (SBP), a 0.47cm increase in waist circumference, and a 0.48mg/dL decrease in high density lipoprotein cholesterol (HDL-C) concentrations.[19] One study reported associations by race, with associations for increased HOMA-IR, triglyceride levels, and waist circumference found among non-Hispanic white and black participants, but null associations among Mexican Americans.[50] Another study

reported a stronger association between SSB consumption and higher HOMA-IR and SBP among overweight/obese participants compared to normal weight participants.[53]

Longitudinal Studies

Only one longitudinal study was conducted to examine this association, reporting that an additional 10g/day of added sugar from liquid sources was associated with a 0.04mmol/L higher fasting glucose, 2.3pmol/L higher fasting insulin, and 0.1 unit increase in HOMA-IR over two-year follow-up.[54]

Dental Caries

A number of studies examined the relationship between SSB consumption and dental caries (cavities or tooth decay) among children and adolescents, with almost all evidence pointing toward a strong positive association. The mechanism for the association is well understood: dental caries are caused by acids produced by bacteria metabolizing sugar in the mouth. Increased sugar from SSBs intensifies the acid production and causes further decay of teeth.[119] While the majority of studies examining SSB intake and dental caries were cross-sectional, there have been several longitudinal studies and one intervention study that also supported the positive likely causal relationship.

Cross-sectional Studies

Of the 16 cross-sectional studies,[55-69,120] 15 found a positive association between SSB consumption and dental caries in at least part of the population.[55-69] For example, one study reported that the prevalence of caries was 22 percent higher for each additional SSB serving consumed by children per day.[67] Several studies replicated this positive association among low-income children,[57,60,69] with one study reporting that high SSB consumption (≥5 ounces/day) was associated with a 4.6 greater odds of dental caries compared to those with lower SSB consumption (<5 ounces/day).[57] Some studies examined how specific timing of SSB consumption affected dental caries, with Hoffmeister et al.[59] finding an association with dental caries and SSBs consumed at bedtime and Declerck et al.[56] finding an association with dental caries and SSBs consumed at nighttime among 3-year-olds and for SSBs consumed between meals among 5-year-olds.

One cross-sectional study reported null results, finding no association between SSB consumption and dental caries among Alaska Natives—a result that may have been related to the small sample size (N = 51).[120]

Longitudinal Studies

All six of the longitudinal studies included in this review found a positive association between SSB consumption and dental caries in at least part of the population.[70-75] One study reported that a high consumption of SSBs (≥3 servings per week) among infants 10 to 12 months old was associated with a 1.8 times greater odds of dental caries at age 6, compared with individuals who did not consume SSBs during infancy.[71] Three studies reported these positive associations among specific subgroups including: low-income,[73] African-American,[70] and American-Indian children.[72] For example, Lim et al. conducted a cluster analysis and reported that African-American children who changed from being low consumers of SSBs at baseline (mean consumption = 567mL/day) to high consumers of SSBs at two-year follow-up (mean consumption = 1032mL/day) had a 1.8 times higher mean number of new dental caries compared with low consumers of SSBs at both baseline and two-year follow-up.[70]

Intervention Studies

Only one intervention study has been conducted to assess SSB consumption and dental caries.[76] Maupomé et al. conducted an intervention to reduce SSB consumption, improve breastfeeding practices, and promote consumption of water for thirst among toddlers in three American-Indian communities. While the intervention communities demonstrated improvements in the number of dental caries, it was not possible to attribute this specifically to reduction in SSB consumption alone as the intervention was a multi-pronged approach.

Caffeine-related Effects

Seven of the eight studies examining the caffeine-related effects of SSBs focused on energy drinks, [77-83] while three analyzed the effects of other caffeinated SSBs such as colas.[82-84] One reason for this may be the considerably higher level of caffeine content in energy drinks: an 8-ounce energy drink has an average of 80mg of caffeine (range: 27-87mg), compared to 40g of caffeine (range: 30-60mg) in an 11-ounce cola drink.[121] While most energy drinks contain sugar, some versions are sugar-free and this distinction is not always made in studies. In general, the literature pointed to an association between energy drinks and a wide range of health issues including poor quality or reduced sleep, headaches, risk-seeking behavior, and depressive symptoms.

Cross-sectional Studies

Seven cross-sectional studies examined the effects of energy drink consumption among children and adolescents,[77-83] with each study often reporting on multiple outcomes and finding a mix of positive and null results. Three studies found evidence for an association between energy drink consumption and sleep-related issues such as sleep dissatisfaction, tiredness/fatigue, and late bedtime,[79,81,82] and three reported an association between energy drink intake and increased headaches.[78,79,82] Two studies reported an association between energy drink consumption and

risk-taking behaviors such as cigarette, marijuana, and drug use,[78] and two studies found an association between energy drink consumption and stress, depressive symptoms, and suicidal ideation, plan, or attempt.[77,81,83] Other outcomes reported include irritable mood,[79] stomachache, and low appetite.[82]

Three cross-sectional studies examined caffeine-related effects of cola drinks.[82-84] One found that both low and high consumption of cola were associated with lower stress, but found null associations with anxiety and depression.[83] Another examined both cola and energy drinks and found that higher consumption of both beverages was associated with headaches, stomachaches, sleeping problems, and low appetite.[82] More specifically, among males drinking more than one cola per day was associated with a 1.3 greater odds of headache compared to no cola consumption, and among females drinking more than one cola per day was associated with a 1.1 greater odds of headache compared to no cola consumption. The third study found that insufficient sleep duration (<10 hours/weekday) was associated with consuming soda more frequently among schoolchildren in Massachusetts.[84]

Longitudinal Studies

Marmorstein et al. found evidence that increased energy drink consumption was associated with attention deficit/hyperactivity disorder, inattention, and hyperactivity at 16-month follow-up, but did not find evidence for associations with depression, panic, and anxiety.[80]

Cardiovascular events and caffeine toxicity are an emerging concern associated with energy drink consumption. While this is outside the scope of this review, a recent review identified 15 cases of energy drink-related adverse cardiovascular events, of which seven occurred in those aged 19 or younger. In many cases, the negative effects of caffeine are exacerbated when combined with alcohol.[122]

Substitution

A substantial body of research broadly examined the health effects associated with substituting SSBs with artificially sweetened beverages, plain water, juice, and milk among children and adolescents. The literature on substitution was quite heterogeneous, with considerable variation in study design, the beverage being substituted, and the outcomes being examined. Most often, research assessed the effect of artificially sweetened beverage substitution on total caloric intake and weight-related outcomes such as BMI and body fatness. While the results were mixed, substitution of SSBs was generally associated with decreased consumption of calories and beneficial body weight outcomes. However, the optimal beverage for substitution of SSBs was unclear. In particular, the literature on artificially sweetened beverages and weight-related outcomes was controversial,[123-125] although discussion of this is beyond the scope of this review. An additional area of interest in substitution research was how increased consumption of SSBs was often associated with a decrease in consumption of healthier alternatives such as water and milk.

Cross-sectional Studies

Two cross-sectional studies were conducted to predict what effect substitution would have on total caloric intake.[85,86] Wang et al. analyzed two non-consecutive days of dietary data for each child in 2003-2004 NHANES and suggested that a hypothetical substitution of 1 percent of SSBs by weight with water would correspond to a 6.6 calorie lower caloric intake overall, with this decrease not negated by compensatory increases in other food or beverages.[86] The analysis suggested no benefit would be observed by hypothetically substituting SSBs for artificially sweetened beverages and a small increase in total caloric intake would be observed when substituting with whole milk or reduced-fat milk. Shamah-Levy et al. also considered the association between water, SSB consumption, and total energy intake, and found that the combination of high water and low SSB consumption was associated with a 230 calorie lower total caloric intake compared to the low water and high SSB consumption combination.[85]

With respect to how SSB consumption affects consumption of healthier beverages, two cross-sectional studies found that greater SSB consumption was associated with lower milk intake, with one of these studies additionally finding these same associations in a longitudinal study design.[33,126]

Longitudinal Studies

Two longitudinal studies examined the effects of substitution on weight-related outcomes.[87,88] Zheng et al. followed a cohort of Danish children for six years and predicted that hypothetical daily substitution of 100g of SSB with 100g of water would be inversely associated with BMI, as would the substitution of 100g of SSB for 100g of milk.[88] A second study based on a secondary analysis of an RCT replicated the result for milk but did not find the same association for water. The study additionally found that hypothetical substitution of 100g of SSB for 100g of artificially sweetened beverages would be associated with a lower BMI.[87]

Intervention Studies

A number of intervention trials have been conducted with children who are regular consumers of SSBs to analyze the effects of beverage substitution. Four intervention studies have examined weight-related outcomes associated with substitution.[46,47,89,90] Albala et al. examined the effects of replacing SSB consumption with 3 servings per day of milk among 98 overweight and obese children and reported no

difference in body fat between the two groups at 16-week follow-up, although beneficial effects were found for lean body mass and height in the intervention group.[89] As discussed in the obesity section, De Ruyter et al. conducted a double-blind randomized controlled trial of 641 normal weight children aged 4 to 11 to examine the effects of masked replacement of 250mL of a SSB with the same quantity artificially sweetened beverage and found that those randomized to artificially sweetened beverages had reduced weight gain and fat accumulation.[46] Muckelbaurer et al. implemented a year-long intervention study aimed to increase water consumption in various schools in Germany. While increasing water consumption by one glass per day was associated with reduced consumption of SSBs by 0.12 glasses per day, no changes in BMI were associated with water substitution.[90] Also discussed in the obesity section, Ebbeling et al. randomized adolescents who reported consuming at least one serving (12 ounces) of SSBs per day to an intervention group that aimed to displace SSBs with non-caloric beverages and reported significant differences in BMI compared to the control group at one-year follow-up, although this was no longer significant at two-year follow-up.[47]

Two intervention studies examined satiety and taste preference outcomes associated with substitution.[127,128] De Ruyter et al. randomized children aged 7 to 11 to either 250mL of an SSB or a similar volume of an artificially sweetened beverage and found no difference in satiety between the two groups, providing evidence that substitution with artificially sweetened beverages will not necessarily cause children to seek the missing calories from other sources.[127] Those assigned to the SSB group reported liking and wanting their beverage more than those in the artificially sweetened beverage group. Another study by de Ruyter et al. also randomized children to taste seven pairs of SSB and artificially sweetened beverages and found that only 24 percent of children were capable of differentiating between the two drink types, providing further evidence that substitution of artificially sweetened beverages may be readily accepted by children.[128]

While this review does not include multi-component health promotion approaches where the effects of SSB substitutions cannot be isolated, these studies can be found in the literature. For example, Singh et al. randomized Dutch secondary schools to receive a biology, physical education, and environmental change program for 20 months and reported that SSB consumption was significantly lower in the intervention group at follow-up.[129] Similarly, another RCT conducted in the Netherlands randomized schools to a web-based computer intervention aimed at increasing physical activity, decreasing sedentary behavior, and promoting healthy eating, again finding that SSB consumption was significantly lower in the intervention group at two-year follow-up.[130]

Taste Preferences

Early childhood (ages 0-5) is a critical period for the development of food preferences that will carry over into adulthood and have serious implications for health over the life course.[91-93] To the best of our knowledge, no published research has been conducted to assess the effect of SSB consumption during early childhood on taste preferences, with the literature instead examining sugar and sweetness more generally.[94-96] Most research indicates that preference for sweetness is an inborn trait, with some evidence suggesting that repeated exposure to sweet foods or drinks may result in an infant preferring that level of sweetness in the future.

Existing research consistently supports an inborn preference for sweetness.[94-96,131] For example, Desor et al. reported that 24- to 84-hour-old infants displayed effective discrimination and a strong preference towards sugar solutions compared with plain water.[132] Another study found that infants born preterm strongly preferred a sucrose-sweetened latex nipple compared with an unsweetened alternative.[133] Finally, Steiner et al. examined the facial expressions of infants tasting a sweet solution and observed that the infants' faces were often relaxed and expressed satisfaction.[134] Taken together, these studies provide evidence that the preference for sweetness is likely innate, although this preference appears to diminish as a child ages.[135-137] This preference is attributable to innate, evolutionary-driven mechanisms, wherein sweetness indicates the presence of caloric sugar necessary for survival and attracts infants to their mothers' milk.[93,95] Additional research has examined the pain-relieving properties of sugar as a possible driving factor for its preference during early childhood.[138-140]

Some evidence suggests that repeated exposure to sweet foods and drinks during early childhood also influences taste preference for sweetness.[94,131] In one of the earliest studies of sweetness, Beauchamp and Moran assessed preference for sucrose solutions among 140 infants and found that those who were routinely fed sweetened water preferred the sucrose solution more than those who were not fed sweetened water on a routine basis.[141] However, a second study by the same authors found that exposure to sweetened water failed to result in a heightened preference for sweetness in general (including fruit-flavored drinks), but rather was limited to a preference for the same sucrose solution.[142] Liem and Mennella analyzed how infant formula history (sweet vs. sour choice) affected preferences for sweet or sour apple juice.[143] The authors found no significant difference in preference for apple juice with added sugar between infant formula histories, although did find that children of mothers who reported adding sugars to food on a routine basis were more likely to prefer apple juices with added sugar. Sullivan and Birch examined how repeated exposure can make a food more familiar, appropriate, and acceptable, finding that children exposed to a sweet version of tofu ultimately preferred that version of tofu over plain and salty varieties during a post-exposure taste test.[144]

Conclusions

Overall, SSB consumption has declined in the last 15 years. However, for some children and adolescents, levels of SSB consumption remain unacceptably high, with many children still consuming more than the recommended amount set by the 2015–2020 Dietary Guidelines.[145] There is clear evidence that consumption of SSBs increases overweight and obesity risk and dental caries among children and adolescents, with emerging evidence linking SSB consumption and both insulin resistance and caffeine-related effects. More research is needed related to substitution and taste preferences. The vast majority of the available literature suggests that reducing SSB consumption would help improve children's health by decreasing the risk for obesity and other negative health consequences.

Policy Implications

For more than a decade, reducing SSB consumption has been the focus of many public health efforts. During this time, there has been progress in passing legislation, regulations, and ballot initiatives that have been used to enact SSB taxes (that have passed in eight jurisdictions to date),[146] remove SSBs from schools,[147-150] limit total added sugars in beverages in schools, and require restaurants to substitute water or milk as the default beverage on kids' menu items in restaurants. There have also been voluntary actions by some large organizations to create healthy beverage defaults (i.e., Disney theme parks removed SSBs as a default on their children's menu and instead offer low-fat milk), increase the availability of healthy beverages (e.g., in hospitals, health systems, universities, and recreation centers), and remove SSBs from children's meals (e.g., McDonald's and Wendy's).[151]

It is not possible to point to one area of policy progress in the public or private sectors as the key reason for the downward trend in SSB consumption among children. What is clear is that a continued focus on environmental changes to reduce SSB consumption, particularly those that alter the food and beverage environment in a permanent way (such as removing SSBs from schools) are generally considered to have a larger potential population effect, and more likely to be cost-effective and equitable when compared to approaches focused on individual behavior change (such as a onetime media campaign).[152,153]

Going forward, more research is needed to both catalog the passage of new policies (in the public and private sector) that aim to reduce SSB consumption as well as the impact of these policies on children's SSB consumption and associated health outcomes. In addition to evaluating the impact of individual policies on SSB consumption and health outcomes, it will be important to understand the relative and collective impact of various SSB policies on reducing SSB consumption and the risk for adverse health outcomes in order to effectively target resources and design future interventions.

There is also a need for new policies which aim to reduce SSB consumption in a few key areas where there has been limited policy progress to date. One is reducing children's exposure to marketing of SSBs,[154] especially marketing approaches targeted to black and Hispanic children. Another is legislation that requires restaurants to remove SSBs from children's combination meals or change the default beverage on the children's menu to milk or water. To date, only a handful of municipalities have passed such statutes.

Future Research Needs

While there is a large and growing body of research examining the impact of SSBs on children's health, important gaps remain. One important area for future research is to address gaps in the literature related to the mechanisms through which SSBs impact children's health. For example, although the link between SSB consumption and excess weight gain is clear, the exact mechanism through which SSBs impact childhood obesity is not entirely understood. Future research should also utilize more rigorous study designs to provide clarity about prior null or mixed results. More specifically, longitudinal study designs with sufficient follow-up and repeated measures are needed to effectively assess the effect of SSB consumption over the life course. Together with observational evidence, more intervention studies should also be conducted, with attention to methodological issues such as loss to follow-up, poor compliance, and lack of blinding. Additional research is needed examining a broader variety of caffeinated SSBs and their impact on children's health beyond energy drinks, the optimal beverage substitution for SSBs, and the effect of SSB consumption during early childhood on taste preferences or shifting norms.

For each of these gaps in the literature, information is needed regarding whether observed outcomes differ within populations at higher risk for obesity, particularly for promising interventions and policy approaches that reduce children's SSB consumption. Better insights in these areas have the potential to inform real-world policies and recommendations that may greatly benefit children's health.

Prepared by Sara N. Bleich, PhD, and Kelsey A. Vercammen, Harvard T.H. Chan School of Public Health.

Peer review was provided by Melissa N. Laska, PhD, RD, University of Minnesota School of Public Health; Y. Claire Wang, MD, ScD, Mailman School of Public Health, Columbia University; and Laurie Whitsel, PhD, FAHA, American Heart Association.

Suggested Citation

Bleich SN, Vercammen KA. *The Associations Between Sugar-Sweetened Beverage Consumption and Children's Health: An Updated Review of the Literature.* Durham, NC: Healthy Eating Research; 2018. Available at: *http://healthyeatingresearch.org*.

References

1. Wang Y. Disparities in pediatric obesity in the United States. *Advances in Nutrition: An International Review Journal.* 2011;2(1):23-31.
2. Ogden C, Carroll M. Prevalence of obesity among children and adolescents: United States, trends 1963-1965 through 2007-2008. Centers for Disease Control and Prevention. June 2010. 2013.
3. Ogden CL, Carroll MD, Lawman HG, et al. Trends in obesity prevalence among children and adolescents in the United States, 1988-1994 through 2013-2014. *Jama.* 2016;315(21):2292-2299.
4. Hales C, Carroll M, Fryar C, Ogden C. Prevalence of Obesity Among Adults and Youth: United States, 2015–2016. NCHS Data Brief. Number 288. *National Center for Health Statistics.* 2017.
5. Healthy People 2020. *https://www.healthypeople.gov/*.
6. Wang LY, Chyen D, Lee S, Lowry R. The association between body mass index in adolescence and obesity in adulthood. *Journal of Adolescent Health.* 2008;42(5):512-518.
7. Dietz WH. Health consequences of obesity in youth: childhood predictors of adult disease. *Pediatrics.* 1998;101(Supplement 2):518-525.
8. Hu FB. Resolved: there is sufficient scientific evidence that decreasing sugar-sweetened beverage consumption will reduce the prevalence of obesity and obesity-related diseases. *Obesity reviews : an official journal of the International Association for the Study of Obesity.* 2013;14(8):606-619.
9. Bleich SN, Wolfson JA. Trends in SSBs and snack consumption among children by age, body weight, and race/ethnicity. *Obesity.* 2015;23(5):1039-1046.
10. Bleich SN, Vercammen KA, Kom JW, Zhonghe L. Trends in Beverage Consumption among Children and Adults, 2003-2014. *Obesity.* 2017.
11. Bingham SA. Limitations of the various methods for collecting dietary intake data. *Annals of Nutrition and Metabolism.* 1991;35(3):117-127.
12. Willett W. *Nutritional epidemiology.* Oxford University Press; 2012.
13. Kohl III HW, Cook HD. *Educating the student body: Taking physical activity and physical education to school.* National Academies Press; 2013.
14. Dollman J, Norton K, Norton L. Evidence for secular trends in children's physical activity behaviour. *British journal of sports medicine.* 2005;39(12):892-897.
15. Hallal PC, Andersen LB, Bull FC, et al. Global physical activity levels: surveillance progress, pitfalls, and prospects. *The lancet.* 2012;380(9838):247-257.
16. Mozaffarian D, Afshin A, Benowitz NL, et al. Population approaches to improve diet, physical activity, and smoking habits. *Circulation.* 2012;126(12):1514-1563.
17. Gortmaker S, Long M, Wang YC. *The Negative Impact of Sugar-Sweetened Beverages on Children's Health: A Research Synthesis.* Minneapolis, MN: Healthy Eating Research; 2009. Available at: *http://healthyeatingresearch.org*.
18. Beck AL, Tschann J, Butte NF, Penilla C, Greenspan LC. Association of beverage consumption with obesity in Mexican American children. *Public health nutrition.* 2014;17(2):338-344.
19. Bremer AA, Auinger P, Byrd RS. Sugar-sweetened beverage intake trends in US adolescents and their association with insulin resistance-related parameters. *Journal of nutrition and metabolism.* 2009;2010.
20. Bremer AA, Byrd RS, Auinger P. Differences in male and female adolescents from various racial groups in the relationship between insulin resistance-associated parameters with sugar-sweetened beverage intake and physical activity levels. *Clinical pediatrics.* 2010;49(12):1134-1142.
21. Clifton PM, Chan L, Moss CL, Miller MD, Cobiac L. Beverage intake and obesity in Australian children. *Nutrition & metabolism.* 2011;8:87.
22. Danyliw AD, Vatanparast H, Nikpartow N, Whiting SJ. Beverage patterns among Canadian children and relationship to overweight and obesity. *Applied physiology, nutrition, and metabolism = Physiologie appliquee, nutrition et metabolisme.* 2012;37(5):900-906.
23. Davis JN, Koleilat M, Shearrer GE, Whaley SE. Association of infant feeding and dietary intake on obesity prevalence in low-income toddlers. *Obesity (Silver Spring, Md).* 2014;22(4):1103-1111.
24. Davis JN, Whaley SE, Goran MI. Effects of breastfeeding and low sugar-sweetened beverage intake on obesity prevalence in Hispanic toddlers. *The American journal of clinical nutrition.* 2012;95(1):3-8.
25. Denova-Gutierrez E, Jimenez-Aguilar A, Halley-Castillo E, et al. Association between sweetened beverage consumption and body mass index, proportion of body fat and body fat distribution in Mexican adolescents. *Annals of nutrition & metabolism.* 2008;53(3-4):245-251.
26. Gibson S, Neate D. Sugar intake, soft drink consumption and body weight among British children: further analysis of National Diet and Nutrition Survey data with adjustment for under-reporting and physical activity. *International journal of food sciences and nutrition.* 2007;58(6):445-460.
27. Grimes CA, Riddell LJ, Campbell KJ, Nowson CA. Dietary salt intake, sugar-sweetened beverage consumption, and obesity risk. *Pediatrics.* 2013;131(1):14-21.
28. Jiménez-Aguilar A, Flores M, Shamah-Levy T. Sugar-sweetened beverages consumption and BMI in Mexican adolescents: Mexican National Health and Nutrition Survey 2006. *Salud pública de México.* 2009;51:S604-S612.
29. Kosova EC, Auinger P, Bremer AA. The relationships between sugar-sweetened beverage intake and cardiometabolic markers in young children. *Journal of the Academy of Nutrition and Dietetics.* 2013;113(2):219-227.

30. Linardakis M, Sarri K, Pateraki MS, Sbokos M, Kafatos A. Sugar-added beverages consumption among kindergarten children of Crete: effects on nutritional status and risk of obesity. *BMC public health.* 2008;8:279.

31. Papandreou D, Andreou E, Heraclides A, Rousso I. Is beverage intake related to overweight and obesity in school children? *Hippokratia.* 2013;17(1):42-46.

32. Schroder H, Mendez MA, Ribas L, et al. Caloric beverage drinking patterns are differentially associated with diet quality and adiposity among Spanish girls and boys. *European journal of pediatrics.* 2014;173(9):1169-1177.

33. DeBoer MD, Scharf RJ, Demmer RT. Sugar-sweetened beverages and weight gain in 2- to 5-year-old children. *Pediatrics.* 2013;132(3):413-420.

34. Dubois L, Farmer A, Girard M, Peterson K. Regular sugar-sweetened beverage consumption between meals increases risk of overweight among preschool-aged children. *Journal of the American Dietetic Association.* 2007;107(6):924-934; discussion 934-925.

35. Fiorito LM, Marini M, Francis LA, Smiciklas-Wright H, Birch LL. Beverage intake of girls at age 5 y predicts adiposity and weight status in childhood and adolescence. *The American journal of clinical nutrition.* 2009;90(4):935-942.

36. Lim S, Zoellner JM, Lee JM, et al. Obesity and sugar-sweetened beverages in African-American preschool children: a longitudinal study. *Obesity (Silver Spring, Md).* 2009;17(6):1262-1268.

37. Millar L, Rowland B, Nichols M, et al. Relationship between raised BMI and sugar sweetened beverage and high fat food consumption among children. *Obesity (Silver Spring, Md).* 2014;22(5):E96-103.

38. Pan L, Li R, Park S, Galuska DA, Sherry B, Freedman DS. A longitudinal analysis of sugar-sweetened beverage intake in infancy and obesity at 6 years. *Pediatrics.* 2014;134 Suppl 1:S29-35.

39. Weijs PJ, Kool LM, van Baar NM, van der Zee SC. High beverage sugar as well as high animal protein intake at infancy may increase overweight risk at 8 years: a prospective longitudinal pilot study. *Nutrition journal.* 2011;10:95.

40. Chaidez V, McNiven S, Vosti SA, Kaiser LL. Sweetened food purchases and indulgent feeding are associated with increased toddler anthropometry. *Journal of nutrition education and behavior.* 2014;46(4):293-298.

41. Field AE, Sonneville KR, Falbe J, et al. Association of sports drinks with weight gain among adolescents and young adults. *Obesity (Silver Spring, Md).* 2014;22(10):2238-2243.

42. Ambrosini GL, Oddy WH, Huang RC, Mori TA, Beilin LJ, Jebb SA. Prospective associations between sugar-sweetened beverage intakes and cardiometabolic risk factors in adolescents. *The American journal of clinical nutrition.* 2013;98(2):327-334.

43. Leermakers ET, Felix JF, Erler NS, et al. Sugar-containing beverage intake in toddlers and body composition up to age 6 years: the Generation R study. *European journal of clinical nutrition.* 2015;69(3):314-321.

44. Libuda L, Alexy U, Sichert-Hellert W, et al. Pattern of beverage consumption and long-term association with body-weight status in German adolescents--results from the DONALD study. *The British journal of nutrition.* 2008;99(6):1370-1379.

45. Zheng M, Rangan A, Olsen NJ, et al. Sugar-sweetened beverages consumption in relation to changes in body fatness over 6 and 12 years among 9-year-old children: the European Youth Heart Study. *European journal of clinical nutrition.* 2014;68(1):77-83.

46. de Ruyter JC, Olthof MR, Seidell JC, Katan MB. A trial of sugar-free or sugar-sweetened beverages and body weight in children. *New England Journal of Medicine.* 2012;367(15):1397-1406.

47. Ebbeling CB, Feldman HA, Chomitz VR, et al. A randomized trial of sugar-sweetened beverages and adolescent body weight. *New England Journal of Medicine.* 2012;367(15):1407-1416.

48. James J, Thomas P, Kerr D. Preventing childhood obesity: two year follow-up results from the Christchurch obesity prevention programme in schools (CHOPPS). *Bmj.* 2007;335(7623):762.

49. Bremer AA, Auinger P, Byrd RS. Relationship Between Insulin Resistance–Associated Metabolic Parameters and Anthropometric Measurements With Sugar-Sweetened Beverage Intake and Physical Activity Levels in US Adolescents: Findings From the 1999-2004 National Health and Nutrition Examination Survey. *Archives of pediatrics & adolescent medicine.* 2009;163(4):328-335.

50. Bremer AA, Byrd RS, Auinger P. Differences in male and female adolescents from various racial groups in the relationship between insulin resistance-associated parameters with sugar-sweetened beverage intake and physical activity levels. *Clinical pediatrics.* 2010;49(12):1134-1142.

51. Kondaki K, Grammatikaki E, Jiménez-Pavón D, et al. Daily sugar-sweetened beverage consumption and insulin resistance in European adolescents: the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. *Public health nutrition.* 2013;16(03):479-486.

52. Santiago-Torres M, Cui Y, Adams AK, et al. Familial and individual predictors of obesity and insulin resistance in urban Hispanic children. *Pediatric obesity.* 2016;11(1):54-60.

53. Wang J, Mark S, Henderson M, et al. Adiposity and glucose intolerance exacerbate components of metabolic syndrome in children consuming sugar-sweetened beverages: QUALITY cohort study. *Pediatric obesity.* 2013;8(4):284-293.

54. Wang J, Light K, Henderson M, et al. Consumption of added sugars from liquid but not solid sources predicts impaired glucose homeostasis and insulin resistance among youth at risk of obesity. *The Journal of nutrition.* 2014;144(1):81-86.

55. Armfield JM, Spencer AJ, Roberts-Thomson KF, Plastow K. Water fluoridation and the association of sugar-sweetened beverage consumption and dental caries in Australian children. *American journal of public health.* 2013;103(3):494-500.

56. Declerck D, Leroy R, Martens L, et al. Factors associated with prevalence and severity of caries experience in preschool children. *Community dentistry and oral epidemiology.* 2008;36(2):168-178.

57. Evans EW, Hayes C, Palmer CA, Bermudez OI, Cohen SA, Must A. Dietary intake and severe early childhood caries in low-income, young children. *Journal of the Academy of Nutrition and Dietetics.* 2013;113(8):1057-1061.

58. Guido JA, MARTINEZ MIER EA, Soto A, et al. Caries prevalence and its association with brushing habits, water availability, and the intake of sugared beverages. *International Journal of Paediatric Dentistry.* 2011;21(6):432-440.

59. Hoffmeister L, Moya P, Vidal C, Benadof D. Factors associated with early childhood caries in Chile. *Gaceta sanitaria.* 2016;30(1):59-62.

60. Jerkovic K, Binnekade J, Van der Kruk J, Van der Most J, Talsma A, Van der Schans C. Differences in oral health behaviour between children from high and children from low SES schools in the Netherlands. *Community dental health.* 2009;26(2):110.

61. Jurczak A, Kościelniak D, Gregorczyk-Maga I, et al. Influence of socioeconomic and nutritional factors on the development of early childhood caries in children aged 1-6 years. *Nowa Stomatologia.* 2015.

62. Lee J, Messer EPL. Intake of sweet drinks and sweet treats versus reported and observed caries experience. *european archives of Paediatric Dentistry.* 2010;11(1):5-17.

63. Majorana A, Cagetti MG, Bardellini E, et al. Feeding and smoking habits as cumulative risk factors for early childhood caries in toddlers, after adjustment for several behavioral determinants: a retrospective study. *BMC pediatrics.* 2014;14(1):45.

64. Mello T, Antunes I, Waldman E, Ramos E, Relvas M, Barros H. Prevalence and severity of dental caries in schoolchildren of Porto, Portugal. *Community dental health.* 2008;25(2):119-125.

65. Pacey A, Nancarrow T, Egeland G. Prevalence and risk factors for parental-reported oral health of Inuit preschoolers: Nunavut Inuit Child Health Survey, 2007–2008. *Rural Remote Health.* 2010;10(2):1368.

66. Skinner J, Byun R, Blinkhorn A, Johnson G. Sugary drink consumption and dental caries in New South Wales teenagers. *Australian dental journal.* 2015;60(2):169-175.

67. Wilder JR, Kaste LM, Handler A, Chapple-McGruder T, Rankin KM. The association between sugar-sweetened beverages and dental caries among third-grade students in Georgia. *Journal of public health dentistry.* 2015.

68. Nakayama Y, Mori M. Association between nocturnal breastfeeding and snacking habits and the risk of early childhood caries in 18-to 23-month-old Japanese children. *Journal of Epidemiology.* 2015;25(2):142-147.

69. Kolker JL, Yuan Y, Burt BA, et al. Dental caries and dietary patterns in low-income African American children. *Pediatric dentistry.* 2007;29(6):457-464.

70. Lim S, Sohn W, Burt BA, et al. Cariogenicity of soft drinks, milk and fruit juice in low-income african-american children: a longitudinal study. *The Journal of the American Dental Association.* 2008;139(7):959-967.

71. Park S, Lin M, Onufrak S, Li R. Association of sugar-sweetened beverage intake during infancy with dental caries in 6-year-olds. *Clinical nutrition research.* 2015;4(1):9-17.

72. Warren JJ, Blanchette D, Dawson DV, et al. Factors associated with dental caries in a group of American Indian children at age 36 months. *Community dentistry and oral epidemiology.* 2016;44(2):154-161.

73. Warren JJ, Weber-Gasparoni K, Marshall TA, et al. A longitudinal study of dental caries risk among very young low SES children. *Community dentistry and oral epidemiology.* 2009;37(2):116-122.

74. Watanabe M, Wang D-H, Ijichi A, et al. The influence of lifestyle on the incidence of dental caries among 3-year-old Japanese children. *International journal of environmental research and public health.* 2014;11(12):12611-12622.

75. Wigen TI, Wang NJ. Does early establishment of favorable oral health behavior influence caries experience at age 5 years? *Acta Odontologica Scandinavica.* 2015;73(3):182-187.

76. Maupomé G, Karanja N, Ritenbaugh C, Lutz T, Aickin M, Becker T. Dental caries in American Indian toddlers after a community-based beverage intervention. *Ethnicity & disease.* 2010;20(4):444.

77. Azagba S, Langille D, Asbridge M. An emerging adolescent health risk: caffeinated energy drink consumption patterns among high school students. *Preventive Medicine.* 2014;62:54-59.

78. Bashir D, Reed-Schrader E, Olympia RP, et al. Clinical symptoms and adverse effects associated with energy drink consumption in adolescents. *Pediatric emergency care.* 2016;32(11):751-755.

79. Koivusilta L, Kuoppamäki H, Rimpelä A. Energy drink consumption, health complaints and late bedtime among young adolescents. *International journal of public health.* 2016;61(3):299-306.

80. Marmorstein NR. Energy drink and coffee consumption and psychopathology symptoms among early adolescents: Cross-sectional and longitudinal associations. *Journal of caffeine research.* 2016;6(2):64-72.

81. Park S, Lee Y, Lee JH. Association between energy drink intake, sleep, stress, and suicidality in Korean adolescents: energy drink use in isolation or in combination with junk food consumption. *Nutrition journal.* 2016;15(1):87.

82. Kristjansson AL, Sigfusdottir ID, Mann MJ, James JE. Caffeinated sugar-sweetened beverages and common physical complaints in Icelandic children aged 10–12years. *Preventive medicine.* 2014;58:40-44.

83. Richards G, Smith A. Caffeine consumption and self-assessed stress, anxiety, and depression in secondary school children. *Journal of Psychopharmacology.* 2015:0269881115612404.

84. Franckle RL, Falbe J, Gortmaker S, et al. Insufficient sleep among elementary and middle school students is linked with elevated soda consumption and other unhealthy dietary behaviors. *Preventive medicine.* 2015;74:36-41.

85. Shamah-Levy T, García-Chávez CG, Rodríguez-Ramírez S. Association between Plain Water and Sugar-Sweetened Beverages and Total Energy Intake among Mexican School-Age Children. *Nutrients.* 2016;8(12):710.

86. Wang YC, Ludwig DS, Sonneville K, Gortmaker SL. Impact of change in sweetened caloric beverage consumption on energy intake among children and adolescents. *Archives of pediatrics & adolescent medicine.* 2009;163(4):336-343.

87. Zheng M, Rangan A, Allman-Farinelli M, Rohde JF, Olsen NJ, Heitmann BL. Replacing sugary drinks with milk is inversely associated with weight gain among young obesity-predisposed children. *British Journal of Nutrition.* 2015;114(09):1448-1455.

88. Zheng M, Rangan A, Olsen NJ, et al. Substituting sugar-sweetened beverages with water or milk is inversely associated with body fatness development from childhood to adolescence. *Nutrition.* 2015;31(1):38-44.

89. Albala C, Ebbeling CB, Cifuentes M, Lera L, Bustos N, Ludwig DS. Effects of replacing the habitual consumption of sugar-sweetened beverages with milk in Chilean children. *The American journal of clinical nutrition.* 2008;88(3):605-611.

90. Muckelbauer R, Gortmaker SL, Libuda L, et al. Changes in water and sugar-containing beverage consumption and body weight outcomes in children. *British Journal of Nutrition.* 2016;115(11):2057-2066.

91. Alles MS, Eussen SR, Van Der Beek EM. Nutritional challenges and opportunities during the weaning period and in young childhood. *Annals of Nutrition and Metabolism.* 2014;64(3-4):284-293.

92. Beauchamp GK, Mennella JA. Early flavor learning and its impact on later feeding behavior. *Journal of pediatric gastroenterology and nutrition.* 2009;48:S25-S30.

93. De Cosmi V, Scaglioni S, Agostoni C. Early Taste Experiences and Later Food Choices. *Nutrients.* 2017;9(2):107.

94. Drewnowski A, Mennella JA, Johnson SL, Bellisle F. Sweetness and food preference. *The Journal of nutrition.* 2012;142(6):1142S-1148S.

95. Mennella JA, Bobowski NK. The sweetness and bitterness of childhood: Insights from basic research on taste preferences. *Physiology & behavior.* 2015;152:502-507.

96. Ventura AK, Mennella JA. Innate and learned preferences for sweet taste during childhood. *Current Opinion in Clinical Nutrition & Metabolic Care.* 2011;14(4):379-384.

97. DiMeglio DP, Mattes RD. Liquid versus solid carbohydrate: effects on food intake and body weight. *International journal of obesity.* 2000;24(6):794.

98. Malik VS, Schulze MB, Hu FB. Intake of sugar-sweetened beverages and weight gain: a systematic review. *The American journal of clinical nutrition.* 2006;84(2):274-288.

99. Ludwig DS. Lifespan weighed down by diet. *Jama.* 2016;315(21): 2269-2270.

100. Slavin J. Beverages and body weight: challenges in the evidence-based review process of the Carbohydrate Subcommittee from the 2010 Dietary Guidelines Advisory Committee. *Nutrition reviews.* 2012;70(suppl 2):S111-S120.

101. Goff Jr DC, Lloyd-Jones DM, Bennett G, et al. 2013 ACC/AHA guideline on the assessment of cardiovascular risk: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *Journal of the American College of Cardiology.* 2014;63(25 Pt B):2935-2959.

102. Ebbeling CB, Swain JF, Feldman HA, et al. Effects of dietary composition on energy expenditure during weight-loss maintenance. *Jama.* 2012;307(24):2627-2634.

103. Coppinger T, Jeanes Y, Mitchell M, Reeves S. Beverage consumption and BMI of British schoolchildren aged 9-13 years. *Public health nutrition.* 2013;16(7):1244-1249.

104. Gómez-Martínez S, Martín A, Romeo Marín J, et al. Is soft drink consumption associated with body composition? A cross-sectional study in Spanish adolescents. 2009.

105. Ha K, Chung S, Lee H, et al. Association of dietary sugars and sugar-sweetened beverage intake with obesity in Korean children and adolescents. *Nutrients.* 2016;8(1):31.

106. Valente H, Teixeira V, Padrao P, et al. Sugar-sweetened beverage intake and overweight in children from a Mediterranean country. *Public health nutrition.* 2011;14(1):127-132.

107. Bremer AA, Auinger P, Byrd RS. Sugar-Sweetened Beverage Intake Trends in US Adolescents and Their Association with Insulin Resistance-Related Parameters. *Journal of nutrition and metabolism.* 2010;2010.

108. Jensen BW, Nichols M, Allender S, et al. Inconsistent associations between sweet drink intake and 2-year change in BMI among Victorian children and adolescents. *Pediatric obesity.* 2013;8(4):271-283.

109. Jensen BW, Nielsen BM, Husby I, et al. Association between sweet drink intake and adiposity in Danish children participating in a long-term intervention study. *Pediatric obesity.* 2013;8(4):259-270.

110. Kral TVE, Stunkard AJ, Berkowitz RI, Stallings VA, Moore RH, Faith MS. Beverage consumption patterns of children born at different risk of obesity. *Obesity.* 2008;16(8):1802-1808.

111. Laska MN, Murray DM, Lytle LA, Harnack LJ. Longitudinal associations between key dietary behaviors and weight gain over time: transitions through the adolescent years. *Obesity (Silver Spring, Md).* 2012;20(1):118-125.

112. Vanselow MS, Pereira MA, Neumark-Sztainer D, Raatz SK. Adolescent beverage habits and changes in weight over time: findings from Project EAT. *The American journal of clinical nutrition.* 2009;90(6):1489-1495.

113. Laurson K, Eisenmann JC, Moore S. Lack of association between television viewing, soft drinks, physical activity and body mass index in children. *Acta Paediatrica.* 2008;97(6):795-800.

114. Stoof SP, Twisk JWR, Olthof MR. Is the intake of sugar-containing beverages during adolescence related to adult weight status? *Public health nutrition.* 2013;16(7):1257-1262.

115. Della Torre SB, Keller A, Depeyre JL, Kruseman M. Sugar-sweetened beverages and obesity risk in children and adolescents: a systematic analysis on how methodological quality may influence conclusions. *Journal of the Academy of Nutrition and Dietetics.* 2016;116(4):638-659.

116. James J, Thomas P, Cavan D, Kerr D. Preventing childhood obesity by reducing consumption of carbonated drinks: cluster randomised controlled trial. *Bmj.* 2004;328(7450):1237.

117. Hu FB, Malik VS. Sugar-sweetened beverages and risk of obesity and type 2 diabetes: epidemiologic evidence. *Physiol Behav.* 2010;100(1):47-54.

118. Malik VS, Hu FB. Fructose and Cardiometabolic Health: What the Evidence From Sugar-Sweetened Beverages Tells Us. *Journal of the American College of Cardiology.* 2015;66(14):1615-1624.

119. Touger-Decker R, Van Loveren C. Sugars and dental caries. *The American journal of clinical nutrition.* 2003;78(4):881S-892S.

120. Chi DL, Hopkins S, O'Brien D, Mancl L, Orr E, Lenaker D. Association between added sugar intake and dental caries in Yup'ik children using a novel hair biomarker. *BMC oral health.* 2015;15(1):121.

121. Ruxton C. The suitability of caffeinated drinks for children: a systematic review of randomised controlled trials, observational studies and expert panel guidelines. *Journal of human nutrition and dietetics.* 2014;27(4):342-357.

122. Goldfarb M, Tellier C, Thanassoulis G. Review of published cases of adverse cardiovascular events after ingestion of energy drinks. *The American journal of cardiology.* 2014;113(1):168-172.

123. Brown RJ, De Banate MA, Rother KI. Artificial sweeteners: a systematic review of metabolic effects in youth. *International Journal of Pediatric Obesity.* 2010;5(4):305-312.

124. Fernstrom JD. Non-nutritive sweeteners and obesity. *Annual review of food science and technology.* 2015;6:119-136.

125. Freswick PN. Artificial Sweetened Beverages and Pediatric Obesity: The Controversy Continues. *Children.* 2014;1(1):31-39.

126. Keller KL, Kirzner J, Pietrobelli A, St-Onge M-P, Faith MS. Increased sweetened beverage intake is associated with reduced milk and calcium intake in 3-to 7-year-old children at multi-item laboratory lunches. *Journal of the American Dietetic Association.* 2009;109(3):497-501.

127. de Ruyter JC, Katan MB, Kuijper LD, Liem DG, Olthof MR. The effect of sugar-free versus sugar-sweetened beverages on satiety, liking and wanting: an 18 month randomized double-blind trial in children. *PLoS One.* 2013;8(10):e78039.

128. de Ruyter JC, Katan MB, Kas R, Olthof MR. Can children discriminate sugar-sweetened from non-nutritively sweetened beverages and how do they like them? *PloS one.* 2014;9(12):e115113.

129. Singh AS, Paw MJCA, Brug J, van Mechelen W. Dutch obesity intervention in teenagers: effectiveness of a school-based program on body composition and behavior. *Archives of pediatrics & adolescent medicine.* 2009;163(4):309-317.

130. Avery A, Bostock L, McCullough F. A systematic review investigating interventions that can help reduce consumption of sugar-sweetened beverages in children leading to changes in body fatness. *Journal of Human Nutrition and Dietetics.* 2015;28(s1):52-64.

131. Mennella JA. Ontogeny of taste preferences: basic biology and implications for health. *The American journal of clinical nutrition.* 2014;99(3):704S-711S.

132. Desor J, Maller O, Turner RE. Taste in acceptance of sugars by human infants. *Journal of comparative and physiological psychology.* 1973;84(3):496.

133. Maone TR, Mattes RD, Bernbaum JC, Beauchamp GK. A new method for delivering a taste without fluids to preterm and term infants. *Developmental psychobiology.* 1990;23(2):179-191.

134. Steiner JE, Glaser D, Hawilo ME, Berridge KC. Comparative expression of hedonic impact: affective reactions to taste by human infants and other primates. *Neuroscience & Biobehavioral Reviews.* 2001;25(1):53-74.

135. De Graaf C, Zandstra EH. Sweetness intensity and pleasantness in children, adolescents, and adults. *Physiology & behavior.* 1999;67(4):513-520.

136. Desor J, Beauchamp GK. Longitudinal changes in sweet preferences in humans. *Physiology & Behavior.* 1987;39(5):639-641.

137. Mennella JA, Lukasewycz LD, Griffith JW, Beauchamp GK. Evaluation of the Monell forced-choice, paired-comparison tracking procedure for determining sweet taste preferences across the lifespan. *Chemical senses.* 2011;36(4):345-355.

138. Barr RG, Pantel MS, Young SN, Wright JH, Hendricks LA, Gravel R. The response of crying newborns to sucrose: is it a "sweetness" effect? *Physiology & Behavior.* 1999;66(3):409-417.

139. Blass EM, Hoffmeyer LB. Sucrose as an analgesic for newborn infants. *Pediatrics.* 1991;87(2):215-218.

140. Stevens B, Yamada J, Lee GY, Ohlsson A. Sucrose for analgesia in newborn infants undergoing painful procedures. *The Cochrane Library.* 2013.

141. Beauchamp GK, Moran M. Dietary experience and sweet taste preference in human infants. *Appetite.* 1982;3(2):139-152.

142. Beauchamp GK, Moran M. Acceptance of sweet and salty tastes in 2-year-old children. *Appetite.* 1984;5(4):291-305.

143. Liem DG, Mennella JA. Sweet and sour preferences during childhood: role of early experiences. *Developmental psychobiology.* 2002;41(4):388.

144. Sullivan SA, Birch LL. Pass the sugar, pass the salt: Experience dictates preference. *Developmental psychology.* 1990;26(4):546.

145. US Department of Health and Human Services USDoA. 2015–2020 Dietary Guidelines for Americans. 8th ed. *Washington (DC): USDA.* 2015.

146. Falbe J, Thompson HR, Becker CM, Rojas N, McCulloch CE, Madsen KA. Impact of the Berkeley excise tax on sugar-sweetened beverage consumption. *Journal Information.* 2016;106(10).

147. Chriqui JF, Turner L, Taber DR, Chaloupka FJ. Association between district and state policies and US public elementary school competitive food and beverage environments. *JAMA pediatrics.* 2013;167(8):714-722.

148. Taber DR, Chriqui JF, Powell LM, Chaloupka FJ. Banning all sugar-sweetened beverages in middle schools: reduction of in-school access and purchasing but not overall consumption. *Archives of pediatrics & adolescent medicine.* 2012;166(3):256-262.

149. Terry-McElrath YM, O'Malley PM, Johnston LD. Factors Affecting Sugar-Sweetened Beverage Availability in Competitive Venues of US Secondary Schools. *Journal of School Health.* 2012;82(1):44-55.

150. Woodward-Lopez G, Gosliner W, Samuels SE, Craypo L, Kao J, Crawford PB. Lessons learned from evaluations of California's statewide school nutrition standards. *American Journal of Public Health.* 2010;100(11):2137-2145.

151. 2014 Progress Report: McDonald's-Alliance for a Healthier Generation Partnership: Clinton GlobaI Initiative Commitment to Action 2014; *https://www.healthiergeneration.org/_asset/5ql33fl2014-Progress-Report_McDonalds-Alliance-Partnership-on-CGI-Commitment-to-Action-06-25-15.pdf*.

152. Gortmaker SL, Swinburn BA, Levy D, et al. Changing the future of obesity: science, policy, and action. *The Lancet.* 2011;378(9793):838-847.

153. Roberto CA, Swinburn B, Hawkes C, et al. Patchy progress on obesity prevention: emerging examples, entrenched barriers, and new thinking. *The Lancet.* 2015;385(9985):2400-2409.

154. Healthy Eating Research. Recommendations for Responsible Food Marketing to Children. Minneapolis, MN: Healthy Eating Research; 2015. Available at: *http://healthyeatingresearch.org*.

Appendix A: Study Designs & Limitations

A variety of study designs have been utilized to examine the association between SSBs and various health outcomes among children and adolescents. In general, cross-sectional studies are seen as the weakest form of evidence and intervention studies are viewed as the strongest, with longitudinal and case control falling in between. However, this hierarchy is greatly impacted by the quality of measures, methodological rigor, the sample size, the study duration, and possible to sources of bias. Many of the study designs share common limitations including: issues with measuring exposure (e.g. single-day dietary assessments may not adequately depict usual SSB intake), heterogeneity in outcome assessment (e.g. use of BMI, BMI z-scores, vs. obesity cut-offs) and insufficient length of follow-up.

Cross-Sectional

Cross-sectional studies collect both exposure and outcome data at the same point in time, limiting the ability to make inferences about causality. Moreover, cross-sectional studies are prone to problematic biases including reverse causality (a two-way causal relationship or a contrary direction of cause-and-effect), recall bias (differences in the accuracy or completeness of the recollections "recalled" by study participants regarding events or experiences from the past), and unmeasured confounding (variables which may impact the exposure and outcome but were not included in the analysis).

Longitudinal

Longitudinal studies observe associations over time, allowing for an examination of how changes in exposure (i.e. SSB consumption) can impact health outcomes at follow-up. Well-designed and methodologically rigorous longitudinal studies are a stronger form of evidence than cross-sectional studies, particularly those with large samples and longer duration, and can provide important insights into the relationship between SSB consumption and health outcomes over time. However, threats to validity still exist including unmeasured confounding and insufficient length of follow-up. Insufficient length of follow-up is an important concern as temporal relationships between SSBs and certain health outcomes are not completely understood; hence, if a study ends before adequate time has passed for a health outcome to appear, the association will be underestimated.

Intervention

Intervention studies evaluate outcome differences (e.g., body weight) between children and adolescents randomized to consume either SSBs or non-caloric alternatives. The randomized nature of intervention studies provides the significant advantage that confounders (both measured and unmeasured) should be approximately equally distributed between groups, allowing for stronger causal inferences to be made. Intervention studies examining SSB consumption are limited by the ethical concerns of randomizing children to increase their SSB consumption. Therefore, most intervention studies randomize current consumers of SSBs to maintain their consumption levels or substitute SSBs with other beverages. Some intervention studies utilize multi-pronged approaches to improve community health, of which reducing SSB consumption is one component. These studies were not included in this report as it is not possible to separate the effect of reducing SSB consumption from other approaches being implemented concurrently. Major methodological concerns in intervention studies include insufficient length of follow-up, adherence, and compliance.

Appendix B: Search Strategies

PubMed, CAB Abstracts and PAIS International were all searched. The start date restriction was Jan 1, 2007 for the searches on obesity, insulin resistance, dental caries, caffeine-related effects and substitution. There was no start date restriction for taste preferences. All searches were restricted to articles published in English.

Obesity: searched on January 31, 2017

PubMed

((“Beverages”[Mesh] OR beverage[tiab] OR beverages[tiab] OR drink[tiab] OR drinks[tiab] OR soda[tiab] OR sodas[tiab] OR juice[tiab] OR juices[tiab] OR pop[tiab] OR tea[tiab] OR teas[tiab] OR coffee*[tiab] OR milk*[tiab]) AND ((“Nutritive Sweeteners”[Mesh] OR sucrose[tiab] OR fructose[tiab] OR sugar[tiab] OR sugary[tiab] OR sugared[tiab] OR sweet[tiab] OR sweetened[tiab] OR sweetener*[tiab] OR nondiet[tiab] OR non diet[tiab] OR high calorie[tiab]) OR (fruit juice*[tiab] OR fruit drink*[tiab] OR regular soda*[tiab] OR caloric beverage*[tiab] OR fruit punch*[tiab] OR sport drink*[tiab] OR energy drink*[tiab]))) AND ((“Child”[Mesh] OR “Adolescent”[Mesh] OR preschooler*[tiab] OR pre schooler*[tiab] OR pre school[tiab] OR preschool[tiab] OR toddler*[tiab] OR child[tiab] OR children[tiab] OR children’s[tiab] OR childhood[tiab] OR adolescent[tiab] OR adolescents[tiab] OR adolescence[tiab] OR teen[tiab] OR teens[tiab] OR teenager[tiab] OR teenagers[tiab] OR teenage[tiab] OR prekindergar*[tiab] OR nursery school*[tiab] OR head start[tiab] OR kindergar*[tiab] OR grade school*[tiab] OR elementary school*[tiab] OR elementary student*[tiab] OR middle school*[tiab] OR high school*[tiab] OR highschool*[tiab] OR public school*[tiab] OR boy[tiab] OR boys[tiab] OR girl[tiab] OR girls[tiab] OR pediatric*[tiab] OR paediatric*[tiab])) AND ((“Overweight” [Mesh] OR “Body Weight” [Mesh:NoExp] OR “Body Weight Changes” [Mesh] OR “Body Composition” [Mesh] OR “Body Mass Index” [Mesh] OR obese[tiab] OR obesity[tiab] OR overweight[tiab] OR weight[tiab] OR weighed[tiab] OR body mass[tiab] OR bmi[tiab] OR body composition[tiab] OR adipose[tiab] OR adiposity[tiab]))

CAB Abstracts and PAIS International

((beverage OR beverages OR drink OR drinks OR soda OR sodas OR juice OR juices OR pop OR tea OR teas OR coffee* OR milk*) AND ((“Nutritive Sweeteners” OR sucrose OR fructose OR sugar OR sugary OR sugared OR sweet OR sweetened OR sweetener* OR nondiet OR “non diet” OR “high calorie”) OR (“fruit juice*” OR “fruit drink*” OR “regular soda*” OR “caloric beverage*” OR “fruit punch*” OR “sport drink*” OR “energy drink*”))) AND (preschooler* OR “pre schooler*” OR “pre school” OR preschool OR toddler* OR child OR children OR children’s OR childhood OR adolescent OR adolescents OR adolescence OR teen OR teens OR teenager OR teenagers OR teenage OR prekindergar* OR nursery school* OR “head start” OR kindergar* OR “grade school*” OR “elementary school*” OR “elementary student*” OR “middle school*” OR “high school*” OR highschool* OR “public school*” OR boy OR boys OR girl OR girls OR pediatric* OR paediatric*) AND (obese OR obesity OR overweight OR weight OR weighed OR “body mass” OR bmi OR “body composition” OR adipose OR adiposity)

Insulin Resistance: searched on February 16, 2017

PubMed

(((((“Beverages”[Mesh] OR beverage[tiab] OR beverages[tiab] OR drink[tiab] OR drinks[tiab] OR soda[tiab] OR sodas[tiab] OR juice[tiab] OR juices[tiab] OR pop[tiab] OR tea[tiab] OR teas[tiab] OR coffee*[tiab] OR milk*[tiab]) AND (“Nutritive Sweeteners”[Mesh] OR sucrose[tiab] OR fructose[tiab] OR sugar[tiab] OR sugary[tiab] OR sugared[tiab] OR sweet[tiab] OR sweetened[tiab] OR sweetener*[tiab] OR nondiet[tiab] OR non diet[tiab] OR high calorie[tiab]) OR (fruit juice*[tiab] OR fruit drink*[tiab] OR regular soda*[tiab] OR caloric beverage*[tiab] OR fruit punch*[tiab] OR sport drink*[tiab] OR energy drink*[tiab])))) AND ((“Child”[Mesh] OR “Adolescent”[Mesh] OR preschooler*[tiab] OR pre schooler*[tiab] OR pre school[tiab] OR preschool[tiab] OR toddler*[tiab] OR child[tiab] OR children[tiab] OR children’s[tiab] OR childhood[tiab] OR adolescent[tiab] OR adolescents[tiab] OR adolescence[tiab] OR teen[tiab] OR teens[tiab] OR teenager[tiab] OR teenagers[tiab] OR teenage[tiab] OR prekindergar*[tiab] OR nursery school*[tiab] OR head start[tiab] OR kindergar*[tiab] OR grade school*[tiab] OR elementary school*[tiab] OR elementary student*[tiab] OR middle school*[tiab] OR high school*[tiab] OR highschool*[tiab] OR public school*[tiab] OR boy[tiab] OR boys[tiab] OR girl[tiab] OR girls[tiab] OR pediatric*[tiab] OR paediatric*[tiab])))) AND ((“Diabetes Mellitus”[Mesh] OR “Insulin Resistance”[MeSH] OR diabetes[tiab] OR diabetic*[tiab] OR insulin resistance[tiab] OR type 2 DM [tiab] OR type II DM [tiab]))

CAB Abstracts and PAIS International

((beverage OR beverages OR drink OR drinks OR soda OR sodas OR juice OR juices OR pop OR tea OR teas OR coffee* OR milk*) AND ((“Nutritive Sweeteners” OR sucrose OR fructose OR sugar OR sugary OR sugared OR sweet OR sweetened OR sweetener* OR nondiet OR “non diet” OR “high calorie”) OR (“fruit juice*” OR “fruit drink*” OR “regular soda*” OR “caloric beverage*” OR “fruit punch*” OR “sport drink*” OR “energy drink*”))) AND (preschooler* OR “pre

schooler*" OR "pre school" OR preschool OR toddler* OR child OR children OR children's OR childhood OR adolescent OR adolescents OR adolescence OR teen OR teens OR teenager OR teenagers OR teenage OR prekindergar* OR nursery school* OR "head start" OR kindergar* OR "grade school*" OR "elementary school*" OR "elementary student*" OR "middle school*" OR "high school*" OR highschool* OR "public school*" OR boy OR boys OR girl OR girls OR pediatric* OR paediatric*) AND (diabetes OR diabetic* OR "insulin resistance" OR "type 2 DM" OR "type II DM")

Dental Caries: searched on March 1, 2017

PubMed

((("Beverages"[Mesh] OR beverage[tiab] OR beverages[tiab] OR drink[tiab] OR drinks[tiab] OR soda[tiab] OR sodas[tiab] OR juice[tiab] OR juices[tiab] OR pop[tiab] OR tea[tiab] OR teas[tiab] OR coffee*[tiab] OR milk*[tiab]) AND (("Nutritive Sweeteners"[Mesh] OR sucrose[tiab] OR fructose[tiab] OR sugar[tiab] OR sugary[tiab] OR sugared[tiab] OR sweet[tiab] OR sweetened[tiab] OR sweetener*[tiab] OR nondiet[tiab] OR non diet[tiab] OR high calorie[tiab]) OR (fruit juice*[tiab] OR fruit drink*[tiab] OR regular soda*[tiab] OR caloric beverage*[tiab] OR fruit punch*[tiab] OR sport drink*[tiab] OR energy drink*[tiab])))) AND ((("Child"[Mesh] OR "Adolescent"[Mesh] OR preschooler*[tiab] OR pre schooler*[tiab] OR pre school[tiab] OR preschool[tiab] OR toddler*[tiab] OR child[tiab] OR children[tiab] OR children's[tiab] OR childhood[tiab] OR adolescent[tiab] OR adolescents[tiab] OR adolescence[tiab] OR teen[tiab] OR teens[tiab] OR teenager[tiab] OR teenagers[tiab] OR teenage[tiab] OR prekindergar*[tiab] OR nursery school*[tiab] OR head start[tiab] OR kindergar*[tiab] OR grade school*[tiab] OR elementary school*[tiab] OR elementary student*[tiab] OR middle school*[tiab] OR high school*[tiab] OR highschool*[tiab] OR public school*[tiab] OR boy[tiab] OR boys[tiab] OR girl[tiab] OR girls[tiab] OR pediatric*[tiab] OR paediatric*[tiab])) AND ("Dental Caries"[Mesh:NoExp] OR caries[tiab] OR tooth decay[tiab] OR dental decay[tiab])

Cab Abstracts and PAIS International

((beverage OR beverages OR drink OR drinks OR soda OR sodas OR juice OR juices OR pop OR tea OR teas OR coffee* OR milk*) AND (("Nutritive Sweeteners" OR sucrose OR fructose OR sugar OR sugary OR sugared OR sweet OR sweetened OR sweetener* OR nondiet OR "non diet" OR "high calorie") OR ("fruit juice*" OR "fruit drink*" OR "regular soda*" OR "caloric beverage*" OR "fruit punch*" OR "sport drink*" OR "energy drink*")))) AND (preschooler* OR "pre schooler*" OR "pre school" OR preschool OR toddler* OR child OR children OR children's OR childhood OR adolescent OR adolescents OR adolescence OR teen OR teens OR teenager OR teenagers OR teenage OR prekindergar* OR nursery school* OR "head start" OR kindergar* OR "grade school*" OR "elementary school*" OR "elementary student*" OR "middle school*" OR "high school*" OR highschool* OR "public school*" OR boy OR boys OR girl OR girls OR pediatric* OR paediatric*) AND (caries OR tooth decay OR dental decay)

Caffeine-related: searched on March 19, 2017

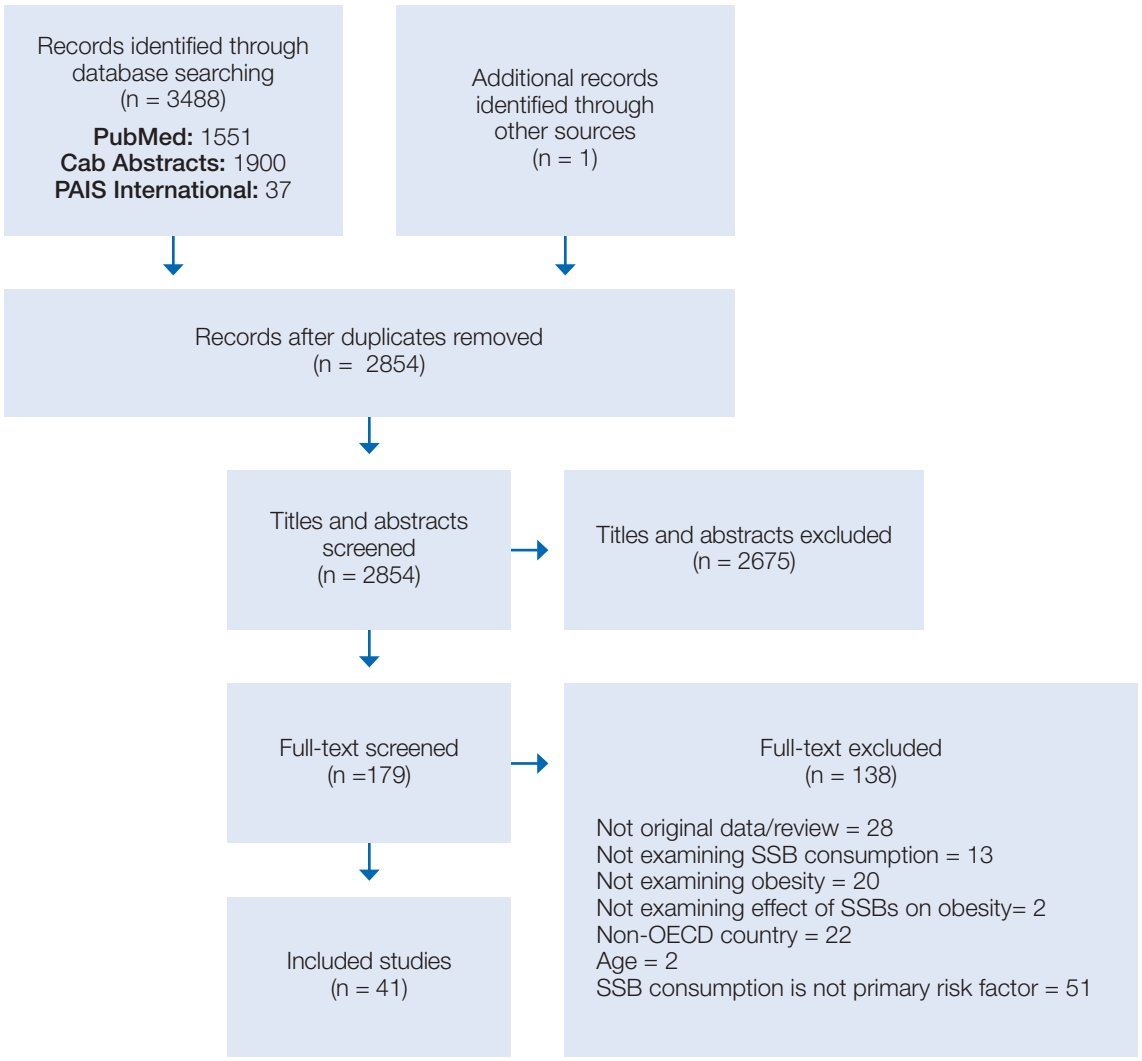
PubMed

(((((("Beverages"[Mesh] OR beverage[tiab] OR beverages[tiab] OR drink[tiab] OR drinks[tiab] OR soda[tiab] OR sodas[tiab] OR juice[tiab] OR juices[tiab] OR pop[tiab] OR tea[tiab] OR teas[tiab] OR coffee*[tiab] OR milk*[tiab]) AND ("Nutritive Sweeteners"[Mesh] OR sucrose[tiab] OR fructose[tiab] OR sugar[tiab] OR sugary[tiab] OR sugared[tiab] OR sweet[tiab] OR sweetened[tiab] OR sweetener*[tiab] OR nondiet[tiab] OR non diet[tiab] OR high calorie[tiab]) OR (fruit juice*[tiab] OR fruit drink*[tiab] OR regular soda*[tiab] OR caloric beverage*[tiab] OR fruit punch*[tiab] OR sport drink*[tiab] OR energy drink*[tiab])))) AND (("Child"[Mesh] OR "Adolescent"[Mesh] OR preschooler*[tiab] OR pre schooler*[tiab] OR pre school[tiab] OR preschool[tiab] OR toddler*[tiab] OR child[tiab] OR children[tiab] OR children's[tiab] OR childhood[tiab] OR adolescent[tiab] OR adolescents[tiab] OR adolescence[tiab] OR teen[tiab] OR teens[tiab] OR teenager[tiab] OR teenagers[tiab] OR teenage[tiab] OR prekindergar*[tiab] OR nursery school*[tiab] OR head start[tiab] OR kindergar*[tiab] OR grade school*[tiab] OR elementary school*[tiab] OR elementary student*[tiab] OR middle school*[tiab] OR high school*[tiab] OR highschool*[tiab] OR public school*[tiab] OR boy[tiab] OR boys[tiab] OR girl[tiab] OR girls[tiab] OR pediatric*[tiab] OR paediatric*[tiab]))) AND ("Caffeine"[Mesh] OR caffeine[tiab] OR caffeinated[tiab])

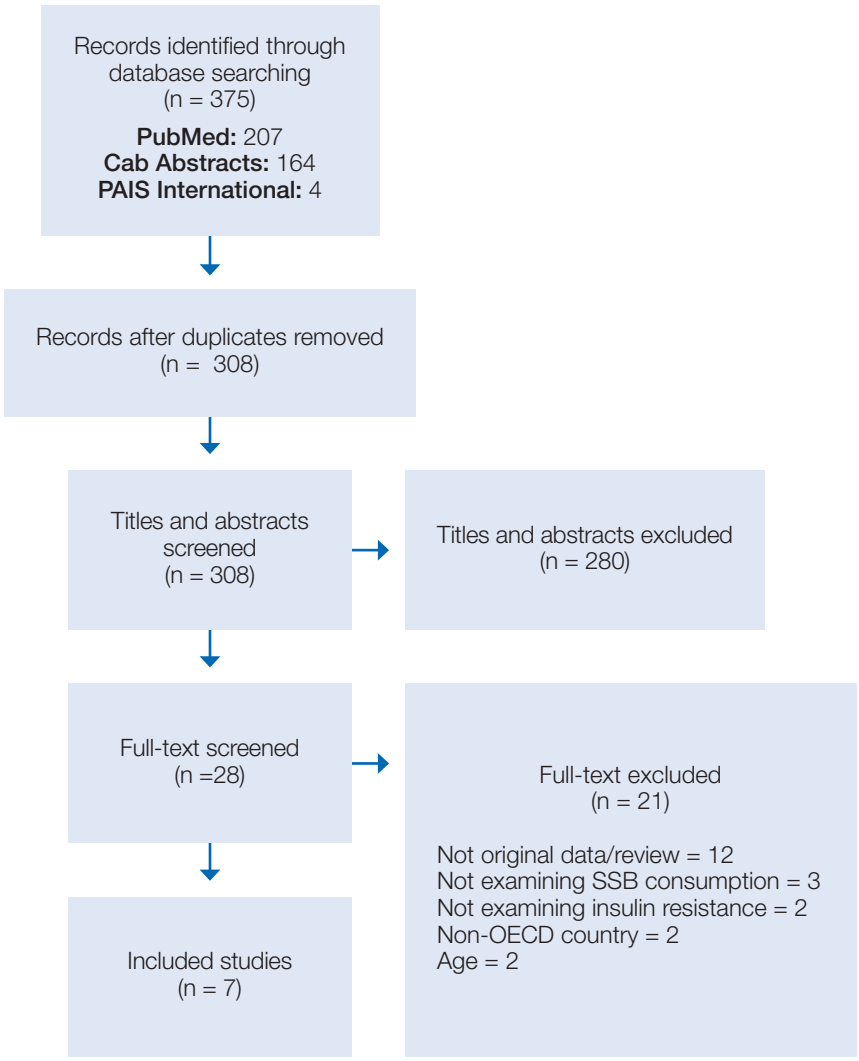
CAB Abstracts and PAIS International

((beverage OR beverages OR drink OR drinks OR soda OR sodas OR juice OR juices OR pop OR tea OR teas OR coffee* OR milk*) AND (("Nutritive Sweeteners" OR sucrose OR fructose OR sugar OR sugary OR sugared OR sweet OR sweetened OR sweetener* OR nondiet OR "non diet" OR "high calorie") OR ("fruit juice*" OR "fruit drink*" OR "regular soda*" OR "caloric beverage*" OR "fruit punch*" OR "sport drink*" OR "energy drink*")))) AND (preschooler* OR "pre schooler*" OR "pre school" OR preschool OR toddler* OR child OR children OR children's OR childhood OR adolescent OR adolescents OR adolescence OR teen OR teens OR teenager OR teenagers OR teenage OR prekindergar* OR nursery school* OR "head start" OR kindergar* OR "grade school*" OR "elementary school*" OR "elementary student*" OR "middle school*" OR "high school*" OR highschool* OR "public school*" OR boy OR boys OR girl OR girls OR pediatric* OR paediatric*) AND (caffeine OR caffeinated)

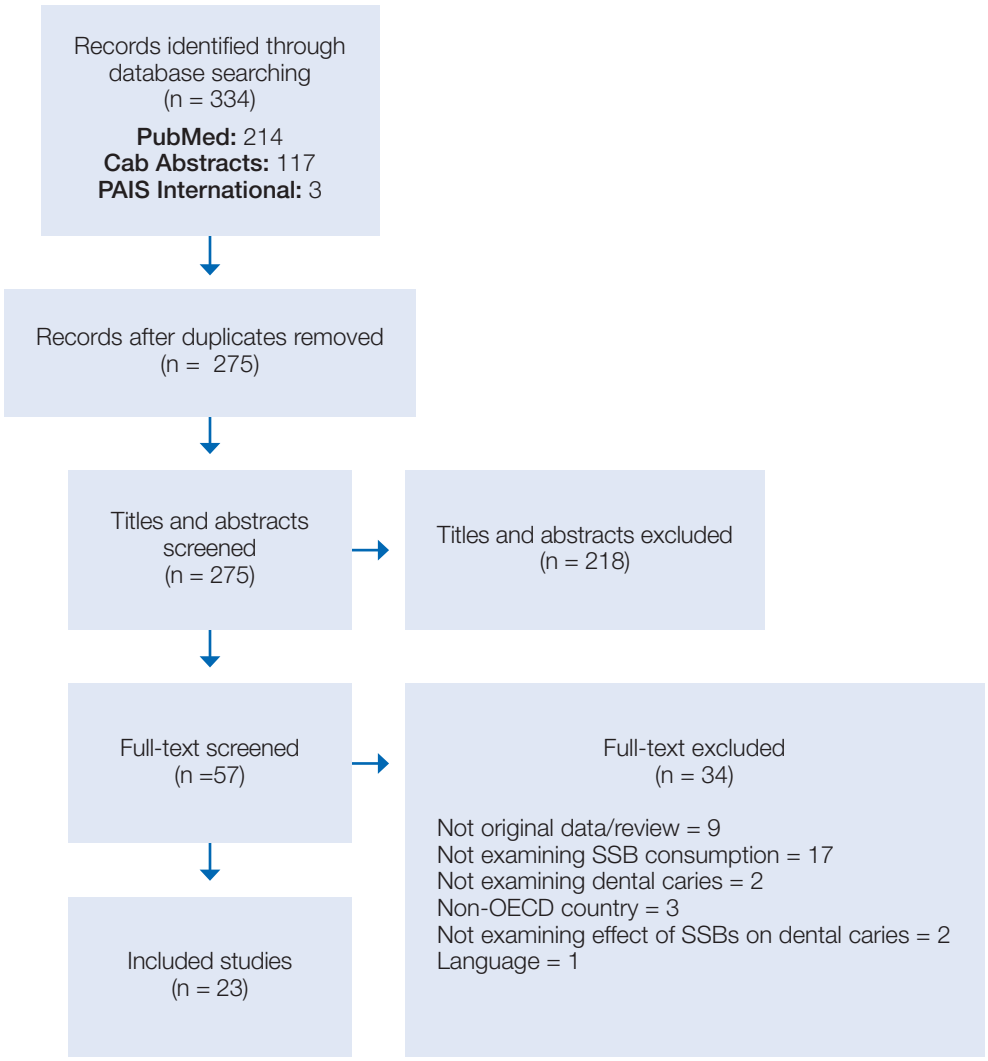
PRISMA Flow Diagram: Obesity



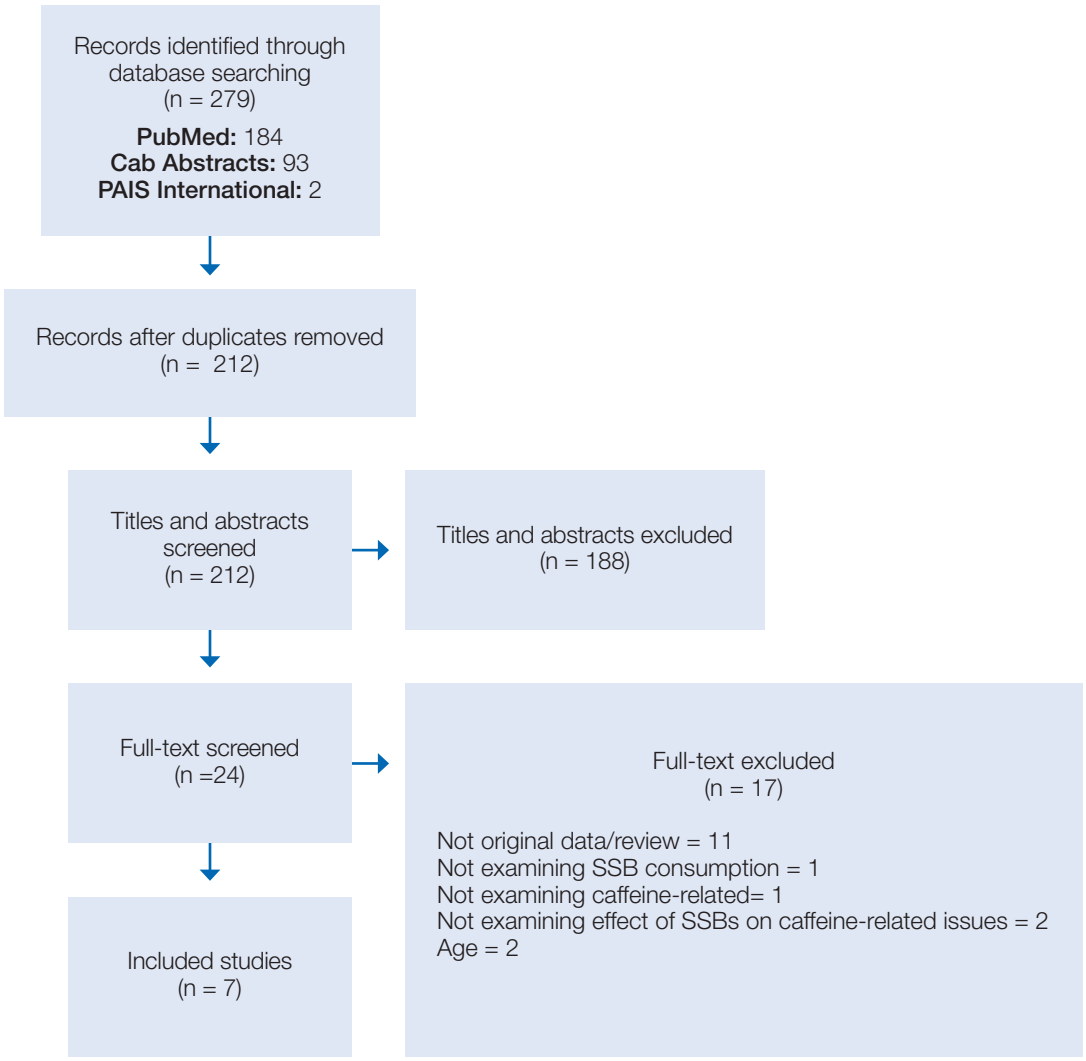
PRISMA Flow Diagram: Insulin Resistance



PRISMA Flow Diagram: Dental Caries



PRISMA Flow Diagram: Caffeine-related



About Healthy Eating Research

Healthy Eating Research (HER) is a national program of the Robert Wood Johnson Foundation. Technical assistance and direction are provided by Duke University under the direction of Mary Story, PhD, RD, program director, and Megan Lott, MPH, RDN, deputy director. HER supports research to identify, analyze, and evaluate environmental and policy strategies that can promote healthy eating among children and prevent childhood obesity. Special emphasis is given to research projects that benefit children and adolescents and their families, especially in lower-income and racial and ethnic populations at highest risk for obesity. For more information, visit ***www.healthyeatingresearch.org*** or follow HER on Twitter at ***@HEResearch***.

About the Robert Wood Johnson Foundation

For more than 40 years the Robert Wood Johnson Foundation has worked to improve health and health care. We are striving to build a national Culture of Health that will enable all to life longer, healthier lives now and for generations to come. For more information, visit ***www.rwjf.org***. Follow the Foundation on Twitter at ***www.rwjf.org/twitter*** or on Facebook at ***www.rwjf.org/facebook***.

Robert Wood Johnson Foundation