Evaluating a Public Health Policy: The Effect of a Sugar-Sweetened Beverage Portion Cap on Food and Beverages Purchased, Calories Consumed and Consumer Perception

By

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ABSTRACT

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Sheri Volger, M.S., RDN.

Rutgers, the State University of New Jersey
August 2020

Dissertation Chair: Dr. Pamela Rothpletz-Puglia

BACKGROUND: Policy makers have proposed implementing sugar-sweetened beverage (SSB) portion size cap policies as a public health initiative to curb SSB consumption and prevent obesity. Such a policy would eliminate larger portion-sizes of SSB and render the smaller-sized portion as the healthier, default option. This study evaluated the effects of an SSB portion-size cap on food and beverages purchased, consumed and caloric intake in three projects.

METHODS: First, a systematic scoping review of obesity prevention efforts in young children described obesity prevention efforts in the United States. Next, a cross-sectional survey study examined the association between a 16 ounces (oz) SSB portion-size cap at the Barclays Center and SSBs oz and food calories purchased and consumed compared to Madison Square Garden, an arena with no SSB portion restrictions. The final study examined the impact of the SSB portion-size limit and offering free SSB refills on food, beverage and SSB calories purchased and consumed during a randomized controlled simulated restaurant dining experience.

RESULTS: The scoping review found a limited number of community and societal public health obesity policy initiatives targeting young children. Study two found the portion-size cap was associated with Barclays customers’ purchasing 2.24 fewer beverage oz (95% confidence interval [CI]= 4.19, .29, p=.024) and purchasing and consuming 11.03 (95% CI= 17.21, 4.86, p<.001) and 12.10 (95% CI= 18.42, 5.78, p<.001) fewer SSB oz, after adjusting for sex, age, BMI, ethnicity, race, marital status, education, and income without
impacting food calories and arena-event experience. Study three did not find any association between an SSB portion-size restriction and food, beverage and SSB calories consumed during the simulated restaurant dinner meal but found that offering free SSB refills along with a 16 oz portion-sized SSB was associated with ordering a greater number of SSB compared with the current restaurant portion, purchase refill condition (0.66 vs. 0.40, p=.048).

**CONCLUSION:** This study provides preliminary real-world evidence of the effectiveness of an SSB portion-size cap in sporting arenas and suggests that SSB portion cap policies may be an effective public health strategy to reduce SSB consumption but may be limited by promotions such as free-refills.
Acknowledgement

First and foremost, I would like to express my deepest gratitude to my dissertation committee: Dr. Pamela Rothpletz-Puglia, Dr. Scott James Parrott and Dr. Christina A. Roberto. Our many meetings and lively discussions inspired this dissertation research and helped me develop new ideas and creative solutions. A special thank you to my Dissertation Chair and my Academic Advisor Dr. Pamela Rothpletz-Puglia who for the past six years provided me with strong encouragement, unwavering support, and valuable scientific guidance while she led me through my doctoral journey. Without the statistical guidance and great knowledge of Dr. Scott James Parrott, along with his unique sense of humor, the success of this dissertation would not have been possible. Many, many thanks to Dr. Christina A. Roberto for joining my dissertation committee at Rutgers and for generously providing access to her sugar-sweetened beverage research projects —Dr. Roberto’s compassionate assistance and scientific expertise cannot be overestimated. It has been a privilege to have had the opportunity to work with and learn from this amazing group of researchers.

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Chapter 1. Introduction and Background

Context and Background of the problem

The global prevalence of obesity has tripled in the last four decades. Obesity is affecting over 650 million (39%) adults worldwide and approximately 18% of all children are overweight or obese (World Health Organization [WHO], 2018). Similarly, the prevalence of adult and childhood obesity in the United States (US) remains at a 10-year high (QuickStats, 2020). Epidemiological data from the 2017-2018 National Health and Nutrition Examination Survey (NHANES) found 42.4% of all adults (≥20 years) and 19.3% of all youth (2 -19 years old) in the US were obese (QuickStats, 2020).

Furthermore, the prevalence of obesity tends to increase with age. For instance, in 2015-2016 the obesity prevalence rate was 13.9% in preschool children age 2-5 years. While during the same time period, the obesity rates among older children aged 6-11 years and 12-19 years were 18.4% and 20.6%, respectively, representing a 30% rise in the prevalence of obesity through adolescence (Hales, Fryar, Carroll, Freedman, & Ogden, 2018b). Moreover, the prevalence of obesity continues to raise through adulthood. In 2017-2018 the prevalence of obesity was 40.0% among younger adults aged 20 - 39 and the prevalence was the highest in adults 40-59 years old (Hales, 2020).

Obesity and Energy Balance
The etiology of obesity is multifactorial, with interacting biological, environmental, behavioral, social and psychological factors contributing to onset and progression of the disease. Unsurprisingly, an increasing number of studies are examining the contribution of various determinants of obesity including diet, activity, sleep, and microbiome (Luger et al., 2017). Obesity ultimately stems from a dysregulation between energy intake and physical activity expenditures, whereas a positive energy balance triggers the cascade of metabolic and physiological changes associated with the onset of obesity (Heymsfield & Wadden, 2017).

**Diet and Sugar-Sweetened Beverages (SSB)**

The largest sources of sugar in the US diets (34.4%) comes from sugar sweetened beverages (SSB) such as soda, energy drinks and sports drinks (Drewnowski & Rehm, 2014). While SSB are high in calories they are devoid of any meaningful nutritional value. In addition, SSB are inexpensive, heavily marketed, and served in large portions (Nielsen & Popkin 2003, Powell et al., 2016, Friedman & Brownell, 2012)

The definition of SSB varies across research studies and is often fit-for-purpose. The 2015–2020 Dietary Guidelines for Americans (US Department of Health and Human Services and U.S. Department of Agriculture [USDHHS & USDA], 2015) refer to SSB as “liquids that are sweetened with various forms
of added sugars (USDHHS & USDA, 2015). This includes beverages such as soda (regular, not sugar-free), fruit aides, sport drinks, energy drinks, sweetened waters, and coffee and tea beverages with added sugars” (USDHHS & USDA, 2015).

Added sugar accounts for approximately 14.0% of the total dietary energy intake in diets of US adults and children (Drewnowski & Rehm, 2014). An examination of beverage consumption patterns from 2013 to 2016 in children ages 2 to 19 years found that soft drinks (e.g., diet soda, non-diet soda, fruit drinks, sweetened bottled waters and fruit nectars) accounted for almost 20% of the total beverages consumed (Herrick, Terry, & Afful, 2018). Moreover, during childhood, the contribution of SSBs to total beverage intake increases with age and is greater in racial and ethnic minorities. For example, the proportion of soft drinks consumed by children ages 2-5 (13.0%) increased to 20.9% in children 6-11, a dramatic 60% increase. In addition, statistically significant differences in SSB consumption patterns were shown between race and ethnic groups with the contribution of SSB to total beverage intake was highest among non-Hispanic blacks (30.4%) compared with Hispanic (21.5%), non-Hispanic white (17.5%), non-Hispanic Asians (8.8%) youth (Herrick et al., 2018).

The definition of what constitutes sugar sweetened beverages (SSB) varies across research studies and is often fit-for-purpose. The 2015-2020
Dietary Guidelines for Americans (US Department of Health and Human Services and U.S. Department of Agriculture [USDHHS & USDA, 2015) refer to SSB as “liquids that are sweetened with various forms of added sugars (USDHHS & USDA, 2015). This includes beverages such as soda (regular, not sugar-free), fruit aides, sport drinks, energy drinks, sweetened waters, and coffee and tea beverages with added sugars” (USDHHS & USDA, 2015).

**SSB and Health**

As awareness of the complex relationship between the diet, physical activity, environment, and obesity has grown, so has the interest in examining the extent to which SSB contribute to the ongoing obesity epidemic. An increasing body of evidence has shown that SSB consumption is associated with obesity and has a negative impact on long-term health. (Bleich & Vercammen, 2018; Luger et al., 2017; Malik, Pan, Willett, and Hu, 2013). Numerous research studies and systematic reviews have demonstrated a positive association between the SSB consumption and weight gain; (Malik, Schulze, & Hu, 2006; Malik et al., 2013; Qi et al., 2012; Schulze et al., 2004), adiposity, type-2 DM (Hu, 2013; Schulze et al., 2004), dyslipidemia, blood pressure and cardiovascular health in adults. (Brown et al., 2011; de Koning et al., 2012; Dhingra et al., 2007; Vos et al., 2017; Yang et al., 2014). Most recently, a secondary analysis from an observational study in US adults, 45
years and older, also found a positive association between sugary beverages and risk of all-cause mortality (Collin, Judd, Safford, Vaccarino, & Welsh, 2019).

Similarly, numerous research studies and literature reviews have shown an association between SSB and increased energy intake in adults and children (Hollands et al., 2015; Mrdjenovic & Levitsky, 2003; Piernas & Popkin, 2011), along with an association between SSB and the risk of overweight and obesity (Bleich & Vercammen, 2018; de Ruyter, Olthof, Seidell, & Katan, 2012; Ebbeling et al., 2012; Ebbeling et al., 2006; Forshee, Anderson, & Storey, 2008; Malik et al., 2013; Zheng et al., 2015), increased adiposity (Zheng et al., 2015), dental carries (Bleich & Vercammen, 2018) and insulin resistance in children (Bleich & Vercammen, 2018).

A meta-analysis of 10 observational and 2 randomized controlled trials (RCTs) in children and adolescents found a small (approximate 0.02 BMI units), nonsignificant relationship between change in BMI and change in SSB consumption (per change in 12-oz serving) (Forshee et al., 2008). However, subsequent reviews by Malik et al., and Luger et al. covering over 70 studies concluded that a positive association exists between SSB consumption and weight in adults and children (Luger et al., 2017; Malik et al., 2013). The authors attributed this new finding to many factors including a larger number high-quality, non-industry studies (Luger et al., 2017).

The majority of the evidence informing the health benefits of limiting SSB is derived from population-based, cross-sectional or longitudinal cohort studies,
which are not designed to either demonstrate causality or to measure the contribution of individual risk factors (Barlow, 2007). In addition, only a limited number of RCTs have been conducted to confirm the relationship between SSB and weight gain during childhood (de Ruyter et al., 2012; Ebbeling et al., 2012; Ebbeling et al., 2006). Thus, there is a need for robust interventions establishing a direct link between the consumption of SSB and obesity, along with studies evaluating the benefits of health policies aimed at reducing the consumption of unhealthy sugary beverages.

Public Health Food and Nutrition Policies

Although there is a lack of scientific evidence demonstrating that SSB causes adverse health outcomes, the abundance of research showing an association between SSB and obesity has triggered numerous proposals to implement SSB public health policies aimed at reducing SSB purchasing and consumption patterns. National, state and local regulations are effective tools that can be employed to protect and promote public health. Taking a lesson from the success of public health policies such as the anti-tobacco policies, seat-belt laws and vaccine regulations, there is convincing evidence to support implementing a similar comprehensive approach towards policies aimed at reducing SSB consumption. Accordingly, professional and scientific organizations unanimously support implementing public health policies that focus on changing the environment to reduce the consumption of dietary sugar
and SSBs. For example, the American Medical Association (AMA) encouraged implementing state and local taxes on SSBs to raise revenues to fund obesity prevention public health initiatives (American Medical Association [AMA], 2017). Furthermore, pediatric societies have endorsed recommendations eliminating the intake of SSB in infants, children and adolescents and have called for national policies aimed at reducing the consumption of added sugars (Fidler et al., 2017).

Research Trends and Gaps: SSB Obesity Prevention Efforts

Major international and national health organizations and scientific societies have recognize the potential negative impact of SSB on short- and long-term health outcomes and thus have called for a reduction in that amount of SSBs consumed by youth and adults (Office of Disease Prevention and Health Promotion [ODPHP], 2018; Office of Surgeons General, 2010; White House Task Force on Childhood Obesity, May 2010; WHO, 2012) Whereas there is overwhelming consensus on the health benefits of programs limiting SSB, experts often disagree about what types of SSB food and nutrition policies are the most cost-effective to implement. Numerous reviews have examined the effectiveness of a wide range of obesity prevention interventions in a variety of populations and settings (Bleich et al., 2018; Laws et al., 2014; Ling, Robbins, & Wen, 2016; Matwiejczyk, Mehta, Scott, Tonkin, & Coveney, 2018; Volger, Rigassio Radler, & Rothpletz-Puglia, 2018; Ward et al., 2017). A
common finding is that very few RCTs have been adequately designed and powered to measure the direct effects of food and beverage public policies, including SSB policies analyzing using real-world data (Mayne, Auchincloss, & Michael, 2015). This gap in the scientific evidence is even more pronounced in studies focused on the effect of obesity prevention policies in young children (Volger et al., 2018).

In general, the small number of policy evaluation studies may be due to the fact that obesity prevention policy initiatives tend to be population-based, multi-level, multi-component interventions, targeting a wide range of outcomes in a variety of settings. Furthermore, obesity prevention policy programs are frequently designed to modify multiple variables, hence, it is challenging to gauge the effectiveness of individual interventional components (i.e., limiting SSB). It is also challenging to evaluate the effects of obesity policy interventions on weight-based measures of population health over time without ongoing state and local health surveillance programs (Blondin, Giles, Cradock, Gortmaker, & Long, 2016). Consequently, obesity prevention policy proposals may include a component limiting SSB and are frequently informed by a limited number of interventional studies and epidemiological survey data, as opposed to real-world evidence (Dietz, 2015).

**Simulation Models**
Considering the lack of empirical evidence, simulation models have evolved to predict the effect and cost-effectiveness of a variety of obesity prevention policies. Microsimulation model studies have estimated the effect of an excise tax of SSBs on BMI, along with the annual cost of the policy and cost per person BMI unit reduction /averted and future health costs savings (Long et al., 2015; Ma & Frick, 2011). Whereas, Markov simulations have been developed to calculate the effectiveness of a range of hypothetical obesity prevention policies such as eliminating tax subsidy of TV advertising to children (Sonneville et al., 2015), mandatory early care education policy changes (Wright et al., 2015), and mandatory active physical education in elementary schools (Barrett et al., 2015). Collectively, simulation models provide policy makers, decision makers and funding bodies with supportive evidence to allow for the comparison of dissimilar policies, including policy reach, cost, effectiveness, and net-cost savings (Gortmaker et al., 2015) and help guide value-based implementation and funding decisions (Dietz, 2015).

**Research Aims, Questions, Hypothesis**

Policy makers have proposed implementing public health initiative aimed at SSB portion size cap policies to reduce the prevalence of obesity. Such a policy would eliminate larger portion sizes of SSB and render the smaller sized portion as the healthier, default option. While a portion size restriction has been proposed it has never been implemented. The goal of the
present dissertation is to answer the overarching research question “what are the effects of a policy that limits the portion size of SSB on beverage purchases, beverage consumption, and caloric intake?”

Therefore, the focus of this dissertation is on evaluating the short-term impact of a policy limiting the portion size of SSB. Three projects were undertaken and are included in the present dissertation. Additional details regarding the Project’s methods and statistical analysis plan are described in detail in Chapter 3.

Project 1: Scoping Review of Obesity Prevention Efforts

The Scoping Review of Obesity Prevention Efforts aimed to identify, “map”, and synthesize a wide-range of scientific evidence examining obesity prevention interventions, programs and policies in children under six years old. The review was not designed to confirm a research hypothesis; instead the goal was to describe the scientific evidence, identify obesity prevention knowledge gaps and subsequently to inform future research projects. The scoping review answered the following research questions: “What types of interventions and policies are being used for obesity prevention across the early life course and at multiple levels of influence?” and “How effective are they?” The secondary aim of the review was to describe the best available evidence on the cost and cost-effectiveness of early childhood obesity prevention interventions and policies.
Project 2: Real-world SSB Limit Policy Study

The objective of the Real-world SSB Limit Policy Study was to examine the impact of a 16 oz SSB portion size limit on the volume of beverages purchased and consumed, and on total caloric intake by adults attending NBA and WNBA games in New York City (NYC). The initial research plan included computing the primary outcome endpoint “total calories” from SSB calories and food calories. Yet, upon review of the final study database, it was determined that the dataset did not include the caloric reference values for SSBs sold at the two arenas. Therefore, the specific aims and hypothesis were revised to instead reflect SSB volume, a more reliable and relevant primary endpoint measurement.

The final specific aims and hypothesis were as follows:

Aim 1: Examine the impact of 16 oz SSB portions on total food and beverage calories purchased.

H1: Fewer average ounces of SSB beverages will be purchased at the Barclays Center, which serves smaller SSB portions, compared to Madison Square Garden.

Aim 2: Determine the impact of smaller SSB portion sizes on customer satisfaction with their event experience, including satisfaction with size of beverages and enjoyment of food and beverage.
H2: There will be no differences in customer satisfaction among the arenas.

**Aim 3:** Determine the impact of the customers’ general perception of restaurant food and beverage portion sizes and their perception of the NYC’s proposed portion cap policy on satisfaction with the size of beverages at the Barclays Center.

H3: There will be an association between satisfaction with the 16 oz portion size of SSB beverages and a general perception that food and beverage portion sizes in restaurants are “too large” and approval of the NYC proposed portion size cap policy, at the Barclays Center.

**Project 3: SSB Portion Limit Dining Lab Randomized Controlled Trial (RCT)**

The objective of *SSB Portion Limit Dining Lab Randomized Controlled Trial (RCT)* was to examine the impact of limiting the portion size of SSB to 16 oz in a laboratory dining setting. Specifically, the study was designed to examine impact of four SSB menu conditions limiting the size of SSB offered on a restaurant menu and the availability of free fills on beverage and food purchases, consumption patterns and caloric intake at the test meal and subsequent meals (over a 24-hour period). After the primary outcome analyses were complete, we did not find a significant portion size effect. Therefore the study team updated the statistical analysis plan and did not to conduct any
further analysis of the 24-hour diet recall data. Therefore, the specific aims and hypothesis were updated accordingly.

The final study aims and hypothesis were as follows:

**Aim 1.** Determine the total calories ordered and consumed from food and beverages at a dinner meal.

H1: Adults in the 16 oz SSB portion limit (16 oz beverage size limit) with the option to purchase refills condition will order fewer total calories during the dinner meal compared to those in the current restaurant SSB portions (control) condition plus free refills conditions.

H2: Adults in the 16 oz SSB portion limit (16 oz beverage size limit) with the option to purchase refills condition will consume fewer total calories during the dinner meal compared to those in the current restaurant SSB portions (control) condition plus free refills conditions.

**Aim 2.** Determine total beverage and food calories ordered and consumed

H3: There will be no significant differences across conditions in food calories consumed after the dinner meal.

H4: Total beverage and total SSB calories ordered and consumed during the dinner meal will be highest in the current restaurant SSB portion with free refills condition and lowest in the SSB portion limit group with no free refills.

**Aim 3.** Examine meal enjoyment and satisfaction.
H5: There will be no differences across SSB menu conditions in participants’ satisfaction and enjoyment of their meal.

**Aim 4.** To examine the relationship between calories from SSB and food consumed and post-meal hunger ratings.

H6: There will be no difference in post-meal hunger ratings between the SSB, no refills condition and the other three SSB menu conditions.

**Significance for the Study**

This project provides empirical evidence of the effects of SSB portion cap policies on SSB purchases, SSB consumption, caloric intake and perception of a portion limit policy. There were several factors that supported the significance for such a study. As previously noted, there is an association between SSB and obesity but there are limited data demonstrating a direct link between SSB policies and a reduction in the SSB sales and consumption patterns, along with a reduction in the energy intake.

While a policy limiting the size of SSB was passed by the NYC Board of Health, the policy was never enacted. Thus, there is no real-world evidence demonstrating the effectiveness of an SSB portion size cap policy.

To foster widespread implementation of SSB portion size policies there is a need to generate scientific evidence demonstrating the effectiveness of the proposed policy. The results of this study will add to the growing body of evidence needed to demonstrate the effectiveness of SSB policies. The results
will inform the design if future policy research studies, promote the development of SSB policy proposals and facilitate the implementation of evidence-based SSB policy decisions. Results of this study will assist local policy makers to overcome the lack of scientific evidence, unfavorable public perceptions and local barriers. Ultimately, this project may support the development, dissemination and adoption of SSB portion size cap polices.

**Study Manuscripts**

Three manuscripts are associated with this dissertation research. The first manuscript titled: “Early childhood obesity prevention efforts through a life course health development perspective: a scoping review,” provided the foundation for this dissertation research and was recently published in PLOS ONE (Volger et al., 2018). The working titles of the 2nd and 3rd manuscripts are “Associations of a Sugar-sweetened Beverage Portion Limit Policy and Beverage Ounces Purchased and Consumed at a Sporting Arena” and “Evaluating a Portion Cap Policy on Sugar-Sweetened Beverages: a Randomized Controlled Restaurant Dining Trial.” A general description of each manuscript, the target journal and the relationship of each manuscript to the overall dissertation research is described below.

A scoping review was conducted to provide an overview of the current state of obesity prevention interventions and policies in normal-weight children
under six years of age in the US. A detailed description of the methodology and published manuscript can be found in Chapter 4.

Among the key findings, the review identified only a small number of studies evaluating the effect of public health policies on childhood obesity. In addition, the review found considerable uncertainty around estimates of the health and economic impact of early childhood obesity prevention interventions and policies. It was concluded that there is a need for future research studies evaluating the effect of obesity prevention public health policies.

Building on the findings of the scoping review, the analysis of data from two additional projects were planned to fill this gap in scientific evidence. The dissertation includes the analysis of data from two studies that were previously conducted but never analyzed. These research studies evaluating the impact of an SSB portion size cap. The manuscript from Project 2, “Real-world SSB Limit Policy Study,” describes the results of a cross-sectional, observational study evaluating the impact of a natural experiment simulating an SSB portion cap policy.

In 2012, the New York City (NYC) Board of Health adopted an amendment (§81.53) to the city’s health code, the Sugary Drink Portion Cap Rule. The regulation limited the maximum size of sugary beverages sold (or provided) in food service establishments (“FSEs”) throughout NYC (Department of Health and Mental Hygiene [DOHMH], 2012). While the regulation was eventually overturned by the NY State Supreme Court (Oldroyd,
Burns, Lucas, Haikerwal, & Waters, 2008), the Barclays Center voluntarily adopted the policy’s maximum size (16 oz) sugary drink and cup size regulation. This study evaluated the effects of the 16 oz SSB portion cap policy at the Barleys Center compared with no SSB portion cap at Madison Square Garden on food and beverage purchases, food energy intake and customer perception of NBA and WNBA arena-goers (See Chapter 3. Methods for study details).

The target journal is the American Journal of Public Health (AJPH) with its interest in population-based, public health policy evaluations. The manuscript has been written for the journal’s primary audience of researchers, public health professionals and health policy decision makers. The results of the study are presented in a manuscript suitable for the “Research Article” submission category. The manuscript format meets AJPH’s requirements for a structured abstract (180 words), a text body of up to 3,500 words and contain the appropriate number of tables and figures combined with the citation of up to 35 references (AJPH, 2020).

The reporting of the research study follows the journals requirements and includes an Introduction, Methods, Results and Discussion sections. The manuscript also summarizes the public health implications of the study's findings. Finally, in accordance with the journals reporting standards for non-randomized controlled studies, the Transparent Reporting of Evaluations with
Nonrandomized Designs (TREND) Statement’s Checklist (Des Jarlais, Lyles, & Crepaz, 2004) was applied during the manuscript writing process.

The third and final manuscript reports the results of a previously conducted RCT evaluating the effect of limiting the portion size of SSB on the beverage and food intake of adults during a simulated restaurant lab-based, dinner meal. The Methods section includes a detailed description of the study design. Briefly, participants were randomized to one of four experimental beverage groups:

1) current SSB restaurant portions with option to purchase refills
2) current SSB restaurant portions plus free refills
3) 16 oz SSB portion with option to purchase refills
4) 16 oz SSB portion plus free refills

Similar to the study comparing the effects of the 16 oz SSB portion cap policy at the Barleys Center, the target journal for the final manuscript is also AJPH. The results of the study will be submitted as a “Research Article.” The format will include a structured abstract (180 words), a text body of up to 3,500 words, contain the appropriate number of tables and figures combined, and cite up to 35 references (AJPH, 2020). Given that this study was an RCT, the preparation and reporting of the study results followed the Consolidated Standards of Reporting Trials (CONSORT) guidelines (Schulz, Altman, & Moher, 2010).

**Relationship of the manuscripts to overall dissertation project**
The three manuscripts are complementary to each other and provide a unique perspective. While there are many studies evaluating the effects of obesity prevention interventions, the first manuscript confirmed the need for additional studies demonstrating the effectiveness and cost-effectiveness of obesity prevention public health food and nutrition policies. Addressing this need, the two subsequent manuscripts examined the effect of a public health food policy —— 16 oz SSB portion size caps. Since SSB portion size cap policies have not been implemented, each manuscript examined the impact of such a policy using two unique lines of research.

In the second manuscript, real-world evidence is presented showing the effect of a natural experiment at the Barclays, mimicking a 16 oz SSB portion size cap policy. While the third manuscript was designed to provide strong empirical evidence from a classic lab-based, RCT study demonstrating the effectiveness of the SSB portion size cap policy under controlled conditions. Together, the three manuscripts build on each other and add to the body of public health policy evaluation evidence documenting the potential effectiveness of a 16 oz SSB portion size cap policy.
Chapter 2. Theory and Literature Review

Introduction

SSB Policy Initiatives

There is a broad range of public health policy options targeting SSB-related purchasing and consumption behaviors. These strategies span in intensity from low intensity educational campaigns focused on increasing public awareness of the health risks associated with excessive SSB consumption to highly restrictive policies eliminating the availability of SSB. Within the range of possibilities are numerous policies that enable and guide the choice of healthy beverages in various populations and settings (Cawley, 2018; Institute of Medicine Committee on an Evidence Framework for Obesity Prevention Decision, [IOM] 2010; Vermeer, Steenhuis, & Poelman, 2014; Willett, 2013). Table 1 presents a general framework for public health policies designed to limit the availability and consumption of SSBs.
### Table 1. Policy Strategies to Limit SSB Availability and Consumption*

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<tr>
<td>Restrictive advertising/marketing</td>
<td>Reduce marketing/exposure</td>
<td>Restricting/banning advertising SSB to youth</td>
<td>Reduce marketing/exposure</td>
<td>Maine regulation, Advertising on School Grounds: Maine Statutes: Title 20 A: Chapter 223, Sub Chapter 9, 6662; prohibits the advertising of certain unhealthy beverages on school grounds (Legislature, 2007).</td>
</tr>
<tr>
<td>SSB Labeling</td>
<td>Provide information (calories in SSB) to influence consumer point-of-purchase behavior and decrease portion of SSB purchased</td>
<td>Menu labeling</td>
<td>Provide information (calories in SSB) to influence consumer point-of-purchase behavior and decrease portion of SSB purchased</td>
<td>National: Section 4205 of the US Patient Protection and Affordable Care Act (2010) requires chain restaurants with 20 or more establishments to display energy information on menu items, including SSB. State and cites with local labeling policies: California, Maine, Massachusetts, New Jersey, Oregon, Tennessee and Vermont; Cites: NYC; King County, WA; San Francisco Nutrition Facts Labels through the 1990 Nutrition Labeling and Education Act</td>
</tr>
<tr>
<td>Economic strategies and incentives</td>
<td>Guide healthy choice at point-of-purchase through economic incentives; healthy</td>
<td>SSB excise and duty tax</td>
<td>Guide healthy choice at point-of-purchase through economic incentives; healthy beverages become</td>
<td>Countries with national taxes on SSB: Bahrain, Barbados, Belgium, Bermuda, Brunei, Chile, Dominica, Ecuador, Fiji, Finland, France, French Polynesia, Hungary, India, Ireland, Kiribati, Latvia, Mauritius, Mexico, Norway, Palau, Peru, Philippines, Portugal, Samoa,</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Information</td>
<td>Provide consumer information</td>
<td>Encourages manufactures to reformulate SSB or reduce package size</td>
<td>Enables healthy choices by displaying on the FOPL simplified nutrient and portion size information and/or supplementary visual indicators or interpretive labels</td>
<td>Reformation of lower calorie beverages and smaller serving sizes</td>
</tr>
<tr>
<td></td>
<td>Encourages manufactures to reformulate SSB or reduce package size</td>
<td>Enable healthy choices by displaying on the FOPL simplified nutrient and portion size information and/or supplementary visual indicators or interpretive labels</td>
<td>Inform consumers of the health risks associated with SSB consumption</td>
<td>Over 30 nations have implemented mandatory or voluntary FOPL laws including: UK, NutriScore label with a color scale ranging from dark green to dark red, associated with a letters score from A to E; Australia and New Zealand, Health Star Rating (HSR) system; in Chili the Law of Nutritional Composition of Food and Advertising requires FOPL in black and white in a stop sign that reads “HIGH IN CALORIES or SUGAR”; Sri Lanka, Red Traffic Light labels on SSB</td>
</tr>
<tr>
<td></td>
<td>Enable healthy choices by displaying on the FOPL simplified nutrient and portion size information and/or supplementary visual indicators or interpretive labels</td>
<td>Inform consumers of the health risks associated with SSB consumption</td>
<td>Hypothetical proposal to add health warning labels to SSB (VanEpps &amp; Roberto, 2016)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Front-of-package labels (FOPL)</td>
<td>Health Warning Labels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limiting availability with food and nutrition standards</td>
<td>Restrict choices and limit the availability of SSB; only provide access to healthy beverages; healthy beverages become the default option</td>
<td>School lunch program nutrition standards and Early childhood education nutrition standards</td>
<td>Restrict choices and limit the availability of SSB; only provide access to healthy beverages; healthy beverages become the default option</td>
<td></td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Capping the amount of sugar food manufactures could add into the food supply</td>
<td>Capping the amount of sugar food manufactures could add into the food supply</td>
<td>Capping the amount of sugar food manufactures could add into the food supply</td>
<td>Saudis Arabia, South Africa, Spain, St Helena, Thailand, Tonga, UAE, UK, Vanuatu</td>
<td></td>
</tr>
<tr>
<td>Cap and Trade policy</td>
<td>Cap and Trade policy</td>
<td>Cap and Trade policy</td>
<td>US excise taxes States: Arkansas, Tennessee, Virginia, and West Virginia; Local taxes: Albany, Berkeley, Boulder, Oakland, Philadelphia and the Navajo Nation, King County, Washington (Paarlberg, Mozaffarian, &amp; Micha, 2017) Hypothetical policy aimed at food manufactures; policy would promote reformation of foods with less sugar and smaller portion sizes (Basu &amp; Lewis, 2014)</td>
<td></td>
</tr>
<tr>
<td>Healthy, Hunger-Free Kids Act of 2010, public law setting nutrition standards in the National School Lunch and School Breakfast Programs; SSB not allowed and only calorie-free carbonated beverages are permitted in high schools (United States Department of Agriculture, 2010)</td>
<td>The Healthy, Hunger-Free Kids Act of 2010, public law setting nutrition standards in the National School Lunch and School Breakfast Programs; SSB not allowed and only calorie-free carbonated beverages are permitted in high schools (United States Department of Agriculture, 2010).</td>
<td>NYC Board of Health enacted local food standards for NYC childcare centers prohibiting SSB and limiting the portion size of 100% juice to 6 oz (Kansagra et al., 2015)</td>
<td>NYC Board of Health enacted local food standards for NYC childcare centers prohibiting SSB and limiting the portion size of 100% juice to 6 oz (Kansagra et al., 2015)</td>
<td></td>
</tr>
<tr>
<td>Vending machine standards</td>
<td>Worksite and public procurement standards</td>
<td>Boston Public Schools vending contracts restricting sales of SSB (Cradock et al., 2011)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Five states (Arkansas, Florida, Washington DC, Texas, Indiana prohibit SSB sales in vending machines in elementary school vending machines</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Massachusetts State Agency Food Standards limiting the maximum levels of calories in beverages supplied to agency run hospitals, prisons, childcare services

| Portion size restriction legislation | Eliminate choice of large portions and changes food environment; limits SSB portion size; default option becomes small serving size | Portion size limits | Eliminate choice of large portions and changes food environment; limits SSB portion size; default option becomes small serving size | NONE |

*Adapted from (Cawley, 2018; IOM Committee on an Evidence Framework for Obesity Prevention Decision, 2010; Vermeer et al., 2014; Willett, 2013)*
Increase Public Awareness and SSB Education

The purpose of public health education campaigns is to educate the public and increase awareness of the health consequences associated with SSB. These campaigns provide consumers with important information about the risks associated with SSB consumption and the benefits of healthy beverage choices. As such, there have been numerous State, City, and Country-wide campaigns explaining the hazards of SSB consumption. For example, the NYC Department of Health sponsored two major health campaigns, “Pouring on the Pounds Campaign” in 2009 and “Your kids could be drinking themselves sick,” in (2013 - 2014) aimed at increasing public awareness about the amount of sugar present in sugary drinks and the association between SSB and obesity (Kansagra et al., 2015). While Howard County, Maryland conducted a multimedia (TV ads, social media marketing, direct mail and open-air advertising) that generated approximately 17 million “views” over a 3-year period and was associate with a downward trend in SSB sales (Schwartz et al., 2017).

Guidelines

Dietary guidelines provide a standard set of healthy dietary recommendations, including establishing recommended limits for the consumption of SSB. For example, the World Health Organization (WHO) recommends that adults and children should reduce their dietary intake of free
sugar to less than 10% of total energy intake, throughout the life course (WHO, 2015). Similarly, the US Dietary Guidelines for Americans 2015-2020 (USDHHS & USDA, 2015) recommends a healthy eating pattern, an appropriate caloric intake and consuming beverages that are nutrient dense and low in added sugar (USDHHS & USDA, 2015). Finally, dietary guidelines endorsed by the American Academy of Pediatrics (AAP) recommend that children should reduce their consumption of dietary sugar and consume a diet free of SSB (Daniels & Hassink, 2015).

**Restrictive Advertising / Marketing**

There is a growing body of evidence demonstrating the negative influence of advertising unhealthy food and beverages on caloric intake and BMI in children (Andreyeva, Chaloupka, & Brownell, 2011; Russell, Croker, & Viner, 2019). Thus, the goals of restrictive advertising policies are to reduce SSB TV/screen advertising exposure, decrease the demand for SSB and decrease SSB purchases and consumption. Sonneville et al. simulated the cost effectiveness of a national policy eliminating the tax subsidy of television advertising of unhealthy food products to youth. They predicted that such a policy would reach around 74 million children aged 2–19 years and costs $1.16 per BMI unit reduced, and result in a decrease in the prevalence of obesity by around 0.30% (Sonneville et al., 2015). Although there are no national polices restricting the advertising of SSB, on a state level, a 2017 State of Maine
legislative regulation prohibited advertising of unhealthy food and beverages in all schools (Maine Legislature, 2007).

SSB Labeling Policies

There are many types of food and beverage labeling policy proposals intended to educate and guide consumers towards healthy food and beverage choices. Menu labeling laws provide consumers with the caloric information for food and beverage items displayed on restaurant’s menus. The national Nutrition Labeling and Education Act requires chain restaurants with 20 or more establishments to display the energy information of all menu items, including SSB (Nutrition Labeling and Education Act of 1990…(2006), 2010); however, more restrictive menu labeling laws have been implemented at the city and local level (Robert Wood Johnson Foundation, 2016). A recent Cochrane systematic review found a small overall positive effect of nutritional labeling on reducing caloric intake without any risk of harm (Crockett et al., 2018). Although only a small number of RCTs were included in the review, a sub-analysis of the 3 RCTs found a significant reduction in the number of kcal purchased (approximately 47 kcal) with menu labeling in restaurants.

In the US, nutrition fact panels display the number of calories in one single serving and the number of servings per package on packaged food and beverage. Recently, the FDA revised the current labeling regulations and mandated that the serving sizes listed on labels be increased to align with the
portion size of typically foods consumed in the US (Food and Drug Administration, 2016). Unfortunately, a recent study conducted by the Economic Research Services found that approximately 42% of consumers reported only low levels of nutrition information usage (Zeballos E, 2018).

Accordingly, there is mounting interest in policy regulations that would require simplified “Front of the Package Labeling” (FOPL) and warning labels. Such policies would require food and beverage manufactures to display easy to understand nutrition labels on the front of food and beverage packages. Requiring FOPL has the potential to improve consumer understanding of the health-related consequences of SSB and would support efforts to decrease the amount of SSB consumed (Roberto, Wong, Musicus, & Hammond, 2016). In addition, to providing consumers with easy access to important nutritional information, FOPL polices may incentivize manufactures to reformulate SSB and/ or reduce package sizes to avoid the need to list undesirable nutrition and health information on the FOPL (Roodenburg, Popkin, & Seidell, 2011).

**Economic Strategies**

A beverage tax is an example of an obesity prevention policy that discourages the consumption of SSB by increasing beverage prices at the point of purchase. Unlike a sales tax that is added to the price of the merchandise at the check-out counter, a beverage excise tax is added to the price of goods at the distributor level. The retailer in turns passes a portion of or the entire tax on
to the customer in the form of a higher list price on the retailer’s shelf. The difference between the shelf price of taxed and untaxed beverages sways consumer purchasing behaviors, and drives down the demand for and consumption of SSB. In the US, the first beverage tax was successfully implemented in Berkeley, California. Initiation of the 1 cent per-ounce beverage excise tax resulted in a 21% reduction in self-reported consumption of SSB within the first 6 months (Falbe et al., 2016), and a 9.6% decline in SSB sales in Berkeley stores within the first year (Silver et al., 2017).

In January 2017, the city of Philadelphia became the second city in the US to enact a 1.5 cents-per-ounce beverage excise tax, levied on both SSB and artificially sweetened diet beverages. For the policy to gain wide-spread support it was framed as a financial strategy, as opposed to a health initiative (Purtle, Langellier, & Le-Scherban, 2018). Thus, the revenues generated by the tax are earmarked to expand public funding of free quality pre-kindergarten education programs, improve the quality of existing early childhood education programs and enhance community parks, recreation centers and libraries. In the first two months following the implementation of the sweetened beverage tax (SBT), a telephone survey found the excise tax was associated with a decrease in self-reported consumption of regular soda and energy drinks, with a parallel increase in bottled water consumption (Zhong, Auchincloss, Lee, & Kanter, 2018). Most recently, Roberto and colleagues showed that the SBT was associated with a considerable increase in the price of taxed sweetened
beverages ranging from 0.65 cents/oz at supermarkets to a 1.56 cents/oz increase at pharmacies. In addition, one-year post SBT initiation there was a 51% reduction in the sales of taxed sweetened beverages in Philadelphia. In total, after accounting for the increase in cross-border beverage sales, total taxed beverage sales in Philadelphia decreased by 38% (Roberto et al., 2019).

**Limiting Availability with Food and Nutrition Standards**

Numerous food and beverage standards have been implemented to restrict access to SSB while at school, work, and in government owned properties. Examples of such standards include: early childhood education and school nutrition standards, vending machine standards, worksite standards, and public procurement standards. One of the most widely recognized food standards is the US Healthy, Hunger-Free Kids Act (HHFKA) of 2010. The federal statute was part a childhood obesity prevention program that established nutrition standards in the National School Lunch and School Breakfast Programs (United States Department of Agriculture, 2010). Specifically, the HHFKA restricts the sale of “foods of minimal nutritional value” including SSB in cafeterias, vending machines, snack bars and school-based fund raisers.

However, states and community school districts have successfully implemented stricter local food standards. For instance, the NYC Board of Health enacted local food standards for NYC childcare centers prohibiting SSB
and limiting the portion size of 100% juice to 6 oz (Kansagra et al., 2015). While a similar school district-wide food standard policy in Boston, MA resulted in a significant reduction in SSB consumption among high school students (Cradock et al., 2011).

**Portion Size Restrictions**

Finally, portion size cap policies are another potential public health initiative that would seek to restrict the availability of larger sized portions of SSB and render smaller sized portions as the healthier default option. However, the effectiveness of a real-world SSB portion size cap policy is unknown since legislators remain reluctant to pass regulations aimed at reducing the consumption of SSBs.

The failure to implement any SSB-limiting policy may be because food and beverage regulations are frequently met with opposition from local businesses, beverage distributors and related associations who fear loss of jobs and revenues (Huang et al., 2015; Purtle et al., 2018). Furthermore, local residents may object to food policies on the basis that they should be allowed to make their own decisions and object to the government creating a “nanny state” (IOM, 2010). Similarly, numerous (non-legal) arguments were made against the proposed NYC SSB portion size cap policy including: SSB are not the proper target for obesity prevention policies; the SSB portion cap policy will not be effective; it is not needed; it is unfair, and it disproportionately hurt businesses and low-income families (Roberto & Pomeranz, 2015).
In order to win stakeholder support for SSB public health policies, educational campaigns are required to educate the public about the benefits of such a policy (Vermeer et al., 2014). For example, drawing from the experiences of cities where SSB tax policies failed to pass, extensive multimedia educational campaigns have been suggested as a way gain support for such initiatives (Paarlberg et al., 2017). Nevertheless, without convincing scientific evidence linking SSB-limiting policies to a reduction in SSB consumption it is challenging to educate the community, moderate community stakeholder concerns, misconceptions and reverse prevailing negative attitudes (towards SSB policies). Therefore, this dissertation proposes to study this SSB-portion limit public health food policy and generate empirical evidence to fill in this gap in the scientific evidence.

**Theoretical Framework**

This dissertation is based on a proposed conceptual framework for the obesity prevention effect of a policy limiting the portion size of SSB (Figure 1). The framework represents several socioecological and behavioral economic theories covering the mechanism through which numerous multidimensional factors influence the availability, affordability, and accessibility of SSB, and influence the choice of large SSB portions (Hunter, Hollands, Couturier, & Marteau, 2018; Leng et al., 2017; Maas, de Ridder, de Vet, & de Wit, 2012). These factors ultimately contribute to the overconsumption of SSB, increased
energy intake, and the risk of obesity. The model illustrates how a policy limiting the size of SSB modifies interactions that contribute to the availability of SSB and the choice to purchase large SSB portions (portion distortion). By regulating the size of SSB and eliminating the availability of large SSB, the smaller-sized SSB options become the status quo, default option. Thus, such a policy has the potential to nudge people towards a healthier food choice and bring about societal changes in SSB consumption patterns, social norms, and improve population health.

For Project 1’s scoping review, the multidimensional National Institute on Minority Health and Health Disparities (National Institute on Minority Health and Health Disparities [NIMHD]) Research framework guided the examination of the multiple levels and domains of influence impacting childhood obesity prevention efforts (NIMHD, n.d.). In addition, the scoping review adopted the Life Course Health Development framework perspective and examined the levels of influence across the early life course. (Halafon, 2018).

As shown in Figure 1, the NIMHD research framework also provides the backbone for the conceptual framework of a portion cap policy on obesity (NIMHD, n.d.). The NIMHD framework facilitates the characterization of modifiable factors at multiple levels and domains of influence that impact the availability of SSB portions sizes and influence SSB purchasing behaviors and consumption patterns and contribute to the risk of obesity. Taken together, the framework suggests the mechanism by which large portions of SSB are a
facilitator of overconsumption and thus linked to excessive caloric intake and energy imbalance.

The proposed portion size cap conceptual model also illustrates the foundation for Projects 2 and 3. Despite utilizing two distinct lines of research, they will both examine the impact of modifying physical (food) environmental factors on individual-level behaviors including SSB purchasing decisions, SSB consumption and energy intake.

In summary, the proposed conceptual framework model displays how a policy limiting the size of SSB modifies these contributing factors and has the potential to impact the access, availability, and affordability of SSB and bring about societal changes.
Figure 1. The conceptual framework for the obesity prevention effect of a policy limiting the portion size of SSB. Adopted from Vermeer et al. 2014. (Vermeer et al., 2014).
Definition of a Portion

The portion size of SSBs is one of many physical/environmental factors that influence SSB intake. A portion size is defined by the US Dietary Guidelines 2015-2020 as “the amount of food served or consumed in one eating occasion” (USDHHS & USDA, 2015). The term “portion size” is meant to serve as a dietary guideline and should not be confused with the term “serving size”, which reflects the Food and Drug Administration’s (FDA) food labeling requirements. Specifically, the FDA definition of serving size represents the amount of food which is “customarily consumed and is expressed in a common household measure” (USDA Agricultural Research Service, [USDA ARS], 2016).

SSB Portion Size Trends in the US

Over a 40-year period, the portion size of SSB have increased considerably (Nielsen & Popkin, 2003; Piernas & Popkin, 2011; Smiciklas-Wright, Mitchell, Mickle, Goldman, & Cook, 2003; Young & Nestle, 2002). In fact, the portion size of soda was shown to be substantially larger than the USDA’s and FDA’s serving size standards (35% and 103%, respectively) (Young & Nestle, 2002). Nielson and Popkins examined nationally representative survey data and found a 200 ml increase in the size of soft drinks between 1977 and 1998, in Americans two-years and older. While more recently, Piernas and colleagues evaluated portion size trends in youth 2-18
years old between 1977 and 2006 and showed a similar trend in portion sizes as those reported earlier, including an approximate 100 ml increase in the portion size of soft drinks consumed by youth. Therefore, it is not unexpected that people consistently drank more SSB when offered larger portion sizes of soft drinks and larger sized beverages were associated with a significant increase in the total caloric intake at the eating occasions when soft drinks were consumed (Hollands et al., 2015; Piernas C., 2011).

**Portion Size and Consumption Behaviors**

The availability of large size SSB is a mediator of overconsumption and linked to excessive caloric intake and energy imbalance (See Figure 1.) Evidence from numerous systematic reviews of portion size experimental studies found that adults and children consume larger quantities of food and beverage when served in larger packages, portion sizes and tableware (e.g., plates and cups) (Ello-Martin, Ledikwe, & Rolls, 2005; Hollands et al., 2015; Steenhuis & Vermeer, 2009). Consuming larger portion sizes at snack or meal time may not result in a compensatory reduction in energy intake at subsequent meals (Rolls, Roe, Kral, Meengs, & Wall, 2004; Rolls, Roe, & Meengs, 2006).

**Linking SSB Portions Size and Obesity**

In summary, there is strong evidence showing that the portion size of SSB have increased over time and there is a positive association between
offering larger portions of SSB and consuming larger quantities of SSB, leading to a greater total energy intake. The trend toward larger sized portions mirror the rise in the prevalence of overweight and obesity (Young and Nestle, 2012). As previously noted in Chapter 1, there is also a known association between SSB and weight gain and obesity; however, direct evidence linking the larger portion size of SSB to the rising rates of obesity is lacking.

**Portion Size Limit Policy Research**

The recent interest in examining the impact of SSB on health has led to the initiation of a growing number of global population-level portion size initiatives (Michelle Crino, Sacks, & Wu, 2016). It has also generated research attention and public interest in various portion size policies aimed at decreasing the consumption of SSB, such as SSB portion size cap policies. As previously described, such policies would restrict the availability of large SSB portions and only allow smaller sized packages and portions. A portion size cap policy would also regulate the maximum standard package size or serving size of SSBs and render the “healthier” smaller portion as the default option. Although portion size interventions have been conducted in experimental setting, it is unclear how the consumers, distributors, retailers and food service establishments will respond to an SSB portion size cap policy in a real-world setting.
Literature Review

Methodology

A systematic literature review was performed to summarize the evidence on the public health impact of a policy limiting the portion size of SSB. The search process followed the recommended guidelines developed by the Thames Valley Research and Development Network (Librarians, 2019). An initial search was conducted in PubMed to identify relevant keywords and search terms.

The preliminary search found only a limited number of SSB portion-size cap behavioral simulation studies. Accordingly, the objective of the literature review was expanded to also include simulation modeling and evaluation studies reporting modelled reductions in beverage sales, beverage consumption and beverage caloric intake. The final aims of the literature review were to answer the following research questions: “In policy/behavioral simulation studies: is a public health policy limiting the portion size of SSB effective at decreasing beverage purchases, beverage consumption and beverage caloric intake?” and “Using predictive models: is a hypothetical public health policy limiting the portion size of SSB effective at decreasing beverage sales, beverage consumption and caloric intake?”

Search Strategy
A focused search strategy was designed with the assistance of an Information and Education Librarian (MG) and subsequently adapted for a variety of data sources. The search syntax included the following keywords and terms: soda, carbonated beverages, carbonated drink, soft drink, pop, sugary drink, fruit juice, sweetener, sweetened beverage, sugar beverage, portion size, portion control, serving size, drink size, policy, policies, law, laws, legislation, prevention, intervention, program, ban and cap. Electronic databases including PubMed®, CINAHL®, EconLit®, Web of Science, Academic Search Premier and Scopus were searched for studies published in English from January 2000 through March 31, 2019. Bibliographies were manually hand-searched for other related articles. The search syntax for PubMed is shown in Table 2.

**Table 2. PubMed Search Strategy**

<table>
<thead>
<tr>
<th>Search Syntax</th>
<th>(soda OR carbonated beverages OR carbonated drink OR soft drink OR pop OR sugary drink OR fruit juice OR vegetable juice OR sweetener OR sweetened beverage OR sugar beverage) AND (portion size OR portion Control OR serving size OR drink size) AND (policy OR policies OR law OR laws OR legislation OR prevention OR intervention OR program OR ban OR cap)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limits</td>
<td>Full text, humans, English language, publication dates January 2000 through present (March 31, 2019).</td>
</tr>
</tbody>
</table>

References were downloaded with Endnotes X8 (Clarivate Analytics) and duplicates deleted. Publication titles and abstracts were screened, and full-
text articles were included in the review if the study examined the influence of an SSB portion size cap policy and reported any of the following outcomes: beverage purchased (amount), beverages consumed (volume) or energy (kcal) from SSB consumed (observed, reported or calculated).

**Search Results**

Figure 2 illustrates the literature search and study selection process. In summary, a total of 945 records were identified. After removing 375 duplicate publications, the abstracts of the remaining 570 articles were screened for inclusion in this review. Despite applying liberal inclusion and exclusion criteria, only 11 studies were eligible for a full text review and eight studies were included in this review.
Figure 2. Flow diagram showing literature and study selection. Adapted from Moher D, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. (Moher, Liberati, Tetzlaff, & Altman, 2009).
Characteristics of included publications

This review identified five policy model simulations predicating the impact of various hypothetical SSB portion limits on beverage sales (M. Crino et al., 2017; Liu, 2014), beverage consumption (Cleghorn et al., 2019; M. Crino et al., 2017; Liu, 2014), and caloric intake (Cleghorn et al., 2019; M. Crino et al., 2017; Elbel, Cantor, & Mijanovich, 2012; Liu, 2014; Wang & Vine, 2013), weight (Cleghorn et al., 2019; M. Crino et al., 2017) and health care costs (Cleghorn et al., 2019; M. Crino et al., 2017) in Australia (M. Crino et al., 2017), New Zealand (Cleghorn et al., 2019) and the US (Elbel et al., 2012; Liu, 2014; Wang & Vine, 2013). In addition, three behavioral simulations publications examined the effect of a portion size cap policy on beverage selection (Wilson, Stolarz-Fantino, & Fantino, 2013), beverage purchase (John, Donnelly, & Roberto, 2017), beverage consumption (Flood, Roe, & Rolls, 2006; John et al., 2017), beverage kcal (Flood et al., 2006; John et al., 2017), meal intake (Flood et al., 2006) and meal revenues (Wilson et al., 2013). On the other hand, one study (Wilson et al., 2013) reported the results of behavioral stimulation where subjects selected from a hypothetical menu and did not consume any SSB.

Modelling Studies

Five modelling studies estimated the potential influence of SSB portion size cap policies. Given the considerable variation in the type, characteristics and construction of simulations models (Levy et al., 2011), a detailed evaluation
of these factors is out of scope for this literature review; however, for completeness, Table 3 presents a summary of the key characteristics of the included simulation models. A brief summary of the predicted effects of the SSB portion limit policies on beverage purchases, consumption and energy intake is provided below.

Cleghorn et. al. modelled the potential impact of a single serving SSB cap of 250 ml in fast food establishments, restaurants and cafes on population health and health system costs in New Zealand (Cleghorn et al., 2019). A base model that included sugar sweetened (SS) carbonated soft drinks, fruit drinks, carbonated energy drinks, and sports drinks showed the 250 ml cap would result in an average reduction of 23.2 ml /person/day. The corresponding decrease in kcals was projected to be approximately 10.5 kcal/day with an estimated net cost savings of NZ $1.70 billion, equivalent to 1.12 billion US dollars at the time of publication (2019). When the beverage parameters were limited to only SS carbonated soft drinks and energy drinks, the volume reducing effect of the beverage cap were reduced, along with the potential health benefits and net cost savings.
Table 3. The characteristics of the policy simulation model studies and the estimated the effect of a sugar-sweetened beverage (SSB) portion size cap policy on SSB purchases, beverage consumption and beverage calorie intake

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Policy Simulation</th>
<th>Setting / Sample Location</th>
<th>Data source/ Population Reach Perspective</th>
<th>Analysis model; Cost parameters</th>
<th>Beverage Intervention</th>
<th>Beverage definition</th>
<th>Impact of Policy</th>
<th>Beverage Purchases</th>
<th>Beverage consumption</th>
<th>Beverage Kcal / Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleghorn 2019</td>
<td>To predict the population health cost and health system cost of a maximum serving size SSB cap of 250 ml in fast food/restaurants/ cafes</td>
<td>NZ Adults</td>
<td>New Zealand Adult National Nutrition Survey (NZANS) 2008-09; New Zealand Health Tracker database; The entire NZ population; Healthcare system perspective</td>
<td>Epidemiological macro-simulation multistate life-table (MSLT) modeling; Total population health costs; - cost of new legislation; - 3% discounting; - NZ$ Converted to US$</td>
<td>Base case: cap of 250ml applied to single serving beverages &lt; 600ml from NZANS</td>
<td>Base case model: SS carbonated soft drinks, fruit drinks, carbonated energy drinks, and sports drinks</td>
<td>N/A</td>
<td>Bases case: -23.2 ml / person/day</td>
<td>Narrow; SS carbonated soft drinks and energy drinks</td>
<td>N/A</td>
</tr>
<tr>
<td>Crino 2017</td>
<td>Cost-effectiveness of changes in BMI produced from changes in KJ consumption arising from a portion size cap of 350 ml on</td>
<td>Across the entire population Australia</td>
<td>Beverage consumption data from the 2011-2012 Australian Health Survey (AHS); Australian Food Labelling Trial (FLT); multi-state, multi cohort, life table Markov model with a lifetime horizon</td>
<td>Bases case: government ban on the sale of single-serve packaged SSBs greater than 375 mL; No</td>
<td>sugar-sweetened: carbonated beverages, favored waters, favored iced teas, sports/electrolyte drinks and sugar-sweetened cordials</td>
<td>-16% of SSB - approx. 2/3rds of single-serve SSBs (59%) &gt; 375 mL</td>
<td>Decrease from 564.4 kJ/person/day to 250 kJ/person/day; - decrease 14.4 kJ/day across the entire population</td>
<td>-0.06 BMI Net cost savings NZ$ 1.3</td>
<td>Narrow; -19.8 ml/ person/day</td>
<td>Base case: -44.2 kJ (10.5 kcal) person/day - 0.22 kg (-0.08 BMI units) / person/ over two years Net cost-saving, NZ$ 1.70 b</td>
</tr>
<tr>
<td>Author</td>
<td>Methodology</td>
<td>Data</td>
<td>Model</td>
<td>Results</td>
<td></td>
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<tr>
<td>Elbel 2012</td>
<td>To estimate the effect of the proposed NYC 16 oz SSB portion size cap</td>
<td>Single-service servings of SSB in the Australian FoodSwitch (FS) Database with a limited societal perspective, -3% discounting expressed in 2010 values</td>
<td>Statistical model changes in the number of calories from SSB beverages per transaction using bootstrapped simulations to generate 95% CI for proportion change</td>
<td>Base case: 62% of beverage purchases subjected to portion size policy Expressed in 2010 values. All beverages listed on the receipt except milkshakes. Bases Case: 62% of beverage purchases subjected to portion size policy, 100% switched to 16-oz beverage: 230 ± 86 kcal / consumer; 74 kcal (95% CI, 78 to 71)/consumer Scenario: 30% switch: no statistically significant difference</td>
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<tr>
<td>Liu 2014</td>
<td>To estimate the effect of downsizing of packaging</td>
<td>Designated market areas: New York, Detroit, Washington D.C., Atlanta, Chicago, Los Angeles, and Seattle 2 Nielsen data sets: Homescan with product characteristics; the advertising data set with brand information for 2006-2008</td>
<td>A random-coefficient logit demand model for carbonated soft drinks (CSD); considered price, package size, advertising and calorie content</td>
<td>Estimate the effect of a ban on 2-liter bottles and only allowing 12-oz can or 20-oz bottles - Regular CSD (sugar-sweetened) - Diet Drinks - Total CSD (sugar-sweetened and diet CSD) 15.75 % in Total CSDs consumption; 16.22 % consumption of Regular CSDs - 16.31 calories consumed from regular soda per capita annually</td>
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<tr>
<td>Wang 2013</td>
<td>To examine the impact of the New York City 16-oz SSB cap in food-service establishments</td>
<td>USA population adults in the USA</td>
<td>NHANES 2007-2010 (N=19,147)</td>
<td>Estimated change in the number of calories from SSB beverage; 95% CI estimated with Monte Carlo simulation</td>
<td>Estimated varied percentage of respondents switching to 16-oz SSB and others were assumed to purchase two 16-oz drinks</td>
<td>Scenario 80/20: Among individuals affected by the policy, assume 80% switch to a 16-oz drink and 20% upsize to 2 x 16-oz drinks</td>
<td>SSBs: soda, fruit punches, sweet tea, sports drinks, and nonalcoholic drinks containing caloric sweeteners; in one eating occasion and purchased at a food-service establishment</td>
<td>Policy affect 7.2% children and 7.6%</td>
<td>Consumed any SSB in 24 hours: children (71.3%); adults (56.7%)</td>
<td>Per-capita reduction in kcal/day: youth (6.3 kcal/d); adults (6.9 kcal/d)</td>
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<td></td>
<td>Estimated varied percentage of respondents switching to 16-oz SSB and others were assumed to purchase two 16-oz drinks</td>
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<td></td>
<td></td>
<td></td>
<td>Only affected SSB consumers: youth, -99.1 (95% CI, 86.7, 111.5) kcal/day; Adults, -102 (95% CI, -93.8, -110.4) kcal/d</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Scenario 80/20: Among individuals affected by the policy, assume 80% switch to a 16-oz drink and 20% upsize to 2 x 16-oz drinks</td>
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**Abbreviations:** Approx. Approximately; b, billion; CI, confidence intervals; CSD, carbonated soft drinks; NHANES, The National Health and Nutrition Examination Survey, NZ, New Zealand; US, United States; US$, US Dollars
In a similar simulations model, Crino et. al. estimated the changes in consumption (ml/day), energy, BMI and cost-effectiveness of a hypothetical legislation banning the sales of single-serve SSB packages greater than 375 ml across the entire population in Australia (M. Crino et al., 2017). The base case scenario estimated 27% of all SSB in Australia were single servings and included the following sugar-sweetened drinks: carbonated beverages, waters, flavored iced teas, sports/electrolyte drinks and cordials. The average consumption of SSB was reduced by 14.4 kJ/day with an average weight loss of 0.12 kg. Considerable lifetime health-adjusted life years gains were projected, as well as an estimated 13,590 lives saved.

Using beverage sales receipts, Elbel et. al. estimated the projected change in SSB calories from the proposed NYC 16 oz Sugary Beverage (Elbel et al., 2012). Customer receipts from 3 fast food restaurant chains in New York City; Newark, New Jersey; Philadelphia, PA; and Baltimore, MD, collected during two previous research studies, showed that 62% of all beverages sold were larger than the 16 oz portion size cap. The simulation assumed that if 100% of all beverages (except milkshakes) were downsized to 16 oz, beverage calories would decrease by 63 kcal (95% CI, 66 to 61) per consumer. However, when only including SSB were included in the simulation, the model projected an even greater reduction in the per customer calorie intake (74 kcal [95% CI, 78 to 71]).
Another simulation model calculated the impact of the proposed NYC 16 oz sugary beverage cap in food-service establishments (Wang & Vine, 2013). In contrast to the analysis conducted by Elbel and colleagues (2012), Wang et al. applied National Health and Nutrition Examination Survey (NHANES) data — a nationally representative sample of non-institutionalized, US population — to predict modelled changes in beverage calorie intake. They reported a greater reduction in daily caloric intake than Elbel and colleagues and found that downsizing SSB to a 16 oz portion would result in a small daily/per capita reduction in kcal/day in youth and adults (6.3 and 6.9 kcal/day, respectively). However, an even larger effect was shown in individuals who were affected by the 16 oz policy cap (100 less kcal/day from SSB).

Finally, Liu and colleagues modeled four policy options aimed at decreasing the consumption of carbonated soft drinks (CSDs) (Liu, 2014). In an alternative approach, they simulated the effect of a package size ban on large 2-liter containers and only allowed 20-ounce bottles and 12-ounce cans. The simulation policy scenario was computed in 2014 and applied market area estimated from 2006 to 2008. The package size policy was projected to induce a 15.75 % reduction in total CSD sales and 16.2% decline in the consumption of SSB, amounting to an annual reduction of 16.31 kcal/per capita.

**Behavioral Simulation Studies**
A description of the three behavioral simulation publications is shown in Table 4 and provided below.

Wilson and colleagues enrolled 100 undergraduate students in a stated choice behavioral simulation experiment to assess a 16 oz beverage portion size limit and the bundling of smaller portions of beverages for college credit (Wilson et al., 2013). Students were provided paper menus and presented eight or nine hypothetical scenarios describing a restaurant, it’s location (i.e., fast food restaurant, movie theater or stadium), and subsequently instructed to record on the menu the quantity of all hypothetical menu item purchases. The compared scenarios stated preferences for the following menu choices:

1. Unregulated (No portion size limit; 16, 24, and 32 oz beverages)
2. Bundle (16 oz portion size limit and 2 bundled portion options: two – 12 oz beverages and two 16 oz beverages)
3. No bundle (16 oz portion size only)

Compared to the Unregulated and No Bundle menu choice, the Bundle menu resulted in significantly greater beverage (ounces) ordered. Furthermore, the largest average meal revenues were associated with the Bundle menu.
Table 4. Description of behavioral simulation studies examining the effect of a sugar-sweetened beverage (SSB) portion size cap policy on SSB purchases, beverage consumption and beverage calorie intake

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Sample Size</th>
<th>Design Setting</th>
<th>Intervention</th>
<th>SSB Portion Size</th>
<th>Measures</th>
<th>SSB Beverage Purchases</th>
<th>Beverage Consumption</th>
<th>Beverage Kcal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood (2006)</td>
<td>33 adults participants from PSU university community</td>
<td>Cross-over design University lab</td>
<td>Compare effect of drink portion size on drink, food and energy intake during a meal</td>
<td>360 g (12 fl oz) vs. 540 g (18 fl oz) drink</td>
<td>Pre and post lunch meal food and drink weights</td>
<td>Cola, diet cola, or water</td>
<td>N/A</td>
<td>larger portion size resulted in greater beverage consumption vs. smaller portion size, P &lt; 0.05; No difference in food intake</td>
</tr>
<tr>
<td>Wilson (2013)</td>
<td>100 undergraduates from UCSD for college credit experiment</td>
<td>Hypothetical scenarios stated choice University lab</td>
<td>Compare purchase preference for a 16 oz beverage portion size and the bundling of smaller portions of beverages</td>
<td>Unregulated: 16 oz, 24 oz, and 32 oz; Bundled: 16 oz portion, bundled 2-12 oz or 2-16 oz; No Bundle: 16 oz only</td>
<td>Soda- did not different between diet and regular soda</td>
<td>More ounces bought and revenue generated Bundle vs Unregulated (10 oz $1.02) (p&lt;0.001); Fewest ounces purchased from No Bundle – 16oz only- p &lt; 0.001); Higher revenue with Bundle (ave. $1.69) vs No Bundle (Ave. $1.02) (p&lt;0.001)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>John (2017) Expx1</td>
<td>623 participants</td>
<td>2 x 2 Cubical in University lab</td>
<td>Compare effects of the factors: “portion limit” and “Service”</td>
<td>See Figure 3</td>
<td>Weighed cups and beverage pre- and</td>
<td>Selected sugar-sweetened lemonade or Iced tea</td>
<td>No main effect; Likelihood of ordering large drinks</td>
<td>Not reported</td>
</tr>
<tr>
<td>John (2017)</td>
<td>470 participants</td>
<td>2 group experimental design</td>
<td>Cubical in University lab</td>
<td>Evaluated the effect of free refills on beverage purchases and consumption</td>
<td>See Figure 3</td>
<td>Weighed cups and beverage pre- and post-experiment</td>
<td>Selected sugar-sweetened lemonade or Iced tea</td>
<td>No main effect; Proportion of large drink purchases in Typical-portions, 39.9% vs. 16 oz with refills, 36.2%, p = 0.55</td>
</tr>
<tr>
<td>John (2017) Epx3B</td>
<td>285 participants</td>
<td>Cubical in University lab</td>
<td>Evaluated the effect of free refills as a function of Service Style</td>
<td>See Figure 3</td>
<td>Weighed cups and beverage pre- and post-experiment</td>
<td>Sugar-sweetened lemonade or Iced tea placed at cubical</td>
<td>N/A- Drinks provided at no cost</td>
<td>Waiter service, 93.82 kcal± 59.2; Typical portion, 51.26 kcal± 29.30, p &lt; .001; Self-service 67.0 kcal± SD = 41.3 vs. Typical portions (see above), p &lt; 0.001</td>
</tr>
</tbody>
</table>

Abbreviations: Ave, average; Lab, Laboratory; PSU, Pennsylvania State University; UCSD, University of California, San Diego
In a randomized, crossover behavioral simulation, Flood et. al. fed 33 participants weekly, lunchtime meals in a laboratory setting, one day per week for 6 weeks (Flood et al., 2006). Unlimited amounts of the same food items were offered at all test meals, but beverages were varied by type (regular cola, diet cola, or water), and portion size (approximately 12 oz or 18 oz). The weight of food and beverage items were measured pre- and post-meals. Unsurprisingly, significantly more beverage was consumed when served as a large 18 oz portion. Consequently, the 18 oz regular cola condition led to the consumption of significantly more kcals compared to the 16 oz diet cola condition (151±8 kcal vs. 128±4 kcal, respectively) (P<0.004). While the total caloric intake from food did not differ with beverage conditions, participants consumed significantly more kcal when the test meal was served with a regular soda compared to meals serving diet soda or water.

In the third and final publication Johns and colleagues conducted a series of four experiments (John et al., 2017). The experiments were designed to evaluate the effect of SSB portion size limit policy on SSB consumption, and purchasing patterns considering the impact of marketing strategies such as bundling and free refills on consumer behavior. The experimental design was informed by a framework of consumer influences stemming from contextual clues, social image concerns and customer convenience. In addition, the experiments were incentive-compatible and sought to elicit real behavioral responses. All experiments took place in a laboratory setting and participants
were provided 40 cents to purchase beverages priced between 20 and 30 cents. Figure 3 shows the major design considerations and experimental conditions evaluated in the four experiments.

<table>
<thead>
<tr>
<th>Experiment 1. Bundles</th>
<th>Service-Style</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portion Limit</td>
<td></td>
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<tr>
<td>2 x 2 Design</td>
<td>Waiter-Service Condition</td>
</tr>
<tr>
<td></td>
<td>Group 1</td>
</tr>
<tr>
<td>Typical-Portion Size:</td>
<td></td>
</tr>
<tr>
<td>Medium 16 oz, $0.20</td>
<td></td>
</tr>
<tr>
<td>Large 24 oz, $0.30</td>
<td></td>
</tr>
<tr>
<td>Bundled Conditions:</td>
<td>Group 2</td>
</tr>
<tr>
<td>Medium 16 oz, $0.20</td>
<td></td>
</tr>
<tr>
<td>Large 2 x 12 oz=24 oz total, $0.30</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Experiment 2. The Perils of Free Refill</th>
<th>Experimental Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical-Portion Size</td>
<td>Restricted Portion and Free Refills</td>
</tr>
<tr>
<td>Medium 16 oz, $0.20</td>
<td>Medium 16 oz, $0.20</td>
</tr>
<tr>
<td>Large 24 oz, $0.30</td>
<td>Medium 16 oz with unlimited refills (raise hand), $0.30</td>
</tr>
<tr>
<td>No drink</td>
<td>No drink</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Experiment 3A. The Perils of Free Refills Mitigated</th>
<th>Experimental Conditions</th>
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</thead>
<tbody>
<tr>
<td>Control</td>
<td>Restricted Portion and Free Refills</td>
</tr>
<tr>
<td>Typical-Portion Sizes</td>
<td>Self-service</td>
</tr>
<tr>
<td>Medium 16 oz, $0.20</td>
<td>Medium 16 oz, $0.20</td>
</tr>
<tr>
<td>Large 20 oz, $0.30</td>
<td>Medium 16 oz with unlimited refills, $0.30</td>
</tr>
<tr>
<td>No drink</td>
<td>No drink</td>
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</table>

<table>
<thead>
<tr>
<th>Experiment 3B. The Perils of Free Refills Mitigated</th>
<th>Experimental conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Restricted Portion and Free Refills</td>
</tr>
<tr>
<td>Typical-Portion Sizes</td>
<td>Self-service</td>
</tr>
<tr>
<td>No Refill</td>
<td>10 oz drink no refills</td>
</tr>
<tr>
<td>10 oz drink no refills</td>
<td>10 oz drink with unlimited 8 oz refills</td>
</tr>
</tbody>
</table>

Figure 3. Panels Experiment 1, 2, 3a and 3b show the major design considerations and experimental conditions evaluated in “Psychologically Informed Implementations of Sugary-Drink Portion Limits” (John et al., 2017).
In Experiment 1, a 2x2 factorial design examined the effect of the factors “portion limit” and “service style.” The study compared typical portion size options with a 16 oz portion size limit and a large drink option that bundled 2-16 oz drinks. Bundling of beverages was not associated with the purchasing of statistically significant greater number of large drinks. In fact, participants were found to be 64.8% less likely to order a large drink with Bundling compared with the typical-portion menu. This effect was shown to be greater in the Self-service condition where a significantly smaller proportion of participants bought a large drink with Bundling compared to the typical-portion (25.6% vs 37.1%, p=0.02; respectively). Nevertheless, participants in the Bundled group did not consumed significantly less calories compared to the Typical Portion condition.

The second experiment, titled “The Perils of Free Refills,” evaluated the effect of free refills on beverage purchases and consumption. Participants were randomized to either the Typical Portion Condition or Restricted Portion and Free Refills condition. There were no significant differences in large drink purchases across the portion limit and service style factors. Importantly, this experiment found that despite the 16 oz portion size limit, the 16 oz Refill condition consumed 21.1% more calories than the Typical Portion conditions (p<0.001). As expected, the consumption of the large drinks resulted in significantly greater caloric intake compared with medium drinks (174.9 ± 87.9 vs. 99.2 ±38.0, P <0.001, respectively) and 44.0% greater caloric intake when large drinks were served in 16 oz cups with free refills.
The aim of Experiment 3a was to evaluate attempts to mitigate the increase in caloric intake shown with free refills in Experiment 2. The intervention down-sized the portion size of the large drink from 24 oz to 20 oz and openly displayed cups labelled with its portion size. Participants were randomized to either the Typical Portion condition, or Restricted Portion size drinks with the options to buy a 16 oz drink with no refills or with free refills delivered by Waiter-service or Self-service. There were no statistically significant differences in the size of drinks purchased or in the amount of medium drinks purchased across service style conditions. However, the greatest number of calories were consumed for large size drinks in the Waiter-service condition (210.6±83.9), followed by large drinks in the self-service condition (138.7±38.0), p <0.001. Overall, the Waiter-service condition consumed 51.9% more calories than the Typical Portion conditions with 19.1% more calories than the self-service group.

The objective of the final Experiment (3b) was to replicate Experiment 3A and evaluate the effect of free refills as a function of Service Style only. In this experiment drinks were provided at no cost and only one drink size portion (10 oz) was offered and positioned in the cubical prior to the start of the experiment. Participants were randomized to the Typical Portions, Free Refills Waiter-Service or Free Refills Self-Service conditions. Participants in the Waiter-Service and Self-Service conditions consumed 83.0% and 30.7% more calories compared with the Typical-Portion group, respectively. Consistent with
the findings in Experiment 3A the Self-Service group consumed significantly fewer calories compared to the Waiter-Service group (40%, p < 0.001).

Discussion and Conclusion

This review identified a limited number of behavioral simulations and modelled simulation studies examining the effectiveness of an SSB portion size cap policy. The results from these studies provide preliminary effectiveness and cost effectiveness evidence in support of a public health policy limiting the portion size of SSB.

Of the studies included in the review, only three implemented behavioral simulations. All behavioral simulation studies occurred in a laboratory setting with various study designs, and none of the studies evaluated the policy in a real-world setting. Each study was subject to well-recognized study design limitations. For example, one study utilized stated choice methods to examine hypothetical purchasing prefaces of food and drinks, without specifying if the drinks were sweetened or not (Wilson et al., 2013). The second study used a cross-over study design to evaluate the portion size of food and beverages at six lunch meals, but the meals were provided free of charge (Flood et al., 2006). While the final publication reported the results from a series of well-designed, adequately powered experiments; however, beverages were sold for a nominal fee (20 to 30 cents) and consumed alone in a cubical as participants completed an unrelated task (John et al., 2017).
Despite their limitations, SSB portion size behavioral simulation studies provide important evidence pertaining to the impact of SSB portion size cap policies, SSB on purchasing behaviors, consumption behaviors and beverage kcal intake. Important findings from these studies include an association between larger beverage portion sizes and the consumptions of a greater volume of beverages (Flood et al., 2006; John et al., 2017), and participants who consume large-sized beverages with excess calories may not reduce their lunch-time food calorie intakes (Flood et al., 2006). Additionally, these studies provide preliminary evidence demonstrating that the effectiveness of an SSB portion-size cap may be diminished in the presence of free SSB refills but self-service SSBs may deter SSB consumption (John et al., 2017), while bundling beverages — a potential marketing promotion — may promote consumption of larger-sized SSB (Wilson et al., 2013). Finally, these results confirm that SSB portion size interventions have the ability to reduce beverage calories intake (Flood et al., 2006).

From these studies it is apparent that consideration needs to be given to the unintended consequences of implementing a portion size limit policy. For example, if an SSB policy size cap policy was to be enacted, food service establishments may respond with marketing strategies such as bundling or free refills, to preserve customer choice and avert losses in revenue. This review found that two such marketing strategies, free refills and bundling, resulted in increased sale volumes (John et al., 2017; Wilson et al., 2013). Thus, it is
plausible that food service establishments may respond to an SSB by offering free refills or bundled SSB to generate additional revenues and off-set potential losses from selling smaller portion size drinks. In contrast, a “nudge” such as requiring participants to walk a short distance to pick-up their free SSB drink refills was an effective counter-response to free SSB refills (John et al., 2017).

This review also identified five simulation studies applying a variety of mathematical techniques to predict the impact of an SSB portion size cap policy in Australia, New Zealand and the US. Two of the five simulation models examined the impact of the NYC 16 oz portion size cap. While the data for one simulation study came from sales receipts (from 2 research studies), the other study examined data from the NHANES database and predicated an even greater reduction in the consumption of SSB. Collectively all simulation models predicted the potential benefit of an SSB portion size cap policy to limit SSB purchases, consumption and caloric intake. Yet, no matter how useful simulation studies may be, empirical evidence is still needed to confirm these finding in real-world settings.

The current evidence from this review shows that a public health policy limiting the portion size of SSB may be an effective obesity prevention intervention. Although SSB tax have been successfully adopted in several cities, to date, a portion size cap policy has never been implemented. Experimental and modelled data have predicated the success of portion size cap in reducing SSB beverage purchases and consumption. In addition,
modelling studies have predicted future health benefits on reducing obesity and health care cost saving.

Relevance of Theory and Literature Review

The present review confirmed the need for scientific evidence demonstrating the effectiveness and cost-effectiveness of an SSB portion size cap in real-world studies. The conceptual framework for the obesity prevention effects of a portion size policy is shown in Figure 1 and was previously discussed. The model supports the theory that multiple factors related to SSB portions and package sizes contribute to the availability of oversized SSB portions sold in food service establishments, excessive energy intake and risk of obesity. Although this model suggests a clear associational benefit between SSB portion size cap polices and lowering the risk of overweight and obesity, the present review of the literature did not identify any real-world data confirming this relationship.

Professional organizations and the scientific community have unanimously endorsed the need for public health policies and policy research focused on reducing the consumption of dietary sugar and SSBs. Pediatric societies have called for national policies aimed at reducing the consumption of added sugars (Fidler Mis et al., 2017). The AMA has encouraged state and local governments to implement taxes on SSBs as a means to raise revenues to fund obesity prevention public health initiatives (AMA, 2017). Whereas, the
Obesity Society recognizes the need for robust scientific evidence demonstrating the physiological benefits of SSB tax policies, and thus called for more research aimed at demonstrating the effects of SSBs on obesity (Obesity Society, 2018).

Considering, the overwhelming interest in SSB policy research combined with the absence of population-level data, the current dissertation examined two lines of research to demonstrate the intermediary link between SSB portion-size caps and factors leading to weight gain and obesity. The respective dependent variables include SSB volume purchase, SSB volume consumed, caloric intake and consumer perception/reaction to SSB policies are described in detail in the Methods section below.
Chapter 3. Methods

Project 1, “Scoping Review of Obesity Prevention,” found a lack of scientific evidence evaluating the effectiveness and cost-effectiveness of early childhood obesity prevention programs and policies (Volger et al., 2018). These findings support the scientific rationale for the complementary projects and the examination of a public health food policy limiting the portion size of SSB utilizing two lines of research. In Project 2, “Real-world SSB Limit Policy Study,” the SSB portion limit policy was examined with a cross-sectional observational study design that leverages a naturally occurring experiment. While Project 3 employed a classic RCT experimental study design to generate empirical evidence.

Project 1: Scoping Review of Obesity Prevention

The aim of scoping review was to provide an overview of the current state of obesity prevention efforts in children less than six years old in the US. The review sought to identify existing early childhood obesity prevention interventions, programs and policies during the early life course and to characterize these efforts considering the components of the NIMHD Research Framework (NIMHD, n.d.)

Consequently, two framework models were applied during the scoping review process to evaluate the childhood obesity prevention efforts and to
characterize their components. The NIMHD Research Framework guided the examination of multiple levels of modifiable and interacting determinants of health that contribute to obesity and health disparities. While the multi-level Life Course Health Development (LCHD) framework acknowledges that health development unfolds over the life course, is sensitive to time and environment, adaptive, and requires a balance among all levels of health (Halafon, 2018; Volger et al., 2018). Therefore, it was employed to classify obesity prevention efforts across the early life course.

The scoping review methodology followed the Arksey and O’Malley’s 5-stage methodological framework (Arksey & O'Malley, 2005; Peters MDJ, 2017). The Joanna Briggs Institute’s Reviewer’s Manual of best research practice guidelines for conducting a systematic scoping review provided the roadmap for the scoping review. Briefly, the main search criteria included English publications from a range of electronic databases published between January 2001 and February 2018, and studies evaluating obesity prevention interventions, programs and policies reporting a weight-based outcome measure.

A detailed description of the scoping review methods and study results is provided in the published manuscript found in Chapter 4 (Volger et al., 2018).

**Project 2: Real-world SSB Limit Policy Study**
The research protocol for the *Real-world SSB Limit Policy Study* (Real-world study) was initially approved by the Office of Human Research Administration at Harvard’s School of Public Health and conducted between March 2014 and June 2014. The aim of the study was to examine the impact of an SSB 16 oz portion size limit on the volume of beverages purchased and consumed, and on total caloric intake from food by adults attending NBA and WNBA games NYC and Brooklyn, NY. Key aspects of the approved protocol are presented below.

Prior to the initiation of the study, NYC had approved a 16 oz sugary beverage portion cap law but it had not yet been implemented. However, the Barclays Center in Brooklyn voluntarily adopted an SSB 16 oz portion size restriction, while a corresponding portion size restriction was not employed at the Madison Square Garden in NYC. Thus, the study sought to take advantage of this natural experiment and gain a better understanding of how consumers respond to a real-world portion size cap policy by evaluating the food and beverage purchasing behaviors of adults attending sporting events at the Barclays Center compared with the Madison Square Garden.

Although the intent of a policy that sets an SSB portion cap is to reduce the amount of SSB purchased, the study also investigated how sporting fans might compensate for the 16 oz sized SSB. For example, it was unknown if they would purchase additional servings of SSB or additional food items, instead purchase unsweetened beverages (e.g., 100% juice, milk, diet soda,
water) or not purchase any beverages at all. Finally, it was unknown how consumers’ perception of the policy would impact their beverage purchasing behaviors or enjoyment of the food and drink purchased.

**Research Design and Data Source**

The research study design, methods and source of data files for Project 2, Real-world Study are described in the study’s original IRB approved protocol (number IRB13-201). The study was conducted under the direction of the Principal Investigator (PI), Christina A. Roberto, PhD. The research project and detailed statistical analysis plan was granted exempt status and approved by Rutgers University Institutional Review Board (IRB Study ID Pro2019001933, Approved October 2019) prior to the initiation of the analysis.

This was a cross-sectional study of adult participants recruited outside of the Barclays Center in Brooklyn, NY and the Madison Square Garden in Manhattan, NY. A study-specific, IRB approved research survey was administered by trained research assistants to arena visitors as they departed NBA and WNBA games between March 2014 and June 2014. Research assistants stood outside of each arena and asked exiting customers if they would be willing to complete a brief, 5-minute Point-of-Purchase Data and Customer Satisfaction Survey” survey covering food and beverage purchases and event experience in exchange for $5.
The survey asked participants about all beverages and food items purchased from the arena’s fast food and casual dining restaurants, including item quantities, size and an estimate of the overall percentage of each beverage and food item consumed. We derived an estimate of the caloric value of all food menu items using caloric values for similar menu items listed in the 2014 version of the MenuStat database, (Department, 2019) a nutritional database of foods and beverages served by the nation's largest chain restaurants. If a menu item was not included in the 2014 MenuStat database, we used the caloric value listed in the USDA National Nutrient Database for Standard Reference, release 28 (2015) (USDA ARS, 2016).

Statistical Analysis Plan

General Analysis Methods

The statistical analyses were conducted using IBM SPSS Statistics 25. The following statistical plan and statistical procedures were implemented to examine the quality and normality of the data, to check statistical assumptions and to carrying out hypothesis testing, as applicable.

Sample size

The data were obtained from de-identified, closed, study-specific databases. The original power calculation and sample size estimation was based on having 90% power to detect a small effect (f = .15) using a two-tailed test at an alpha level of .05 with the specified covariates required 307
participants at each site. The sample size for this present analysis was derived from the total number of surveys (N=759) present in the study database.

**Measures and Outcomes**

All outcome variables were collected and entered in the de-identified “Point-of-Purchase Data and Customer Satisfaction Survey.” The survey data were extracted, transformed (as needed) and entered in corresponding statistical program files (Stata and SPSS).

**Examination of Data Quality**

The data files and individual variables were examined for implausible (out-of-range) data values using univariate statistics such as means, SD, median, frequencies, ranges, proportions and percentiles. Graphs of continuous data (volume of SSB, SSB calories purchased and consumed, food calories purchased and consumed, self-reported weight and height, and age) were generated to further examine for outliers or data that may be considered biologically implausible. All questions related to the quality of the data were investigated before any statistical testing was conducted to ensure the accuracy of the data estimates and confidence intervals.

Normality of continuous participant characteristics (age, weight, and height) and continuous outcome variables (total number of
beverages purchased; total number of SSB purchased; SSB volume purchased and SSB volume consumed, food calories purchased and food calories consumed; total food calories purchased and consumed) were examined with statistical testing, and graphics. For the interpretation of non-normality, data were tested for skewness, significant skew z scores, Kurtosis and using the Kolmogorov-Smirnov (KS) and Shapiro-Wilks (SW) test. However, due to the large sample size, the KS and SW tests yielded significant results judged not representative of a meaningful deviation from a normal distribution. Therefore, histograms and boxplots were reviewed to assess if the distribution of data was symmetrical or skewed. Data were graphed on normal Q-Q plots to check for a departure from normality (data points deviating from the straight line). Based on all the available evidence, it was determined that all continuous data, with the exception of the “total number of beverages purchased” and “total number of SSB purchased” were reasonably normally distributed, thus non-parametric testing were only used to examine these non-normally distributed outcomes.

**Missing Data**

All analyses were conducted with all available data. The proportion of missing data for all participant characteristics were less than 9%. A missing value analysis utilizing the Little’s MCAR showed
that the data was missing completely at random (p=.236), thus no imputations were performed for missing data.

**Significance Testing**

All statistical tests were performed using 0.05 significance level. Each test is presented with statistics with the associated 2-sided 95% confidence interval. Thus, comparisons were judged as a “statistically significant difference” when a p-value is smaller than the 0.05 significance level. Unless otherwise stated, no adjustments were made for multiplicity.

**Participant Characteristics**

The demographic and socioeconomic characteristics of participants were listed and summarized for each arena using descriptive statistics.

Continuous variables (age, weight, height, BMI) were reported as mean and standard deviation (SD). Categorical variables (sex, race, ethnicity, education, marital status, household income category, body weight goal) were reported as frequency and percentage (%).

Comparison between the baseline characteristics of the two arena populations were conducted to identify statistically significant differences between the two arena populations. An Independent t-test
was applied to compare means of normally distributed continuous variables age, weight, height, BMI). Chi-square statistic were used to test for differences between categorical variables:

- Age, (years)
- Sex, (male, female)
- BMI, \([703 \times \text{weight (lbs)} / \text{[height (in)]}^2]\)
- Race, (White, Black or African American, Asian/Pacific Islander, other)
- Hispanic, Latino(a) or Spanish, (yes, no)
- Education, (< high school, high school or GED, vocational training, some college [less than 4 years]; college/university degree [4 years], graduate or professional education
- Marital status, never married, married, not married, living with significant other, separated, divorced/widowed
- Household income category, (Less than $25,000; $25,000-$50,000; 50,001-$75,000; $75,001-$100,000; $100,000-$125,000; $125,001-$150,000; More than $150,000)
- Body weight goal, (trying to: lose weight, gain weight, maintain weight and not trying to do anything)
**Aim 1**: In order to examine the impact of 16 oz SSB portions on ounces of beverages, and SSB and calories of food purchased and consumed the following endpoints were summarized and compared between arenas:

- Number of beverages purchased
- Number of SSB purchased
- Volume of sugar-sweetened beverage ounces purchased, (8, 12, 16, 20, 25, and 40 ounces, or “other”).
- Volume of sugar-sweetened beverage ounces consumed, (volume of SSB ordered x percentage consumed [100%, 75%, 50%, 25% 0%]).
- Food calories purchased, (food items purchased x calories per item derived from Menustat)
- Volume of all beverage ounces purchased, (8, 12, 16, 20, 25, and 40 ounces, or “other”).
- Volume of all beverage ounces consumed, (volume of all beverages ordered x percentage consumed [100%, 75%, 50%, 25% 0%]).

For the primary analysis, univariate general linear model procedures (GLM) was performed to examine the relationship between the “ounces of SSB purchased” and Arena (Barclays vs. MSG) in the full survey dataset, and only among participants who purchased an
SSB. Diagnostic tests were carried out to check model assumptions of linearity and normality of residuals as well as to identify outliers with unacceptable influence on the model. Residual plots were examined and homoscedasticity was judged as tenable. R-squared values confirmed the best fitting models, accounting for the largest proportion of variance. Due to the small number of participants with “< high school” (n=1) and “vocational training” (n=1) who purchased an SSB, we collapsed “< high school”, “vocational training” and “high school or GED” into a new education category “< some college”. Similarly, the martial status category “separated” was combined with “divorced/widowed” to create a combined category. The models were controlled for variables known to associated with SSB consumption (sex, race, ethnicity, BMI, educational level, income). The fixed effects in the final models were sex, ethnicity, race, marital status, education, household income, and the covariates were age and BMI.

Additional univariate GLM procedures with the same fixed factors and covariates as in the primary analysis were performed to examine the influence of Arena on the secondary outcomes: ounces of SSB consumed (rather than purchased), total ounces of drinks purchased, total calories of food purchased, and total calories of food consumed. Arena differences in the non-normally distributed outcomes
“total number of drinks purchased” and “total number of SSB purchased” were tested using Mann-Whitney U test.

**Sensitivity analysis.**

A non-parametric, sensitivity analysis of the primary outcome “ounces of SSB purchased” was run using inverse propensity of treatment weighting (IPTW) derived from a propensity score. The IPTW approach creates a pseudo-population in which the overall distribution of the measured baseline confounders is balanced between the two arenas, thereby minimizing the bias of confounding linked to estimating the treatment effect in non-randomized studies. The propensity score was generated using a logistic regression model with Arena choice as the dependent outcome and including all independent variables in the primary analysis model. The top and bottom 1% of the propensity score weights were truncated (Austin & Stuart, 2015). For Barclays’ participants the weight was calculated as, IPTW=1/Propensity Score(X) and for MSG the weight was the inverse, IPTW=1/ (1 – Propensity Score[X]). IPTW approach does not make parametric assumptions about how the individual covariates and exposure of interest (i.e., arena) together affect the outcome, and thus can check robustness of the GLM estimate of the arena effect. IPTW, however, does not provide effect estimates for the covariates on the outcome.

**Aim 2:** In order to determine the impact of smaller SSB portion sizes on customer satisfaction with their event experience, including satisfaction
with size of beverages and enjoyment of food and beverage the following endpoints were summarized and compared between arenas:

- Satisfaction with the size of beverage ordered, 5-point Likert item (1= not at all, 5= extremely)
- Beverage enjoyment, 5-point Likert item (1= did not like it at all, 5= liked it a lot)
- Food enjoyment, 5-point Likert item (1= did not like it at all, 5= liked it a lot)
- Event experience, 5-point Likert item (1= poor, 5= excellent)
- Satisfaction with the price of beverage ordered, 5-point Likert item (1= not at all, 5= extremely)

For these endpoints, the frequency and percentage of responses for each discrete response category was tabulated by arena group. In addition, histograms were generated showing the percentage of responses for each response category. The initial statistical comparison compared the proportion of responses for each response option/levels (1, 2, 3, 4, 5) between arena groups using the Chi-square test.

Although the 5-point Likert event experience items were comprised of contrasting verbal labels anchoring the bottom and the top of the scale, every point/integer was not assigned a respective verbal label, therefore the event experience variables were treated as a categorical variable. As part of the initial statistical analysis plan, we
intended to collapse the 5-point Likert scale items into a 3-point scale and build multinomial logistic models to compare event experience between arenas. Yet, after examining the relationship between each potential predictor variable and the primary outcome we did not identify any confounding variables associated with both Arena and any measure of event satisfaction and SSB volume purchased, thus multinomial logistic regression analyses were no longer needed. Instead, bivariate statistics were computed using the full 5-point scale to evaluate differences in the relationship between the dependent variables and Arena. The statistical significance of the Chi-square statistics (p <0.05) and the standardized residuals (± 1.96) for each category (cell) were examined to assess categorical differences between Arenas by identifying cells where the number of cases in that cell were smaller than would be expected.

**Aim 3**: To determine the impact of the customer's general perception of restaurant food and beverage portion sizes and their perception of the NYC’s proposed portion cap policy on satisfaction with the size of beverages at the Barclays Center the following endpoints were summarized and compared between arenas:

- Opinion about restaurant food portion sizes (too small, just right, too large, no opinion)
- Opinion about restaurant beverage portion sizes (too small, just right, too large, no opinion)
- Perception of NYC SSB portion size policy: in favor of or against New York City sugary beverage portion size cap regulation (against, no opinion, in favor)

The responses to questions about the participants opinion about “restaurant food portion size” and “restaurant beverage portion size” (against, no opinion, in favor) and how strongly they feel about the regulations (strongly, somewhat, no opinion) were combined to create a 5-point scale. The combined response options ranged from -2 (strongly against); -1 (somewhat against); 0 (no opinion); somewhat in favor (1); strongly in favor.

Here again, we did not identify any confounding variables associated with the primary outcome and both Arena and the customer’s general perception of restaurant food and beverage portion sizes and their perception of the NYC’s proposed portion cap policy. Therefore, instead of conducting multinomial logistic regression analyses we used bivariate statistics to evaluate differences in the relationship between these outcomes and Arena.
Individual item evaluation

Descriptive statistics for the responses to the remaining survey items will be summarized and compared between arena groups using t-tests for continuous variables and chi-square for categorical variables including:

- Ordered beverage (yes, no)
- Number of beverages ordered (N)
- SSB ordered (yes, no)
- Proportion of participants who purchased at least one SSB
- Beverage ounces per drink ordered, (8, 12, 16, 20, 25, 40, other)

Project 3: SSB Portion Limit Dining Lab RCT

The research protocol for Project 3, SSB Portion Limit Dining Lab RCT was approved by the Office of Human Research Administration at Harvard’s School of Public Health and conducted between January 2015 and August 2015. At the time of the original research proposal, no study had been conducted to determine the impact of a policy limiting the portion size of SSB on consumer behaviors and perceptions. Therefore, the aim of the study was to examine the impact of SSB portion size cap policy in a dining setting on
energy intake and to examine the causal relationship between an SSB portion cap policy intervention and food choices, as well as subsequent food and beverage intake. Key aspects of the approved protocol are presented below.

**Research Design and Data Source**

The research study design, methods and source of data files for the SSB Portion Limit Lab RCT are described in the study’s IRB approved protocol (number IRB14-2926). This study was also conducted under the direction of the PI, Christina A. Roberto, PhD. The present research project and detailed statistical analysis plan was granted exempt status and approved by Rutgers University Institutional Review Board (IRB Study ID Pro2019001933, Approved October 2019) prior to the initiation of the analysis.

Briefly, this was an RCT of 359 adults recruited from the Boston / Cambridge area conducted at the PI’s eating behavior lab at the Landmark Center (Lab). Participants were adults (over 18), with the ability to speak and read English, without severe food allergies, and blinded to the purpose of the study and were randomized to one of four conditions:

1) current SSB restaurant portions with the option to purchase refills
2) current SSB restaurant portions plus free refills
3) 16 oz SSB portions with the option to purchase refills
4) 16 oz SSB portions plus free refills
To conceal the purpose of the study, participants were asked to participate in a pseudo-focus group pretending to conduct consumer research on restaurant preferences. Participants were asked not to eat after 3pm prior to the 5:30pm focus group. Participants were seated at individual dining tables and were asked to order and purchase dinner from a restaurant menu and consumed the meal while in the restaurant Lab. After the focus group, participants completed electronic questionnaires (e.g., demographic information, eating behaviors, and perceptions of the meal) and were instructed to returned to the Lab the following day where they completed a brief dietary recall interview conducted with the National Cancer Institute’s web-based Automated Self-Administered 24-hour Dietary Recall program (ASA-24®) (National Cancer Institute, 2019).

The compensation component of the study was designed to simulate a real-world dining experience, while encouraging study enrollment. Participants received $45 towards the purchase of the dinner meal. They were instructed to spend as much or as little of the money on the dinner meal and were allowed to use their own money to supplement the $45. Additionally, participants were told that they were allowed to keep any of the unspent money but were not allowed to take home any uneaten food. Study meals were offered at a discounted price to facilitate enrolling study participants from a diverse socio-economic background and to assure that participants returned the following day (between 5:00pm and 8:00pm) to collect the unspent money and complete
the study. Finally, participants were debriefed and paid any surplus amount of their $45 credit that they did not spend on dinner the previous night.

**Statistical Analysis Plan**

**Sample size**

No prior studies measured the effect of an SSB portion size limit policy on SSB intake in a restaurant setting. Thus, the power calculation used to guide the primary enrollment plan utilized the effect size derived from a similarly designed experiment examining the effect of calorie labeling on eating behaviors (Roberto, Larsen, Agnew, Baik, & Brownell, 2010). An estimated target sample size of at least 137 participants per SSB menu condition (n=548 total) were needed to obtain 80% power to detect a statistically significant difference and a Cohen’s \( d \) effect size of 0.34 using two-sided test with an alpha level of 0.05. Therefore, the study planned to recruit a total of approximately 560 adults (140 per condition). Because the PI was moving to another University, the study prematurely ended data collection earlier than anticipated and the final sample was comprised of 359 subjects. A post-hoc power analysis was planned to determine the observed power if the hypothesized relationships were found to be non-significant.

**General analysis methods**
The analysis was be conducted using IBM SPSS Statistics 25. Similar to what was done for Project 2, the initial examination of the quality of the data included screening the data and confirming the appropriateness of the statistical procedures. This included conducting tests confirming the plausibility and normality of the continuous baseline and outcomes variables, checking statistical assumptions and appropriateness of the testing procedures, conducting model diagnostics, and assessing missing data, as applicable. See Project 2 Analysis Plan for additional details.

Normality of continuous baseline characteristics (age, weight, height, BMI) and continuous outcome variables (total calories ordered and consumed during the test meal) were examined using statistical procedures and a visual inspection of histograms and graphs as previously described for Project 2.

**Missing data**

All analyses were conducted with the available data. No systematic patterns of missingness were identified and imputations were not performed for missing data.

**Significance testing**

Statistical tests were performed using 0.05 significance level. Each model presents statistics with the associated two-side 95% confidence interval and two-sided p-values.
Measures and Outcomes

Most outcome variables were collected with study-specific *Demographic and Eating Habits Questionnaire* by trained research assistants using standardized research protocols and scripting.

Although 24-hour diet recall information was collected on study day two and assessed using the ASA-24®, after reviewing the preliminary study results (for differences in food and SSB calories between menu conditions), the 24-hour dietary intake data was judged to be no longer relevant and it was decided not to include this outcome in the final analysis plan.

Participant Characteristics

The demographic and socioeconomic characteristics of participants were summarized and compared between each of the four experimental conditions.

Continuous variables (age, weight, height, BMI) were reported as mean, SD, median, minimum and maximum values. Categorical variables (sex, race/ethnicity, education, and household income category) were reported as frequency and percentage.

To test for significant differences in the baseline characteristics between the 4 experimental conditions, an ANOVA will be applied for continuous variables, Chi-square test statistics (for sex, race, ethnicity, marital status) or Kruskal Wallis test (KW test) statistic (for education,
income) were used to compare categorical variables. Data for the following baseline characteristics was reported in the Demographic and Eating Habits Questionnaire:

- Age, (years)
- Sex, (male, female)
- Race (White, Black or African American, Asian, Pacific Islander, Other)
- Ethnicity (Hispanic, Latino, of Spanish Origin, Non-Hispanic)
- Education, (did not complete high school, completed high school or received a GED, vocational training beyond high school, some college (< 4 years), College/ university degree (4 years), graduate or professional degree)
- Marital status, (Never married, Married, Not married, living with significant other, Separated, Divorced, Widowed)
- Household income category, $ (0-19,999; 20,000-29,999; 30,000-39,999; 40,000-49,999; 50,000-59,000; 60,000-69,000; 70,000-79,000; 80,000-89,000; 90,000-99,999; 100,000+)
As with Project 2, the characteristics education, marital status and income were collapsed due to the small number of participants in many of the response options.

In addition, the participants’ ratings of their level of hunger and fullness assessed with the *Demographic and Eating Habits Questionnaire* were compared for differences between the four conditions using Kruskal Wallis test statistics:

- Now that the meal is complete, how full do you feel? [7-point Likert item (1=not at all full, 7= extremely full)]
- Before eating this meal, how hungry were you? [7-point Likert item (1= not at all hungry, 7= extremely hungry)]

**Aim 1.** In order to examine the total calories ordered and consumed from food, beverages and SSB at a dinner meal the following endpoints will be summarized and compared between the 4 conditions:

Primary endpoints

- Total calories ordered at the dinner meal
- Total calories consumed at the dinner meal

Secondary endpoints

- Total beverage calories ordered at the dinner meal
- Total beverage calories consumed at the dinner meal
- Total food calories ordered at the dinner meal
- Total food calories consumed at the dinner meal

A one-way ANOVA test was used to compare continuous variables (age and BMI) for significant differences across the four SSB menu conditions. Categorical variables were compared using either Chi-square test statistics for comparisons of proportions (for sex, race, ethnicity, marital status) or Kruskal Wallis test (KW test) statistic for education and income, along with participants’ ratings of their level of hunger and fullness.

A series of univariate ANOVAs were conducted to assess for differences in the primary endpoints total food and beverage calories ordered and consumed at the dinner meal. Additional, separate ANOVA tests were conducted to compare the following secondary continuous outcomes between SSB menu conditions: total beverage calories ordered and consumed at the dinner meal; total food calories ordered and consumed at the dinner meal, and total SSB calories ordered and consumed.

Adjusted univariate GLM models were constructed controlling for income the only characteristics found to be statistically significant different between SSB menu conditions. Of note the Eating Habits Questionnaire categorical item variables “how full” after completing the meal” or “how hungry” before eating the meal” variables were also examined and no statistically significant differences were found between SSB menu conditions and thus these variables were not included as factors in the adjusted model.
**Aim 2.** In order to examine the calories ordered and consumed from food, beverages and SSB at the dinner meal were summarized and compared using univariate unadjusted and adjusted GLM testing as described above.

Since the statistical analysis from Aim 1 and Aim 2 did not detect any statistically significant between SSB menu condition no further statistical testing were needed.
Chapter 4. Manuscript 1

Early childhood obesity prevention efforts through a life course health development perspective: A scoping review


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Abstract

Introduction: The obesity rate in preschool children in the United States (US) is 13.9%, while even higher rates are associated with racial and ethnic minorities and children from low-income families. These prevalence patterns underscore the need to identify effective childhood obesity prevention programs.

Method: A scoping review was conducted following Arksey and O’Malley’s framework to provide an overview of the types, effectiveness and cost-effectiveness of obesity prevention interventions and policies in children up to 6 years old. Inclusion criteria were studies at least 6-months duration; included a weight-based outcome, conducted in the US, English publications from January 2001 to February 2018. Exclusions: studies in overweight/obese children and obesity treatments, no comparator group. Evidence was characterized across the early life course and multiple-levels of influence.

Results: From the 2,180 records identified, 34 met the inclusion criteria. Less than half of the interventions initiated during pregnancy, infancy or preschool reported a significant improvement in a weight-based outcome. All interventions included strategies to influence individual- or interpersonal-level health behaviors, yet few removed obstacles in the healthcare system, physical/built environment, or sociocultural environment. The majority (78%) of the interventions occurred during preschool years, with 63% conducted in early childcare education settings serving low-income families. The health impact of
the state-wide and national policies on children under age 6 years remains unclear. There was considerable uncertainty around estimates of the health and economic impacts of obesity prevention interventions and policies.

**Conclusion:** There is a need to intensify early childhood obesity preventive efforts during critical periods of health development in the US. Future studies should estimate the feasibility, program effectiveness, and cost of implementing multilevel obesity prevention interventions and policies. Addressing these research gaps will provide stakeholders with the scientific evidence necessary to facilitate funding and policy decisions to decrease the prevalence of early childhood obesity.

**Introduction**

Despite recommendations to prioritize obesity prevention efforts, [1-4] epidemiological data from the 2015-2016 National Health and Nutrition Examination Survey (NHANES) found that the prevalence of early childhood obesity remains at a 10-year high [5]. Furthermore, obesity rates among school-aged children aged 6-11 years are approximately 25% higher compared with preschool children aged 2-5 years [5]. In addition, even higher obesity rates are differentially associated with minorities and children from low-income families [6]. These prevalence patterns underscore the need to focus on early childhood obesity prevention efforts with the goal of meeting the Healthy People 2020 obesity rate target of 9.4% [2].
The evaluation of such efforts should be guided by framework models that consider the various levels that influence an individual’s health trajectory [7, 8]. For example, the National Institute on Minority Health and Health Disparities (NIMHD) Research Framework represents the multiple levels of modifiable and interacting determinants that contribute to health disparities (S1 Fig) [9]. While the multi-level Life Course Health Development Framework perspective also recognizes that health-development unfolds over the life course, it is sensitive to time and environment, adaptive, and requires a balance among all levels of health [10]. Together, these models are well-suited for evaluating and characterizing childhood obesity prevention efforts and informing future interventions.

S1 Fig. Framework used to characterize components of early childhood obesity prevention interventions across the early life course. Adapted from The National Institute on Minority Health and Health Disparities (NIMHD) Research Framework [9].

We conducted a scoping review to provide an overview of the current state of obesity prevention efforts in the United States (US) with children less than 6 years of age, and to answer two questions: "What types of interventions and policies are being used for obesity prevention across the early life course and at multiple levels of influence?" and “How effective are they?” The secondary aim was to describe the best available evidence on the cost and
cost-effectiveness of implementing obesity prevention interventions and policies.

**Methods**

A scoping review was conducted to expand on previous systematic and narrative reviews of obesity prevention efforts in young children and to identify scientific evidence from a broad range of interventional studies, government and non-governmental programs, and local and national policies in the US. The scoping study design was chosen because it offers a framework to identify, “map,” merge evidence, and synthesize a broad range of evidence. Furthermore, the scoping review methodology is focused on providing conceptual clarity and allows researchers to focus on questions with relevance to target populations and locations [11-12].

The scoping review process is based on the Arksey and O’Malley’s 5-stage methodological framework [11]. The 5-stages that served as a roadmap for the present review are:

1. identifying the research question
2. identifying relevant studies
3. study selection
4. charting the data
5. collating, summarizing and reporting the results [11].
While the Joanna Briggs Institute’s Reviewer’s Manual of best research practice guidelines for conducting a systematic scoping review, they served as a guide for the present review [12]. To ensure consistency, transparency, and reproducibility an a priori scoping review protocol was developed and directed the review process.

**Data sources**

After formulating the review objectives and the research questions (Stage 1), a literature search was conducted to identify relevant studies (Stage 2) in the Cochrane Central Register of Controlled Trials, MEDLINE PubMed, CINAHL, PsycINFO, and EconLit databases from January 2001 to February 2018. The timeframe was chosen because in 2001 the Department of Health and Human Services published “The Surgeon General's Call To Action To Prevent and Decrease Overweight and Obesity” [13] prioritizing the public health response to the growing obesity epidemic.

**Search strategy**

A search strategy was devised with the assistance of an Information & Education Librarian (MG) for PubMed using keywords from obesity prevention articles and modified for the additional electronic databases. Table 1 shows the search syntax and strategy.

*INSERT TABLE 1 HERE*
Study selection

During study selection (Stage 3), publication titles and abstracts were screened, duplicates deleted, and full-text articles reviewed for eligibility based on the review’s inclusion criteria. References from the bibliographies of included trials were hand-searched. Two researchers (SV, PRP) independently reviewed, discussed, and agreed upon the eligibility of all studies. While systematic reviews adhere to rigid inclusion criteria, scoping studies’ inclusion criteria are broad to allow for the evaluation of a wide range of information [12]. Eligible studies were included if they incorporated a comparator group; were conducted in children with a normal or healthy weight (BMI-for-age percentile between the 5th percentile to less than the 85th percentile); children under the age of 6 or woman in any setting, and reported at least one weight-based outcome measure of growth or weight status (Table 1). While critical appraisal of methodology is not the focus of scoping reviews, we followed a standardized research protocol and applied the Dixon Woods threshold to exclude articles judged "fatally flawed" [14].

Data extraction

Data extraction (Stage 4) was done using a two-step process. First, a Microsoft Excel, version 2016 (Microsoft, Redmond, WA) data extraction template was developed to chart continuous and categorical variables and perform summary statistics. S1 Appendix shows a list of the key data extraction
variables. Next, included articles were imported into Nvivo 11 Pro (QRS International, Doncaster, Australia) and qualitative data were extracted by selecting, coding, and creating nodes (files) representing key concepts. A coding structure and organizational hierarchy was created to characterize major themes by life course, concepts and context pertaining to the NIMHD Framework (S1 Fig).

Results

Collating, summarizing and reporting the results (Stage 5)

S2 Fig describes the literature search and study selection process. We identified a total of 2,467 records. After removing duplicate records, the titles and abstracts of 2,180 records were screened for inclusion. The full text of 73 articles were reviewed for eligibility and 34 studies were included in the review. S2 Fig. Flow diagram showing literature and study selection. Adapted from Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ (Clinical research ed). 2009;339:b2535, [15].

Study characteristics

The included studies examined the collective experiences of approximately 900 pregnant women, 1,600 infants and 10,000 preschool aged children across 16 states, in 10 urban centers, and a mix of suburban and rural
communities (Tables 2 - 4). The interventions (n=25) were initiated during three stages in the early life course: pregnancy (n=3), [16-18], infancy (n=3), [19-21] and preschool (n=19), [22-40]. The majority (88%, 22/25) of the interventions used an experimental study design (19-40).

We identified 6 publications examining the impact of city, state, and national obesity prevention policies [41-46]. Three additional studies calculated the net cost or cost-effectiveness of obesity prevention interventions [47-49]. In total, 11 (44%) interventions reported a positive benefit on a weight-based measure of growth or weight status (e.g., weight, weight/weight percentiles, BMI/ BMI z-score, and BMI categories) [17, 19, 20, 22-25, 28, 31, 36, 38]. The effectiveness of the interventions was inconsistent and contradictory across all stages of the early life course. Tables 2-4 provide descriptions of the characteristics and outcomes of the interventions.

**Studies initiated during pregnancy**

This review identified 3 studies initiated during pregnancy conducted in children from low-income families and members of racial-ethnic minority groups who are at higher risk of obesity [6] and in a variety of settings [urban healthcare clinic-bases [16]; community-wide plus home-visits [17]; community-wide plus primary care practice], (Table 2), [18]). All three interventions focused on similar individual- and interpersonal-level behaviors (preventing excess gestational weight gain [16, 18] and accelerated infant
growth [16-18]), two studies also focused on community-level influences [17-18] but only the one study [17] that implemented interventional components at multilevel domains of influence demonstrated a positive effect on Body Mass Index z-score (BMI-z) in American Indian/Alaskan Native tribal communities in the multi-level, community wide-plus home-visit intervention.

**INSERT TABLE 2 HERE**

**Interventions during infancy**

Two [19, 20] of the three [19 - 21] studies identified were initiated during infancy and showed a positive effect on infant growth (Table 3). All studies included behavioral strategies at the individual and interpersonal level aimed at increasing knowledge of healthy food choices and appropriate growth patterns. The Well Baby Group (WBG) intervention also targeted community levels of influence by delivering sociocultural adapted nutrition education and providing a peer social support network while maximizing the physical environment and healthcare system resources at a federally qualified community health center [19]. At two years, the infants of low-income, predominately Hispanic mothers attending the WBG were significantly less likely to have a BMI-for-age ≥ 85th percentile compared with a randomly selected comparisons group of infants. Also, at one year, infants of mothers who received both the home-based intervention Soothe/Sleep and Introduction
to Solids interventions had lower mean weight-for-length percentiles (33rd vs. 50th) compared to the no intervention group [20].

INSERT TABLE 3 HERE

Interventions in preschool aged children

Childcare center-based interventions

Over half (63%, 12/19) of the preschool-aged interventions enrolled children from low-income, racially and ethnically diverse families from Head Start centers (n=7), YMCA-affiliated childcare centers (n=2) or other subsidized childcare programs (n=3), (Table 4). The childcare center-based interventions included in this review were designed with interventional components that primarily focused on influencing individual- or interpersonal-level health behaviors of the children and preschool teachers. Only 42% (5/12) of these interventions reported a significant improvement in either BMI-z score [22], BMI [23-24, 28] and BMI percentile [36].

INSERT TABLE 4 HERE

Of the interventions demonstrating a positive effect on BMI, two studies administered 30 minutes of moderate to vigorous physical activity (MVPA) for primarily African American (AA) children attending YMCA-affiliated preschools.
Similarly, the “Hip-Hop to Health” efficacy trial [28] enrolled predominately AA preschoolers attending Head Start and used trained educators to deliver 20-minute healthy-lifestyle behavior themed lessons and 20 minutes of directed physical activity (PA); however, the same intervention did not have a beneficial effect on BMI in Latino preschoolers [29], nor did other similar effectiveness trial in Latino [30] and AA preschoolers [33, 50]. Another study found that five, 1-hour long healthy-lifestyle themed workshops presented by trained nurse childcare health consultant to parents, childcare teachers and staff, significantly decreased mean BMI-z scores in children from underserved minority families [22]. Finally, a multilevel, childcare-based intervention [36] showed a significantly smaller increase in the BMI percentile when intervention centers implemented early childcare center policies focused on modifying individual-level child, parent, and teacher behaviors with physical/built and sociocultural environment changes.

**Primary care providers clinic-based**

Two primary care clinic-based studies [25, 37] reported contradictory results. Both studies targeted individual- and interpersonal-level behavioral changes, implemented in a healthcare environment. Only Cloutier and colleagues found a significantly greater reduction in BMI percentile in the intervention group that participated in bilingual, culturally adapted, motivational
interviewing (MI) sessions during primary care provider (PCP) visits and phone-coaching session [25].

**Community center-based**

Similarly, two interpersonal-level, family-based studies were conducted in a community center-based environment with mixed results. Slusser and colleagues [38] randomized Latino mothers of preschoolers to receive nine culturally tailored, Spanish language, parent-training sessions or be in a Wait List Group (WLG). Despite reporting 33.3% attrition, the intervention group experienced a greater reduction in BMI percentile differences compared with the WLG at nine months. In contrast, Haines and colleagues [32] failed to demonstrate a significant improvement in BMI with a family-based, community health center intervention.

**Other settings**

Additional preschool-aged interventions were conducted at a WIC site [40], online [39] and in the home and over the telephone [31]. Only one study reported a positive effect on BMI. In the “Healthy Habit, Healthy Home,” [31] health educators used MI coaching techniques during home and phone coaching sessions, along with text messages to promote interpersonal-level changes in healthy family routines and PA, encourage family meals and beverage choices, adequate sleep and change the physical-built environment.
by asking families to remove TVs from the child’s bedroom. Although a WIC-based intervention within the community-wide Massachusetts Childhood Obesity Research Demonstration [51] found no effect on BMI-z scores, a post-hoc analysis excluding Asians (due to disproportionate distribution of Asian children in the comparison community) found a significant improvement in BMI-z scores [40].

**Costs of obesity prevention interventions**

Table 5 includes a summary of three studies appraising the cost of preventing obesity. Cradock and colleagues [47] estimated the total annual cost per child associated with implementing and nationally disseminating the PA component of the childcare center-based “Hip-Hop Jr.” PA intervention was $22.65 yearly [33]. Also, Wright and colleagues [45] calculated the net cost of a primary-care based intervention [52], aimed at reducing obesity related behaviors and BMI in overweight and young, obese children at $196 per child [49]. In the third study, Ma and Frick [48] modeled the breakeven point of a hypothetical intervention producing a 1% reduction in the prevalence of obesity among children 0-6 years. Accounting for future medical costs, population-based interventions could cost up to $339 per child and still have a favorable health benefit/cost profile.

*INSERT TABLE 5 HERE*
**Policy interventions**

Six studies [41-46] estimated the cost and health benefits of city-wide, state, and national policies aimed at preventing future weight gain and obesity (Table 5). Kuo and colleagues [41] developed a simulation model estimating the impact on annual weight gain in Los Angeles (LA) County of a California menu law mandating large restaurant chains to display the caloric content of menu items. The model assumed 10% of all customers would consume 100 calories less per meal and found the law was projected to avert as much as 500,000 lbs. of the estimated annual LA County population weight gain (1.25 million lbs.) in children 5 to 17 years old.

The Northeast Iowa Food and Fitness program enacted multilevel changes during a 6-year long program. The changes targeted schools and home meals and PA, established school gardens, and at the community-level provided access to outdoor recreational spaces and programs, local farmers markets and affordable healthy food. It was shown that children ages 4-12 years who had longer periods of program exposures (2 to 6 years) demonstrated a greater improvement in appropriate growth rate compared with children with shorter periods of program exposure (0 to 1 year) [46].

Dharmasena et al. utilized an economic demand model based on household purchasing habits to assess the impact of a 20% tax on SSB consumption, caloric intake and weight. Results using the most conservative estimate showed an overall reduction in SSB with corresponding increases in fruit juice
and low-fat milk consumption. The interrelated changes in beverage consumption patterns was forecast to produce an average reduction of 449 calories per month resulting in a mean body weight reduction of 1.54 lbs/year.

**Costs and cost effectiveness analysis**

Finally, three studies describe the economic impact and health consequences of obesity prevention policies using a Markov-based cohort model to estimate the cost effectiveness of: an excise tax on SSBs, [44] eliminating the tax subsidy for TV advertising, [42] and implementing a set of hypothetical childcare center-based policy changes [45], (Table 5). Sonneville and colleagues [42] found that eliminating the ability of food manufactures to deduct the cost of advertising unhealthy foods would result in a mean BMI reduction 0.028 per child [42]. Likewise, Wright and colleagues [45] estimated that a hypothetical childcare center-based policy (eliminating SSBs, limiting fruit juice, serving low-fat milk, limiting screen time and increasing MVPA) would result in a mean BMI reduction of 0.019 BMI units per child [45]. Finally, Long and colleagues [44] estimated that a tax of $0.01/ounce on SSBs would reduce the total calories consumed by children ages 2-4 and 5-9 years, by -1 to -13 kcal/day, respectively, and result in a mean reduction in BMI of approximately 0.16 units for children 2-19 years. The cost per unit BMI reduction based on these policies ranged from $1.16 for eliminating the advertising subsidy to $57.80 for the childcare center-based policy.
Discussion

This scoping review identified the characteristics and effectiveness of obesity prevention interventions, programs and policies across the early life course and at multiple levels of influence in the US. There were a number of key findings (S2 Appendix). We found slightly less than half of the interventions initiated during pregnancy, infancy or preschool were effective at improving a weight-based measure of growth or weight status in young children [17, 19, 20, 22-25, 28, 31, 36, 38]. All interventions included strategies to influence health behaviors at an individual or interpersonal level. However, few studies removed obstacles in the physical/built environment, sociocultural environment or healthcare system. The majority of the interventions were conducted in children at higher risk of obesity, in early childcare education settings. The impact of menu labeling laws, taxing SSBs and eliminating incentives for TV advertising of unhealthy foods, on a direct weight-based measure of growth or weight status in children under age six years remains unclear. Finally, this review confirmed the lack of available data on the cost of implementing obesity prevention efforts in the US.

We used the NIMHD Research framework [53] to guide our examination of obesity prevention efforts considering factors relevant to obesity and health equality research. We found that all interventions initiated during pregnancy and infancy focused on modifying biological risk factors of obesity by enhancing
individual-level knowledge of healthy eating patterns, appropriate gestational weight gain, prolonged breastfeeding, delayed introduction of complementary feeding, responsive feeding techniques and appropriate infant growth patterns [19, 20]. For example, in the primary care setting, MI coaching techniques were applied to reduce obesogenic behaviors [25, 37], while in the childcare center setting, parents and teachers gained the necessary knowledge and skills to serve as role-models of healthy-lifestyle behaviors [19, 28, 36, 38]. Also, preschool children were encouraged to modify their behaviors using culturally adapted, nutrition and PA lessons [19, 28, 31, 36, 38], food group-themed, hand puppet activities [29], English and Spanish-language CDs [30], healthy snacks [22, 28, 36] and structured MVPA [23, 24, 28].

All effective interventions identified in this review incorporated interpersonal-level strategies affecting family behaviors and home routines. Parental and family participation was either a primary or secondary component of all successful interventions. Parents attended culturally tailored education sessions [38], home visits [17, 20, 31], or were assigned homework, received instructional handouts and newsletters promoting frequent family meals, adequate sleep, family PA and limiting screen time [20, 22, 25, 28, 31, 36, 38]. The inclusion of parent-direct strategies in successful interventions is consistent with the findings of a recent review of obesity prevention interventions in early childcare centers. Ward and colleagues [54] found that higher parent engagement in the early childcare settings enhanced the
effectiveness of interventions by achieving a positive weight related outcome [54].

Recognizing the influence of physical environments on the risk of childhood obesity and health disparities is critical to the design of multilevel obesity prevention interventions. Yet, less than one-third of the studies aimed to modify a component in the physical/built environment. These interventions effectively removed barriers to facilitate healthier lifestyle behaviors. They included components such as removing TVs from bedrooms, providing alternative playtime activities, and implementing childcare centers polices limiting SSBs, serving water, low-fat milk, fruits and vegetables as snacks; increasing hours of PA, and limiting screen time [22, 31, 36]. At the community-level, Karanja and colleagues [17] enacted tribal-wide policies providing access to breast feeding rooms and reallocating resources by stocking vending machines with water and providing water coolers at community-sponsored activities. Collectively, these types of physical environment changes rendered healthy behaviors as the default behavior.

Approximately half of the interventions integrated strategies to change sociocultural environmental-level factors, with considerable variability in the intensity of the components. Few included primary objectives examining the effectiveness of culturally-tailored training programs [38, 39] or other high-intensity activities such as media campaigns encouraging drinking water and breastfeeding as cultural values [17] or establishing group sessions intended
to support shared sociocultural values [19]. While the majority of studies included the following types of moderate- to low-intensity components: using bi-cultural/bilingual interventionalist [19, 25, 29, 30, 32, 36, 38, 39], culturally adapted curriculum [25, 26, 28-31, 33, 34, 36, 38, 39] and providing culturally relevant recipes [19, 25, 26, 35, 39].

Healthcare system-level changes facilitate access to healthcare resources, engage parents in healthcare decisions and improve parent-healthcare provider relationships. Furthermore, the early initiation of interventions in the healthcare setting might alter the course of health and disease, and reduce future health disparities [55]. Yet, of the five healthcare-based interventions [16, 19, 21, 25, 37], only two reported improvements in a measure of obesity. One was informed by the chronic care model and used brief MI format [25], while the other used a patient-centered approach and group sessions [19]. In contrast, others failed to improve childhood growth trajectories [16, 21, 37]. Such results suggest that even in a healthcare setting, the intensity of the program and study population are important considerations for the success of any intervention.

This review identified studies that estimated the health and economic impact of regional and national SSBs pricing strategies, labeling laws and food marketing policies. These strategies were shown to change purchasing behavior and improve the prevalence of obesity, and potentially to generate tax revenue, drive the reformulation of unhealthy foods, and change social norms
Although the population reach and societal-level impact of obesity prevention policies are high, the long-term outcome on the prevalence of early childhood obesity remains uncertain.

None of the included interventions reported on the costs or cost effectiveness of the study. The lack of economic evaluations is a surprising finding given that the annual cost of obesity-related medical spending was estimated to exceed $147 billion [56]. Consistent with our findings, Wolfenden and colleagues [57] noted that 88% of the systematic reviews of obesity prevention intervention in children did not report whether a cost analysis has been conducted. In the absence of CEA data, a reliable cost threshold could assist stakeholders to determine the amount of money to spend on obesity prevention interventions. Ma and Frick [48] established the break-even cost of $339 per child as a “good value” for interventions resulting in a 1% reduction in childhood obesity prevalence.

There were several limitations to our review. First, our scoping review presented a comprehensive overview of the quantity and context of current childhood obesity prevention efforts in the US, which limits the generalizability of our findings to other countries. Next, our review did not identify any obesity prevention interventions conducted during pre-pregnancy and identified very few studies conducted during pregnancy. It is likely that our search strategy may not have been sensitive enough to identify the full breadth of research activities during these early life stages. Since we followed standardized
methodology for scoping reviews, we did not assess the effect size of the interventions or systematical evaluate the quality of the individual studies including the risk of bias quality. We acknowledge that many of the studies were of varying quality based on study design, sample size, intensity, analytical approaches, high attrition rates and low parent attendance rates. Although we excluded studies judged to be fatally flawed, our results are subject to a range of biases due to these many threats to the internal and external validity of the study results. Furthermore, given that studies reporting positive results are more likely to be published, conclusions may also be subject to publication bias [44]. Finally, our synthesis was based on interventions reporting a weight-based measure of growth or weight status in normal weight children. Because we did not consider favorable behavioral or PA outcomes, the generalization of our results may be limited.

Conclusions

This review presents an overview of the current state of obesity prevention efforts across multiple levels of influence and the early life course in the US. The majority of efforts focused on individual and interpersonal-level health behavior changes in preschoolers. Thus, there is a need to intensify obesity preventive efforts during critical periods of health development and target multiple levels of influence, especially regarding physical, sociocultural and healthcare system-level obesity risk factors. Furthermore, there is
considerable uncertainty around estimates of the economic impacts of obesity prevention interventions and policies. Future studies should estimate the feasibility, effectiveness, and cost-effectiveness of obesity prevention interventions and policies. Addressing these research gaps may provide government agencies, policy makers, and healthcare payers with the necessary scientific evidence to make informed decisions regarding the allocation of funds for initiatives aimed at decreasing the prevalence of early childhood obesity.

Acknowledgements

We thank Mina Ghajar (Librarian, George F. Smith Library of the Health Sciences, University Libraries Rutgers) for her assistance with the literature search strategy.
References:


Tables

Table 1. Search Strategy and Study Selection Criteria

<table>
<thead>
<tr>
<th>Search Strategy</th>
<th>PubMed Search Strategy</th>
<th>Limits</th>
<th>Study Selection Criteria (PICOTS)</th>
</tr>
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<tbody>
<tr>
<td><strong>Search Strategy</strong></td>
<td>(((policy[Title/Abstract] OR policies[Title/Abstract] OR prevention[Title/Abstract] OR &quot;primary prevention&quot;[Mesh]) AND (&quot;Child, Preschool&quot;[Mesh] OR &quot;Infant&quot;[Mesh] OR childhood[Ti] OR childcare[Ti] OR early childhood[Ti] OR preschool[Ti]) AND (obesity[mh] OR obese[tiab] OR obesity[tiab] OR overweight[tiab] OR over-weight[tiab])) NOT (((&quot;Review&quot;[Publication Type] OR &quot;Meta-Analysis&quot;[Publication Type] OR &quot;Meeting Abstracts&quot;[Publication Type] OR &quot;research design&quot;[Mesh]))</td>
<td>Full text; Publication date from 2001/01/01; Humans; English; Newborn: birth-1 month; Infant: birth-23 months; Infant: 1-23 months; Preschool Child: 2-5 years</td>
<td><strong>Inclusion Criteria</strong>&lt;br&gt;-Children under the age of 6&lt;br&gt;- Records/ separate analysis of children under the age of 6, if older children were also included&lt;br&gt;-Otherwise healthy</td>
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</table>
overweight, obese) compared to a comparator group

| **Timing** | - Interventions/programs lasting at least 6 months long or collecting a weight-based outcome measure 6 months after initiation  
| - Policies since 2001 | - Interventions/programs less than 6 months |
| **Setting** | - Individual (primary-care based)  
| - Interpersonal (home-based, peers)  
| - Community (childcare-based, community organizations)  
| - Societal (policies, health information, social norms) | - Non-US settings or policies |
| **Year Range** | Publications from Jan 2001 to Feb 2018 | - Publication prior to 2001 |

Studies estimating implementation costs, cost effectiveness analyses and policy studies were included provided that the assumptions and datasets included children under 6 years of age.
### Table 2. Characteristics of interventions during pregnancy

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Study Name</th>
<th>Study Setting</th>
<th>Population</th>
<th>Study Design</th>
<th>Theoretical Framework</th>
<th>Level of Influence</th>
<th>Intervention</th>
<th>Participant</th>
<th>Treatment provider</th>
<th>Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gregory [16] 2016</td>
<td>Nutrition in Pregnancy clinic (NIP)</td>
<td>Baltimore, MD Urban hospital, health care clinic</td>
<td>Pregnant, &lt; 21 weeks gestation; Pre-pregnancy BMI &gt; 30 kg/m2; Medicaid insurance; Mainly AA</td>
<td>Retrospective cohort</td>
<td>Obstetrical model</td>
<td>Individual, interpersonal</td>
<td>Behavior, Diet, Appropriate GWG</td>
<td>Infant</td>
<td>Mother, Infant</td>
<td>Not significant: at 1-year, infant WFL ≥ 95th percentile I=17%; C=15%, P = .66</td>
</tr>
<tr>
<td>Olson [18] 2014</td>
<td>Healthy Start Partnership (HSP)</td>
<td>Rural, NY 8-counties with below state median family income; higher rates of childhood overweight/obesity in 6 of the counties</td>
<td>Pregnant, &lt;24 weeks gestation and 6 months post-partum; infant weights through 6 months</td>
<td>Prospective cohort study</td>
<td>Community coalition action theory</td>
<td>Individual, Interpersonal, Community, Societal</td>
<td>Environmental community changes, Diet, PA, Appropriate GWG, Breastfeeding</td>
<td>Infant, Community</td>
<td>Mother, Infant, Community</td>
<td>Not significant: at 6 months, WFL z-score in (%), I = 34.2%; C=31.4%, P = .52</td>
</tr>
<tr>
<td>Karanja [17] 2010</td>
<td>Portland Area Indian Health Services (Idaho, Oregon, WA)</td>
<td>Pregnant: affiliated with 1 of 3 AI / AN tribes with children at higher risk for overweight</td>
<td>Before and after design</td>
<td>Home-visiting model</td>
<td>Individual, interpersonal, community</td>
<td>Environmental community changes, Behavior, Diet, Breastfeeding, Reduce SSB</td>
<td>Mother, Infant, Community</td>
<td>Significant: at 24 months, BMI- z scores increased less in the community-wide plus home groups (Tribes B &amp; C) compared with community only (Tribe A) (−0.75, P = .016)</td>
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<tr>
<td>The toddler overweight and tooth decay prevention study (TOTS)</td>
<td>Combination community-wide plus home-visit/phone</td>
<td>Mothers: I=142; C=63; Infants: I=125; C=53</td>
<td>Biological, Behavioral, Physical/ built, Socio-cultural, Healthcare system</td>
<td>Individual, face to face, Phone, Multimedia</td>
<td>Trained, peer, community worker</td>
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</tbody>
</table>

Abbreviations: AA, African American; AI, American Indian; AN Alaskan Native; BMI, Body Mass Index kg /m²; C, comparator group; GWG, gestational weight gain; I, Intervention group; PA, physical activity; PCP, primary care provider; WFL, weight-for-length; Wt, weight

*a Sample size is the analytical sample or sample included in the primary analysis
Table 3. The characteristics of the policy simulation model studies and the estimated the effect of a sugar-sweetened beverage (SSB) portion size cap policy on SSB purchases, beverage consumption and beverage calorie intake

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Policy Simulation</th>
<th>Setting / Sample Location</th>
<th>Data source/ Population Reach Perspective</th>
<th>Analysis model; Cost parameters Year of Costing - Discount Rate</th>
<th>Beverage Intervention</th>
<th>Beverage definition</th>
<th>Impact of Policy</th>
<th>Beverage kcal / Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleghorn 2019</td>
<td>To predict the population health cost and health system cost of a maximum serving size SSB cap of 250 ml in fast food/restaurants/ cafes</td>
<td>NZ Adults</td>
<td>New Zealand Adult National Nutrition Survey (NZANS) 2008-09; New Zealand Health Tracker database - The entire NZ population - Healthcare system perspective</td>
<td>Epidemiological macro-simulation multistate life-table (MSLT) modeling - Total population - health costs; - disease costs; - cost of new legislation - 3% discounting - NZ$ Converted to US$</td>
<td>Base case: cap of 250ml applied to single serving beverages &lt; 600ml from NZANS</td>
<td>Base case model: SS carbonated soft drinks, fruit drinks, carbonated energy drinks, and sports drinks</td>
<td>Narrow; SS carbonated soft drinks and energy drinks</td>
<td>Base case: - 23.2 ml / person/day; Narrow: - 19.8 ml / person/day</td>
</tr>
<tr>
<td>Crino 2017</td>
<td>Cost-effectiveness of changes in BMI produced from changes in KJ consumption arising from a portion size cap of 350 ml on single-servings of SSB</td>
<td>Across the entire population Australia</td>
<td>Beverage consumption data from the 2011–2012 Australian Health Survey (AHS); Australian Food Labelling Trial (FLT) ; the Australian FoodSwitch (FS) Database - Limited societal perspective</td>
<td>multi-state, multi cohort, life table Markov model with a lifetime time horizon - 3% discounting - expressed in 2010 values</td>
<td>Bases case: government ban on the sale of single-serve, packaged SSBs greater than 375 ml; No compensatory eating</td>
<td>sugar-sweetened: carbonated beverages, favored waters, favored iced teas, sports/ electrolyte drinks and sugar- sweetened cordials</td>
<td>-16% of SSB - approx. 2/3rds of single-serve SSBs (59%) &gt; 375 mL</td>
<td>Decrease from 564.4 kJ/person/day to 550 kJ/person/day; - decrease 14.4 kJ/day across the entire population</td>
</tr>
<tr>
<td>Elbel 2012</td>
<td>To estimate the effect of the proposed NYC 16 oz SSB portion size cap</td>
<td>USA</td>
<td>Secondary data from 2 other trials; Receipts (N=1624) from three different fast-food restaurants in</td>
<td>Statistical model changes in the number of calories from SSB beverages per transaction</td>
<td>Base case: assume 100% consumers switch to a 16-oz beverage</td>
<td>All beverages listed on the receipts except milkshakes</td>
<td>62% of Beverage purchases subjected to portion size policy</td>
<td>Bases Case; All beverages, −63 kcal (95% CI, −61 to −66) per consumer -Scenarios:</td>
</tr>
</tbody>
</table>
four cities: New York City; Newark, New Jersey; Philadelphia; and Baltimore; Beverage data from restaurant's website

- bootstrapped simulations to generate 95% CI for proportion change

- only SSB purchases and 100% switched to 16 oz: 230 ± 86 kcal / consumer; −74 kcal (95% CI, −78 to −71)/ consumer
- 30% switch: no statistically difference

| Liu 2014 | To estimate the effect of downsizing packages | Designated market areas: New York, Detroit, Washington D.C., Atlanta, Chicago, Los Angeles, Seattle, USA | 2 Nielsen data sets: Homescan with product characteristics; the advertising data set with brand information for 2006-2008 | A random-coefficient logit demand model for carbonated soft drinks (CSD); considered price, package size, advertising and calorie content | Estimate the effect of a ban on 2-liter bottles and only allowing 12-oz can or 20-oz bottles | - Regular CSD (sugar-sweetened) - Diet Drinks - Total CSD (sugar-sweetened and diet CSD) | - 15.75 % in Total CSDs consumption; -16.22 % consumption of Regular CSDs | -16.31 calories consumed from regular soda per capita annually; |
| Wang 2013 | To examine the impact of the New York City 16-oz SSB cap in food-service establishments | USA population adults in the USA | NHANES 2007-2010 (N=19,147) | Estimated change in the number of calories from SSB beverage; 95% CI estimated with Monte Carlo simulation | Estimated varied percentage of respondents switching to 16-oz SSB and others were assumed to purchase two 16-oz drinks Scenario 80/20: Among individuals affected by the policy, assume 80% switch to a 16-oz drink and 20% upsize to 2 x 16-oz drinks | SSBS: soda, fruit punches, sweet tea, sports drinks, and nonalcoholic drinks containing caloric sweeteners; in one eating occasion and purchased at a food-service establishment | Policy affect 7.2% children and 7.6% | Consumed any SSB in 24 hours: children (71.3%); adults (66.7%) | Per-capita reduction in kcal/day: youth (6.3 kcal/d); adults (8.9 kcal/d) - Only affected SSB consumers: youth, -99.1 (95% CI, 86.7, 111.5) kcal/day; Adults, -102 (95% CI, -93.8, -110.4) kcal/d) - 80/20: Youth, - 57.6 (95% CI, - 65.0, - 50.1); adults, -62.6 (95% CI, - 67.9, - 57.4) |

Abbreviations: Approx. Approximately; b, billion; CI, confidence intervals; CSD, carbonated soft drinks; NHANES, The National Health and Nutrition Examination Survey, NZ, New Zealand; US, United States; US$, US Dollars
Table 4. Description of behavioral simulation studies examining the effect of a sugar-sweetened beverage (SSB) portion size cap policy on SSB purchases, beverage consumption and beverage calorie intake

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Sample Size</th>
<th>Design</th>
<th>Intervention</th>
<th>SSB Portion Size</th>
<th>Measures</th>
<th>SSB</th>
<th>Beverage Purchases</th>
<th>Beverage Consumption</th>
<th>Beverage kcal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood (2006)</td>
<td>33 adults participants from PSU university community</td>
<td>Cross-over design University lab</td>
<td>Compare effect of drink portion size on drink, food and energy intake during a meal</td>
<td>360 g (12 fl oz) vs. 540 g (18 fl oz) drink</td>
<td>Pre and post lunch meal food and drink weights</td>
<td>Cola, diet cola, or water</td>
<td>N/A</td>
<td>larger portion size resulted in greater beverage consumption vs. smaller portion size, P &lt; 0.05; No difference in food intake</td>
<td>Regular cola large portion (151 +/-8 kcal) vs. Regular cola small portion (128 +/-4 kcal) P&lt;0.004</td>
</tr>
<tr>
<td>Wilson (2013)</td>
<td>100 undergraduates from UCSD for college credit experiment</td>
<td>Hypothetical scenarios stated choice University lab</td>
<td>Compare purchase preference for a 16 oz beverage portion size and the bundling of smaller portions of beverages</td>
<td>Unregulated: 16 oz, 24 oz, and 32 oz; Bundled: 16 oz portion, bundled 2-12 oz or 2-16 oz; No Bundle: 16 oz only</td>
<td>Soda did not different between diet and regular soda</td>
<td>More ounces bought and revenue generated Bundle vs Unregulated (10 oz $1.02) (p&lt;0.001); Fewest ounces purchased from No Bundle – 16 oz only- p &lt; 0.001); Higher revenue with Bundle (ave. $1.69) vs No Bundle (Ave. $1.02) (p&lt;0.001)</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>John (2017)</td>
<td>623 participants</td>
<td>2 x 2 Cubical in University lab</td>
<td>Compare effects of the factors: &quot;portion limit&quot; and &quot;Service&quot;</td>
<td>See Figure 3 Weighed cups and beverage pre- and</td>
<td>Selected sugar-sweetened lemonade or Iced tea</td>
<td>No main effect; Likelihood of ordering large drinks</td>
<td>Not reported</td>
<td>Bundled group, 115.7 ±70 kcal vs Typical Portion</td>
<td></td>
</tr>
<tr>
<td><strong>John (2017) Epx2</strong></td>
<td>470 participants</td>
<td>2 group experimental design</td>
<td>Cubical in University lab</td>
<td>Evaluated the effect of free refills on beverage purchases and consumption</td>
<td>See Figure 3</td>
<td>Weighed cups and beverage pre- and post-experiment</td>
<td>Selected sugar-sweetened lemonade or Iced tea</td>
<td>No main effect: Proportion of large drink purchases in Typical-portions, 39.9% vs. 16 oz with refills, 36.2%, p=0.55</td>
<td>No between group difference in medium drink consumption, p = .57</td>
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</tr>
<tr>
<td><strong>John (2017) Epx3A</strong></td>
<td>557 participants</td>
<td>Cubical in University lab</td>
<td>Evaluated efforts to mitigate an increase in caloric intake shown with 16 oz portion size restrictions with free refills</td>
<td>See Figure 3</td>
<td>Weighed cups and beverage pre- and post-experiment</td>
<td>Selected sugar-sweetened lemonade or Iced tea</td>
<td>Same proportion of participants purchased 20 oz drink vs. 16 oz with refills, p = 0.79;</td>
<td>Large size drinks: Typical-portion, 138.7 kcal ±37.9; Waiter-service, 210.6 ±83.9; Self-service, 138.7 ±38.0, p &lt;0.001.</td>
<td></td>
</tr>
</tbody>
</table>
John (2017) Epx3B 285 participants Cubical in University lab Evaluated the effect of free refills as a function of Service Style See Figure 3 Weighed cups and beverage pre- and post-experiment Sugar-sweetened lemonade or Iced tea placed at cubical N/A- Drinks provided at no cost

| Waiter service, 93.82 kcal ± 59.2; Typical portion, 51.26 kcal ± 29.30, p < .001; Self-service 67.0 kcal ± SD = 41.3 vs. Typical portions (see above), p < 0.001 |

Abbreviations: Ave, average; Lab, Laboratory; PSU, Pennsylvania State University; UCSD, University of California, San Diego
### Table 5. Cost and cost effectiveness of interventions and policies

<table>
<thead>
<tr>
<th>Author Year</th>
<th>Study Objective</th>
<th>Setting / Sample Location</th>
<th>Data source/ Population Reach</th>
<th>Analysis model; Year of Costinga</th>
<th>Key evaluation components Perspectivea</th>
<th>Domains of influence Levels of Influence</th>
<th>Outcome measures</th>
<th>Net Results: Impact on Obesity and Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ma [48] 2011</td>
<td>Estimate lifetime obesity-related medical costs and establish the break-even cost saving of obesity prevention intervention</td>
<td>US population</td>
<td>Obesity prevalence estimates from 30,000 children ages: 0 to 6 years; 7 to 12 years; 13 to 18 years; NHANES, 2003-2006; MEPS 2006</td>
<td>Simulation; Year of costing: 2006 US$ Discount: medical costs 3% annually</td>
<td>Medical cost perspective Biological, Behavioral, Healthcare system</td>
<td>Individual, Interpersonal, Community, Societal</td>
<td>Preventing and reducing childhood obesity (defined as ≥ 95th percentile of age and gender BM)</td>
<td>In healthy 0-6-year-old children, spending up to $339 per child will result in a positive cost benefit. An intervention that results in 1% reduction in obesity in children 0-6 years would result in a $1.7 billion-dollar cost savings</td>
</tr>
<tr>
<td>Wright [49] 2014</td>
<td>Estimate the cost of a cluster RCT, obesity prevention intervention to reduce TV viewing time; fast food SSB intake</td>
<td>Non-profit pediatric offices; Eastern, MA</td>
<td>Children 2.0 to 6.9 years old; BMI ≥ 95th percentile or ≥ 85th &lt; 95th percentile with 1 overweight parent (BMI ≥25)</td>
<td>Cost Study; net cost analysis: difference in cost for the I vs. C group; Year of costing: 2011 US$</td>
<td>Costs include: Parent time and costs; Provider’s direct visit-related -costs: 4 chronic care visits; 2 phone calls; Educational materials; Interactive website</td>
<td>Biological, Behavioral, Healthcare system</td>
<td>At 1 year, no significant difference in BMI, kg/m2 and BMI z-score; Total I group cost = $65,643 (95% CI, $64,522, $66,842); Total C group cost = $12,192 (95% CI, $11,393, $13,174)</td>
<td>The intervention costs per child, mean I group = $259 (95% CI, $255, $264); C group = $63 (95% CI, $59, $69)</td>
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<tr>
<td>Cost Study: based on the High Five for Kids intervention [51]</td>
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<tr>
<td>I group: Sites (n=5); Children, (n=253); C group: Sites (n=5); Children (n=192)</td>
<td>Discount: medical equipment 3.5%</td>
<td>Societal perspective</td>
<td>Individual, interpersonal</td>
<td></td>
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<tr>
<td>Discount: future cost 3% annually</td>
<td>Net difference in cost between I and C: $196; (95% CI, $191, $202) per child</td>
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</table>

| Cradock [47] 2017 | Estimate the cost of a national policy to implement the Hip-Hop Jr. physical activity intervention in licensed childcare centers | National Association for Regulatory Administration 2013, Census Bureau, MEPS 2001-2003; Implementation cost estimates from similar intervention | Microsimulation modeling of outcomes and costs; Year of costing: 2014 US$ | All intervention costs; State level: training, labor and travel; Program level: training, labor and materials |
| CEA: based on the Hip-Hop to Health Jr. intervention (Kong 2016) | Discount: future cost 3% annually | Modified Societal perspective | Biological, Behavioral, Healthcare system |
| | Case assumptions based on Hip-Hop results: Reduction in mean BMI (-0.13. SE=0.11); PA increase in mean mins per day 7.4 (SE=3.09) | Costs of obesity prevented (2015-2025) 93,065 (95% UI; 88,279, 248,174) | Cost per BMI unit changed per person $361 (95% UI, $2031, $3454) |

<p>| Kuo, [41] 2009 | Assess the impact of menu-labeling law on population weight gain | LA county Health Survey; California Department of Education Physical Fitness Testing Program | Simulation model | Estimates of total annual revenue, market share, and average meal price of large chain restaurants, total annual revenue; |
| | | | Biological, Behavioral, Physical/built, Sociocultural | Assumed 10% of customers would order reduced-calorie meals with an average 100 calories reduction |
| | | | Intervention prevents a total average annual weight gain of 507,500 lbs. in children 5 - 17 years |</p>
<table>
<thead>
<tr>
<th>Policy, city &amp; county wide law: menu labeling</th>
<th>(1999 and 2006.) National Restaurant Association</th>
<th>Health impact assessment approach; weight gain averted</th>
<th>Assumed similar weight gain patterns for all school-aged children aged 5 to 17 years</th>
<th>Individual, Interpersonal, Societal</th>
<th>Estimated annual weight gain in children 5-17 years is 1.25 million lbs.</th>
<th>No cost data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dharmasena [43] 2012</td>
<td>Estimate the impact of a 20% SSB tax, considering the expected effect on other beverages</td>
<td>Four regions in the US (East, Midwest, South and West).</td>
<td>Quadratic Almost Ideal Demand System (QUAIDS) model</td>
<td>Estimating direct and indirect effects of a tax on SSB consumption, caloric intake and per capita annual body weight;</td>
<td>Direct own-price and indirect cross-price effects on other beverages (milk, fruit juice, sports drinks)</td>
<td>Biological, Behavioral</td>
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<tr>
<td>Policy, National: a tax on SSBs</td>
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<tr>
<td>Policy, National: A multi-component early childhood care center policy intervention</td>
<td>Estimate the health and economic costs of early childcare center obesity prevention policies</td>
<td>Licensed child care facilities in the US; Eligible population - 6.5 million preschool children</td>
<td>U.S. 2012: 2007 census; Child Care Licensing Study; 2005 NAP; NHANES 2009–2012; US Bureau of Labor Statistics 2013; Agriculture Marketing Service, USDA; Beverage, PA and screen time data from research studies; Population reach: 6.50 million preschoolers attending childcare</td>
<td>Simulation: Markov-based cohort model; Estimated: licensing, training, and beverage costs; Assumed 73% policy adoption rate; Year of costing: 2014 US$</td>
<td>Hypothetical policy intervention: for preschoolers attending childcare centers: Replacing SSBs with water, limiting fruit juice to 6 ounces /child/day, serving reduced fat milk; 90 minutes of MVPA /day; limit screen time to 30 min./week</td>
<td>Hypothetical policy components’ contribution to change in BMI: PA (28%); Beverage (32%); Screen time (40%); Short term outcomes: First-year intervention cost ($ million): 4.82 (6.02, 12.6); Ten-year (2015–2025) intervention cost ($ million): 8.39 (– 10.4, 21.9); Net healthcare cost savings ($ million): 51.6 (14.2, 134)</td>
</tr>
<tr>
<td>Policy, National: Eliminating the tax subsidy for TV advertising</td>
<td>Estimate the impact of eliminating the TV advertising tax subsidy on BMI</td>
<td>US children and adolescents aged 2–19 years</td>
<td>The Nielsen Company; National Longitudinal Survey of Youth; Rudd Report; US Bureau of Labor Statistics 2013 salary; TV viewing/advertising data from published studies</td>
<td>Simulation: Markov-based cohort model[^6]; Year of costing: 2014 US$</td>
<td>CEA of the elimination of the tax subsidy of TV advertising costs for nutritionally poor foods and beverages during children’s programming (&gt;35% child audience share)</td>
<td>Biological, Behavioral</td>
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<tr>
<td><strong>Sonnenville</strong>[^42] 2015</td>
<td><strong>Population reach:</strong> 74 million</td>
<td><strong>Discount:</strong> healthcare costs 3% annually</td>
<td><strong>Societal perspective</strong></td>
<td><strong>Individual, Interpersonal, Societal</strong></td>
<td>Two-year costs per BMI unit reduced ($ million): 1.16 (0.51, 2.63)</td>
<td></td>
</tr>
<tr>
<td>Source</td>
<td>Study Details</td>
<td>Data Sources</td>
<td>Methodology</td>
<td>Cost and Impact</td>
<td>Policy, National: SSB Excise Tax</td>
<td>Notes</td>
</tr>
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<tr>
<td>Long [44] 2015</td>
<td>To quantify health and economic benefits of a national sugar-sweetened beverage excise tax</td>
<td>NHANES; U.S. Bureau of Labor Statistics 2013; MEPS; Washington and West Virginia State Department of Revenue; SSB intake data from published research studies;</td>
<td>Simulation: Markov-based cohort model; Year of costing: 2014 US$</td>
<td>CEA of the implementing a $0.01/ounce SSB excise tax estimating; The cost and impact of the change in BMI on healthcare costs; Life-years lost DALYs averted; QALYs gained; For the simulation the tax did not apply to 100% juice, milk products, or artificially sweetened beverages</td>
<td>Biological, Behavioral</td>
<td>A tax of $0.01/ounce of SSBs was estimated to result on a 20% (11%, 43%) reduction in baseline SSB consumption; First-year intervention cost ($ million): 51.0 (35.4, 65.5); Ten-year intervention cost (2015–2025). ($ million): 430 (307, 552)-Tax would result in a total healthcare cost savings ($ millions) -23.6 (-54.9, -9.33)</td>
</tr>
<tr>
<td>Policy, National: SSB Excise Tax</td>
<td></td>
<td>Population reach: 313 million</td>
<td>Discount: healthcare costs 3% annually</td>
<td>Societal perspective</td>
<td>Individual, Interpersonal, Societal</td>
<td>Mean per capita BMI unit reduction for youth 2–19 years of age 0.16 (0.06, 0.37); Estimated 1.38% reduction in youth obesity prevalence rate</td>
</tr>
<tr>
<td>Toussaint [46] 2017</td>
<td>Examine the impact of the school-based changes, on BMI trajectory in 6 rural county regions in the Northeast Iowa initiative</td>
<td>Longitudinal cohort data from 4,101 elementary school-aged children (ages 4-12 years)</td>
<td>Linear growth models to determine growth rates; sensitivity analysis to identify</td>
<td>School policies supporting healthy living, healthy diet and active play; Community resources for healthy,</td>
<td>Biological, Behavioral, Physical/built</td>
<td>Program exposure slowed overall BMI growth rates (P &lt; .05); Program exposure of 1 year or less = BMI growth rate 1.02 (about 5 BMI</td>
</tr>
<tr>
<td>Program, regional Northeast Iowa Food and Fitness Initiative</td>
<td>elementary school-aged children over 6 years</td>
<td>program exposure needed to impact BMI growth rates</td>
<td>affordable foods; Environment changes to support physical activity and play</td>
<td>Individual, Interpersonal, Community</td>
<td>increase between kindergarten to fifth grade;</td>
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<tr>
<td>Population Reach: 100,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Program exposure of 2 to 6 years = BMI growth rate of 0.67 (about 3.4 BMI increase from kindergarten to 5th grade); No cost data</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: BMI, Body mass index (kg/m²); C, Comparator group; CEA, cost-effectiveness analysis; DALYs, disability adjusted life-years; I, Intervention; ICER incremental cost-effectiveness ratio; LA, Los Angeles; MA, Massachusetts; MEPS, Medical Expenditure Panel Survey; NAP, Nutrition and Physical Activity Self-Assessment for Child Care; NHANES, National Health and Nutrition Examination Survey; PA, Physical activity; RCT, randomized control study; SSBs, sugar-sweeten beverages; TV, television; USDA, United States Department of Agriculture; QALYS, quality adjusted life-years.

* Year of costing, discount rate and perspective or other key considerations are shown, if applicable

^ Applied modified Australian Assessing Cost Effectiveness (ACE) methodologies using U.S. data, and recommendations from the U.S. Panel on Cost-Effectiveness in Health and Medicine to create the Childhood Obesity Intervention Cost Effectiveness Study (CHOICES) model.

ˆ Mean and 95% uncertainty intervals reported
Fig 1. Framework used to characterize components of early childhood obesity prevention interventions across the life course. Adapted from The National Institute on Minority Health and Health Disparities (NIMHD) Research Framework (9).
Supporting information

S1 Appendix. Table of Data Extraction Information for Interventions.

<table>
<thead>
<tr>
<th>Data categories</th>
<th>Response options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographic location</td>
<td>Urban, Rural, Suburban, Mixed</td>
</tr>
<tr>
<td>Study design type</td>
<td>RCT, cRCT, nRCT, Prospective Cohort, Retrospective Cohort, Before and After Study, Other</td>
</tr>
<tr>
<td>Study population</td>
<td>Pre-pregnancy, Pregnancy, Infancy, Preschool</td>
</tr>
<tr>
<td>Primary setting</td>
<td>Home, Childcare center, Primary-care provider, Hospital clinic, Community-wide, Health Center, Other</td>
</tr>
<tr>
<td>Primary participants</td>
<td>Child, Parent, Mother, Primary Caregiver, Childcare Center Teacher, Childcare Center Staff, Primary Care Provider, Community Worker, Other, Other</td>
</tr>
<tr>
<td>Treatment provider</td>
<td>Parent, Teacher, Pediatrician, Physician, Nurse, clinic Staff, Social worker, Other, Other</td>
</tr>
<tr>
<td>Domains of influence</td>
<td>Biological, Behavioral, Physical/Built Environment, Sociocultural Environment, Healthcare System</td>
</tr>
<tr>
<td>Levels of Influence</td>
<td>Individual, Interpersonal, Community, Societal</td>
</tr>
<tr>
<td>Format</td>
<td>Individual Session, Group session</td>
</tr>
<tr>
<td>Intervention Type</td>
<td>Behavior, Diet, PA, Policy, Cost-effectiveness Analysis</td>
</tr>
<tr>
<td>Mode of Delivery</td>
<td>Face-to-Face, Email, Phone, Multimedia, Text, Internet, Other</td>
</tr>
<tr>
<td>Obesity Outcomes</td>
<td>Change in: Weight, BMI, BMI-z score, BMI percentile, Other</td>
</tr>
<tr>
<td>The following data</td>
<td>Name of the program; Location of the study; Study setting;</td>
</tr>
<tr>
<td>categories were collected</td>
<td>Population inclusions criteria; Sample size, Attrition rate, Effectiveness / statistics</td>
</tr>
</tbody>
</table>
Appendix. Summary of key findings.

- Less than half of the interventions improved a measure of obesity in children less than 6 years of age (16, 18, 19, 21-24, 27, 30, 35, 37)
- All interventions focused on individual or interpersonal levels of behavioral change
- Most interventions took place in early childhood education centers (21-23, 25-29, 32-35)
- Very few interventions were initiated during pregnancy (15-17) and infancy (18-20)
- All effective interventions included parenting and family participation (16, 18, 19, 21-24, 27, 30, 35, 37)
- Interventions with MI coaching techniques reported mixed results (24, 30, 36)
- Very few interventions focused on the physical or built environment changes (16, 17, 21, 25, 26, 30, 34, 35) and only 4 interventions were effective in improving a measure of obesity in young children (16, 21, 30, 35)
- The intensity of interventional components aimed at changing sociocultural environmental factors varied from high- to low-intensity. Examples of high-intensity activities included interventions aimed at changing social norms (16) and providing sociocultural support groups (18). While moderate to low intensity activities included: the use of bilingual interventionists (18, 24, 28-30, 35, 37, 38), culturally relevant curriculum (25, 27-30, 32-35, 37, 38) and providing recipes adapted for cultural preferences (18, 34, 35, 38)
- Health care system level intervention may be costly (48) and produced inconsistent results (15, 18, 20, 24, 36)
- Policy level interventions aimed at labeling laws, (40) local, state and national pricing strategies (42, 43), and food marketing (41) may improve the prevalence of childhood obesity and generate tax revenue
- There is a lack of evidence about the cost-effectiveness of pediatric obesity prevention interventions
Chapter 5. Manuscript 2

Associations of a sugar-sweetened beverage portion limit policy and beverage ounces purchased and consumed at a sporting arena

Objectives. To examine the association between a 16 oz. sugar-sweetened beverage (SSB) portion-size cap at a Brooklyn, NY arena (Barclays) compared to a New York, NY arena with no portion-size restriction (MSG, control) on volume of SSBs and food calories purchased and consumed during basketball games.

Methods. Cross-sectional survey data from adults exiting basketball games at Barclays (n=464) and MSG (n=295) from March through June 2014 were analyzed using linear regression models (GLM) to examine the association between the SSB portion cap and SSB ounces (oz) and food calories purchased and consumed, and event satisfaction.

Results. Response rate was 45.9%. Among SSB consumers (n=140), the portion-size cap was associated with Barclays customers’ purchasing 2.24 fewer beverage oz (95% confidence interval [CI]= 4.19, 0.29, p=.024) and purchasing and consuming 11.03 (95% CI= 17.21, 4.86, P<.001) and 12.10 (95% CI=18.42, 5.78, p<.001) fewer SSB oz, after adjusting for sex, age, BMI, ethnicity, race, marital status, education, and income. There were no differences between arenas in food calories and event satisfaction.
Conclusion. An SSB portion-size cap was associated with purchasing and consuming fewer SSB ozs. without influencing food calories and arena-event experience.

Introduction

There is considerable interest in policies to reduce sugar-sweetened beverage (SSB) intake, (Force; ODPHP, 2018; Office of the Surgeon General (US). The Surgeon General's Vision for a Healthy and Fit Nation 2010) as overconsumption of these drinks is linked to weight gain,(Malik, Schulze, & Hu, 2006; Malik, Pan, Willett, & Hu, 2013; Qi et al., 2012; Schulze et al., 2004) obesity, (Bleich & Vercammen, 2018; de Ruyter, Olthof, Seidell, & Katan, 2012; Cara B. Ebbeling et al., 2012; C. B. Ebbeling et al., 2006; Forshee, Anderson, & Storey, 2008; Malik et al., 2006; Zheng et al., 2015) adiposity, (Zheng et al., 2015) type-2 diabetes mellitus, (Hu, 2013; Schulze et al., 2004) high blood pressure, (Brown et al., 2011) cardiovascular disease, (Brown et al., 2011; de Koning et al., 2012; Micha et al., 2017; Yang et al., 2014) and all-cause mortality (Collin, Judd, Safford, Vaccarino, & Welsh, 2019). On any given day, about half of Americans consume SSBs, with consumption levels highest among low-income groups. These beverages provide little nutritional value and are the leading source of added sugar in the American diet. SSBs are inexpensive, heavily marketed, and served in large portions (Friedman & Brownell, 2012; Nielsen & Popkin, 2003; Powell et al., 2016).
Over the past 70 years there has been an 8-fold increase in the standard size of SSBs sold in the United States (U.S.). Prior to 1950, SSBs were typically sold in 6.5-ounce (oz) bottles, (Company) which increased to 12 oz in 1977 and 20 oz in 1994 (Nielsen & Popkin, 2003). Beverages as large as 64 oz are being sold in national chain restaurants and convenience stores across the US. The widespread availability of larger portion sized SSB is associated with overall increased caloric intake (Ello-Martin, Ledikwe, & Rolls, 2005; Hollands et al., 2015). Furthermore, people who consume large portions of SSBs at one meal may not reduce their consumption of energy at subsequent meals, (Rolls, Roe, Kral, Meengs, & Wall, 2004; Rolls, Roe, & Meengs, 2006) which could promote positive energy balance and weight gain.

A policy proposal to curb SSB intake was put forth in New York City (NYC) in 2012 (DOHMH, 2012). The Board of Health proposed placing a portion size cap to limit the maximum SSB package or cup size sold in restaurants to 16 ounces. This policy generated controversy and the NY State Supreme Court overturned the regulation in 2014, contending that it exceeded the scope of the Board of Health’s regulatory authority. Since then, no jurisdiction has tried to implement a portion cap policy. Therefore, the only evidence on the potential effect of such a policy comes from simulation (Cleghorn et al., 2019; Crino et al., 2017; Elbel, Cantor, & Mijanovich, 2012; Liu, 2014; Wang & Vine, 2013) or lab studies (Flood, Roe, & Rolls, 2006; John, Donnelly, & Roberto, 2017; Wilson, Stolarz-Fantino, & Fantino, 2013).
Behavioral simulation studies have shown that participants drink significantly more beverage from a larger sized cup (18 oz vs. 12 oz), and consume more energy at lunch meals served with SSBs, as opposed to non-caloric drinks (Flood et al., 2006). In contrast, individuals who are offered smaller beverage portions consume smaller volumes of beverages on average (John et al., 2017). In addition, simulation models computed from the National Health and Nutrition Examination Survey (NHANES) data (Wang & Vine, 2013) and beverage sales receipts (Elbel et al., 2012) projected a 62 to 74 kcal reduction in SSB calories per person from a 16 oz portion cap policy.

In 2013, prior to the final portion cap ruling, the Barclays Center (Barclays), an indoor arena in Brooklyn, NY and home to the Brooklyn Nets of the National Basketball Association (NBA) and New York Liberty of the Women’s NBA, voluntarily adopted the policy’s maximum 16 oz SSB portion cap (Grynbaum, 2012). This provided an opportunity to collect real-world data on the potential influence of such a policy. The primary aim of this study was to examine the association of the Barclays 16 oz SSB portion size restriction on self-reported volume of SSBs purchased and consumed using Madison Square Garden (MSG), a nearby sports arena with no SSB portion restrictions as a control site. We hypothesized that customers at Barclays would purchase fewer ounces of SSBs compared to MSG, without differences in energy from food purchased. Our secondary aim was to evaluate the impact of smaller SBB portion sizes on satisfaction with the size and price of beverages, enjoyment of
beverages and food and event experience between arenas. We hypothesized no impact of smaller SBB portion sizes on the satisfaction and enjoyment levels between the arenas.

**Methods**

Data were collected between March 17, 2014 and June 5, 2014. The study was reviewed and approved by the Harvard School of Public Health IRB (IRB13-2041) and exempt status was granted by Rutgers University Institutional Review Board (IRB Study ID Pro2019001933, Approved October 2019).

Trained research assistants recruited participant to complete a survey as they exited Barclays in Brooklyn, NY and MSG in Manhattan, NY after attending WNBA and NBA sporting events. Surveys were administered after 17 basketball games (Barclays n=11; MSG n=9); three games were played on the same date. Participants were eligible if they were 18 years or older, and able to speak and read English. After providing written informed consent, participants completed a 5-minute survey developed for this study (see Appendix A) and were provided with $5.

**Measures**

**Primary Outcomes: Self-reported SSB purchase and consumption.**
To assess our primary outcome of ounces of SSBs purchased and consumed, we asked participants during the arena exit interviews to report each type of beverage purchased (beer, juice, sparkling water/seltzer, regular soda, hot tea, water, diet soda, iced tea, wine, coffee, liquor/mixed drink, or “other, specify”) while at the arena. Detailed information was recorded about each beverage purchased, including beverage size (No size/one size, small, medium, large, extra-large, bottle, don’t know) and the number of ounces in beverages purchased (8, 12, 16, 20, 25, 40 oz; other) as well as their estimate of how much of each beverage was consumed (100%, 75%, 50%, 25%, or 0%). We also examined the number of SSBs purchased by summing the number of regular sodas, lemonades and energy drinks purchased. Nine participants (Barclays, n=5; MSG, n=4) purchased iced tea but these beverages were not included in the SSB count as we failed to capture if these were sweetened or unsweetened.

**Secondary outcomes.**

**Self-reported food calories purchased and consumed.**

Detailed information was also recorded for all food items purchased from the arena’s fast food and casual dining restaurants (see Appendix B), including item size and an estimate of the overall percentage of each food item consumed. We derived an estimate of the caloric value of the menu items by using values for similar menu items in the 2014 version of the MenuStat
database, (New York City Department of Health and Mental Hygiene, 2019) a nutritional database of foods and beverages served by the nation’s largest chain restaurants. If a menu item was not included in the 2014 MenuStat database, we used the caloric value listed in the USDA National Nutrient Database for Standard Reference, release 28 (2015) (USDA ARS, 2016). Appendix C describes the methodology used to assign caloric values to arena menu items.

Event experience.

**Overall arena experience.** Participants provided ratings of their satisfaction with overall arena experience with 1 being poor and 5 being excellent.

**Satisfaction with beverage size and price.** Satisfaction with the price and size of beverages items ordered was measured with 1 being “not at all” to 5 being “extremely satisfied.”

**Liking of beverage and food items.** Ratings for each beverage and food item purchased was assessed with 1 representing “I did not like it at all” to 5 representing “I liked it a lot.”

**Sociodemographic characteristics.**

The last page of the survey asked participants about sociodemographic characteristics (Table 1). Due to the small number of participants with “< high school” (n=1) and “vocational training” (n=1) who purchased an SSB, we
collapsed “< high school,” “vocational training” and “high school or GED” into a new education category “< some college.” Similarly, the martial status category “separated” was combined with “divorced/widowed” to create a combined category. We applied the Office of Management and Budget’s 1997 race and ethnicity standards (Office of Management and Budget [OMB], 1997) to code the Race response option “Other,” if a country of origin was provided rather than the listed race category options. We also asked participants to report weight and height, which we used to calculate BMI. In addition, we asked those participants who did not purchase beverages to provide a reason (not thirsty, too expensive, did not think they would taste good, they were too big, they were too small, there were no healthy options or other).

Perception of SSB portion size policy: The following questions assessed the participant’s perception of the SSB portion size policy:

**Opinion about portion sizes at restaurants in general:** Participants reported their opinion about restaurant portion sizes with responses to questions that asked if food portion sizes and beverage portions sizes at restaurants in general are “too small,” “just right,” “too large” or “no opinion.”

**Perception of NYC SSB portion size policy:** “Are you in favor of or against this regulation in New York City?” (against, no opinion, in favor) and “how strongly do you feel about this regulation?” (strongly,
somewhat, no opinion) were combined to create a 5-point scale. The combined response options ranged from -2 (strongly against); -1 (somewhat against); 0 (no opinion); somewhat in favor (1); strongly in favor (2).

**Statistical Analysis**

First, survey data were examined descriptively. Differences between Barclays and MSG arena-goers were assessed with chi-square and exact test statistics for categorical variables, and the Independent Samples t-test to compare continuous variables.

For the primary analysis, we used a general linear model (GLM) to examine the relationship between the self-reported ounces of SSB purchased and Arena (Barclays vs. MSG) in the full sample, and then only among participants who purchased an SSB. Diagnostic tests were carried out to check model assumptions of linearity and normality of residuals as well as to identify outliers with unacceptable influence on the model. Residual plots were examined and homoscedasticity was judged as tenable. R-squared values confirmed the best fitting models, accounting for the largest proportion of variance. The fixed effects in the final model were sex, ethnicity, race, marital status, education, household income, and the covariates were age and BMI. For our secondary analyses, we used the same GLM procedures with same fixed effects. Arena differences in the non-normally distributed outcomes “total
number of drinks purchased" and "total number of SSB purchased" were tested using Mann-Whitney U test. All data were analyzed using IBM SPSS Statistics 25, and significance for all two-sided statistical tests was considered at p<0.05.

**Sensitivity analysis.**

A non-parametric, sensitivity analysis of the primary outcome "ounces of SSB purchased" was run using inverse propensity of treatment weighting (IPTW) derived from a propensity score. The IPTW approach creates a pseudo-population in which the overall distribution of the measured baseline confounders is balanced between the two arenas, thereby minimizing the bias of confounding linked to estimating the treatment effect in a non-randomized study. The propensity score was generated using a logistic regression model with Arena choice as the dependent outcome and including all independent variables in the primary analysis model. The top and bottom 1% of the propensity score weights were truncated (Austin & Stuart, 2015). For Barclays' participants the weight was calculated as, IPTW=1/Propensity Score(X) and for MSG the weight was the inverse, IPTW=1/(1 – Propensity Score[X]). Balance was compared graphically using side-by-side boxplots. IPTW approach does not make parametric assumptions about how the individual covariates and exposure of interest (i.e., arena) together affect the outcome, and thus can check robustness of the GLM estimate of the arena effect. IPTW, however, does not provide effect estimates for the covariates on the outcome.
Secondary Aim: Event Experience

Preliminary analyses did not identify any confounding variables associated with both Arena and any measure of event satisfaction. Thus, bivariate statistics were computed to evaluate differences in the relationship between these outcomes and Arena.

Results

A total of 759 participants completed the survey with an overall response rate of 45.9% (Figure 1). A total of 140 participants purchased SSBs with no statistically significant difference between the proportion of participants who purchased SSBs at Barclays (17.7%) and MSG (19.7%).

INSERT FIGURE 1 HERE

Arena-Goers Characteristics

Participants were predominantly male (62.6%), mean age 32.7±11.2 with a mean BMI of 26.5±5.3. Over half reported never being married and approximately 44% reported a household income of $50,000 or less (Table 1). A smaller proportion of participants at Barclays compared with MSG identified themselves as White (34.5% vs. 46.4%), while a greater proportion of participants at Barclays were Asian (8.6% vs. 3.4%) and never married (63.4%
Post hoc testing found participants at MSG were more likely to be less educated (completed <college, \( p = .033 \); some college, \( p = .043 \)) than participants at Barclays. There were, however, no statistically significant differences in these characteristics among those participants who purchased SSBs (Appendix D).

Arena-goers portion-size opinions

There were no differences between arenas in participant opinions about typical beverage and food portion sizes served in restaurants or the NYC sugary-drink portion cap policy (Table 1).

Beverages purchased

Among all participants a smaller volume of beverages was purchased (-2.24 oz, 95% CI [-4.19, .29], \( p = .024 \)) and consumed (-2.16 oz, 95% CI [-4.02, -.30], \( p = .023 \)) at Barclays compared with MSG (Table 2). The mean number of beverages and SSBs purchased at Barclays 1.52, 95% CI [1.39,1.65] and 0.23, 95% CI [0.18, 0.28], compared to MSG 1.80, 95% CI [1.55, 2.05], and 0.26 95% CI [0.18, 0.33], respectively. There were no statistically significant differences on these variables between arenas. There were also no significant differences in the proportion of participants who purchased SSBs (\( p = .491 \)).

SSB Purchased and Consumed
The GLM models confirmed that Arena was significantly associated with ounces of SSB purchased and consumed among all arena goers and among participants who purchased at least one SSB (shown in Table 2 and Appendix E).

Among all arena goers, participants at Barclays purchased significantly fewer SSB oz (-2.24 oz, 95% CI [-3.95, -0.53], p=.010) and consumed significantly fewer SSBs oz (-2.34 oz, 95% CI [-4.01, -0.68], p=.006) (Appendix E) compared with MSG after adjusting for sex, age, BMI, ethnicity, race, marital status, education, and income. Being male and Black or African American (compared with White) was associated with purchasing more ounces of SSB (Barclays: 1.86 oz, MSG: 2.43 oz, respectively), while a household income of $125,000 - $150,000 was associated with purchasing 5.28 more ounces of SSB compared with the highest income category (> $150,000). No other relationships were significant.

Among participants who purchased at least 1 SSB, the overall model remained significant and explained 35% of the variance ($R^2 = .354$). Barclays' participants purchased and consumed (Table 2) significantly fewer ounces of SSBs compared with MSG. The Arena effect contributed to participants at Barclays on purchasing on average -11.03 (95% CI= -17.21, -4.87, p<.001) fewer ounces of SSB while consuming -12.10 (95% CI= -18.42, -5.78, p<.001) fewer SSB oz (Appendix Figure 2). Only income remained significantly related to ounces of SSB purchased.
Estimates derived from the GLM model incorporating IPTW scale weighting confirmed the findings from the primary GLM analysis and showed among all participants, significantly fewer adjusted mean ounces of SSBs [mean difference=\(-1.83\); Wald=4.26; \(p=.039\)] were purchased at Barclays (2.52, [95% CI, 1.29, 3.75]) compared with MSG (4.35, [95% CI, 3.12, 5.59]). In the subgroup of participants who purchased SSBs, significantly fewer ounces of SSBs [mean difference=\(-8.49\); Wald=6.26; \(p=.012\)] were purchased at Barclays (15.03 [95% CI, 10.23, 19.84]) compared with MSG (23.53 [95% CI, 18.93, 28.11]).

**Food Calories Purchased and Consumed**

Total food calories purchased and food calories consumed did not differ significantly between Arena. The adjusted mean self-reported food calories purchased at Barclays was 461.05 (95% CI, 362.53, 559.56) kcals compared to 399.37 (95% CI, 299.42, 499.31) kcals at MSG, \(p=.17\), while mean self-reported food calories consumed were 388.52 (95% CI, 296.84, 480.20) kcals and 323.39 (95% CI, 230.95, 415.83) kcals, \(p=.11\), respectively.

**Secondary outcomes.**

Among all participants, there was no bivariate relationship between Arena and overall arena experience, beverage enjoyment, satisfaction with the size and price of beverage ordered and food enjoyment (Table 3). Among
participants who purchased SSBs, however, a smaller proportion at MSG (5.5%) reported being extremely satisfied with beverage prices compared to those at the Barclays arena (25.3%), $X^2(4) = 12.12, p < .015$. In addition, a higher proportion of Barclay participants (75%) were extremely satisfied with their food purchases compared with 25% of MSG participants.

There were no statistically significant differences between the arenas for participants’ reasons for not purchasing a drink ($p = .117$). Of the 182 participants who provided a response for not purchasing a beverage, “Not thirsty” ($n = 88, 48.4\%$) was the most frequently reported response. None of the participants at either arena reported small drink size as a reason for not purchasing a drink. There was a significant difference in the reason food was not purchased $X^2(6) = 12.28, p < .034$ with a greater proportion of participants at Barclays compared with MSG (70.1% vs. 53.5%) reporting that they did not buy food because they were not hungry.

**Discussion**

Consistent with the results reported in simulation (Cleghorn et al., 2019; Crino et al., 2017; Elbel et al., 2012; Liu, 2014; Wang & Vine, 2013) and lab studies, (Flood et al., 2006; John et al., 2017; Wilson et al., 2013) this cross-sectional study found a policy limiting the portion size of SSBs to 16 oz served in restaurants at a major arena in Brooklyn, NY was associated with purchasing and consuming fewer ounces of SSBs without any differences in food calories.
purchased and consumed compared to a similar NYC arena without such a policy. The smaller volume of SSBs purchased at the Barclays arena was not associated with a corresponding difference in the total number of beverages purchased or a decrease in the likelihood of purchasing SSBs. Furthermore, the policy at Barclays was not associated with diminished arena-event experience. These findings suggest that a policy limiting the portion size of SSBs to 16 oz in restaurants may achieve its goal of reducing the amount of SSBs consumed at restaurants, though our study is limited to fans attending WNBA and NBA games. These results also highlight that the policy was not associated with fans reporting increased negative perceptions of their overall or food and beverage experiences at the arena.

In our analysis restricted to arena-goers who purchased SSBs, we found that those who attended sporting events at Barclays, where the maximum SSB portion size was 16 ounces, self-reporting purchasing on average 11 fewer ounces of SSBs than participants at MSG, that had no SSB portion limit. Given that typical SSBs contain approximately 13 kcal/ounce (US Department of Agriculture, 2016), the difference amounts to a reduction of 143 kcal SSBs purchased. This exceeds previous effect estimates of a 74 kcal (50%) reduction from a simulation conducted by Elbel and colleagues based on 1,624 fast food restaurant receipts collected in NYC, Newark, and Baltimore and the assumption that all consumers who purchased SSBs would instead purchase 16 oz portions (Elbel et al., 2012). In our study, participants at Barclays self-
reported *consuming* approximately 12 fewer ounces of SSB compared to participants at MSG, without a compensatory increase in the food calories. This effect is equivalent to a reduction of 156 SSB calories and equivalent to 7.8% of the total caloric intake of adults (with estimated caloric needs for 2000 kcal/day). Considering that the Dietary Guidelines 2015-2020 recommends that all Americans limit their added sugar intake to no more than 10 percent of their daily caloric intake, our results suggest that a policy that reduces the maximum portion size of SSBs has the potential to improve public health. This effect is larger, but consistent with a simulation study using NHANES, a nationally-representative database. That study predicted a 102-kcal reduction in SSB calories consumed from the most liberal model that assumed 100% of people who consume SSBs would downsize to 16 oz (Wang & Vine, 2013).

Consistent with these findings, recent trends in SSB consumption from 2003 to 2016 in the US showed a decline in SSB consumption that is associated with a significant downward trend in the percentage of larger sized (>12–24 oz and ≥24 oz) SSBs being consumed (Marriott, Hunt, Malek, & Newman, 2019). Although these results suggest that SSB portion limit policies might be an effective way to curb SSB intake without limiting freedoms or significantly raising prices, there was considerable opposition in New York City when the policy was first introduced, citing concerns about government encroachment on freedom (IOM, 2010). In our data, however, Barclays arena-goers did not differ from those attending games at MSG in terms of their
satisfaction with the size of SSBs sold in the arena or with the food or overall arena experience. In addition, no participants indicated that the size of beverages was a reason why they did not purchase a drink.

Limitations and Strengths

This is the first study to our knowledge to use real-world data to examine the potential impact of a 16 oz SSB portion limit policy on the SSB beverage consumption patterns. This study has several limitations. First, our sample was limited to NBA and WNBA fans who attended events at Barclays and MSG in New York City. The beverage consumption habits among this sample might not generalize to other arenas or large events and may look very different from restaurant beverage purchasing. Next, our study is limited by self-reported data. Recall bias, a poor understanding of the size or number of ounces in beverages purchased and the underreporting of portion sizes associated with dietary surveys (Baranowski, 2013), as well as our inability to assess sharing of beverages may have led to misreporting of the volume of beverages purchased and consumed (though this is unlikely to have introduced systematic error). Additionally, despite the large sample, only a small number of participants purchased SSBs, information on event, food and beverage pricing were not collected and since this study was a cross-sectional study design we are not able to test for a causal relationship between the 16 oz portion limit policy and a change in SSB consumption behaviors. We are encouraged,
however, that our key findings are robust to sensitivity analyses using IPTW, which helps to minimize the potential of bias from confounding in a nonrandomized study. The propensity scoring, however, was derived using available data, thus we cannot account for unmeasured variables.

This study has several strengths including a large number of survey respondents with similar response and completion rates between arenas and assessments of self-reported food and beverage purchasing and consumption as well as perceptions of satisfaction. This study provides some of the first real-world data on how such a policy might influence consumers.

Conclusion

These data suggest that SSB portion limit policies hold promise as a way to curb SSB intake at sporting arenas while preserving consumer choice. There is a need for more real-world research on such policies across diverse settings where beverages are frequently consumed.
References


Hu, F. B. (2013). 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, 14*(8), 606-619. doi:10.1111/obr.12040


Heart Disease, Stroke, and Type 2 Diabetes in the United States. *Jama*, 317(9), 912-924. doi:10.1001/jama.2017.0947


doi:10.1016/j.ypmed.2016.01.011

doi:10.1056/NEJMoa1203039

doi:https://doi.org/10.1016/S0195-6663(03)00117-X

doi:10.1016/j.jada.2006.01.014


doi:10.1016/j.amepre.2015.02.026


Table 1. Characteristics and portion-size opinions of the arena-goers

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total (N=759)</th>
<th>Madison Square Garden (n = 295)</th>
<th>Barclays Center (n = 464)</th>
<th>P-value(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>473 (62.6)</td>
<td>177 (60.0)</td>
<td>296 (64.3)</td>
<td>.228</td>
</tr>
<tr>
<td>Age, years, Mean (SD)</td>
<td>32.67 (11.2)</td>
<td>33.1 (11.7)</td>
<td>32.7 (11.0)</td>
<td>.644</td>
</tr>
<tr>
<td>BMI, Mean (SD)</td>
<td>26.53 (5.33)</td>
<td>26.05 (4.94)</td>
<td>26.79 (5.52)</td>
<td>.078</td>
</tr>
<tr>
<td>Hispanic, Latina/o, Spanish</td>
<td>140 (18.4)</td>
<td>61 (20.7)</td>
<td>79 (17.0)</td>
<td>.206</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>297 (39.1)</td>
<td>137 (46.4)</td>
<td>160 (34.5)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Black or African American</td>
<td>295 (38.9)</td>
<td>100 (33.9)</td>
<td>195 (42.0)</td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>50 (6.6)</td>
<td>10 (3.4)</td>
<td>40 (8.6)</td>
<td></td>
</tr>
<tr>
<td>Some other race, more than one race</td>
<td>49 (6.5)</td>
<td>25 (8.3)</td>
<td>24 (5.2)</td>
<td></td>
</tr>
<tr>
<td>Not Reported</td>
<td>68 (9.0)</td>
<td>23 (7.8)</td>
<td>45 (9.7)</td>
<td></td>
</tr>
<tr>
<td>Marital Status</td>
<td></td>
<td></td>
<td></td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Married</td>
<td>151 (19.9)</td>
<td>61 (20.7)</td>
<td>90 (19.4)</td>
<td></td>
</tr>
<tr>
<td>Never married</td>
<td>442 (58.2)</td>
<td>148 (50.2)</td>
<td>294 (63.4)</td>
<td></td>
</tr>
<tr>
<td>Not married, living with significant other</td>
<td>117 (15.4)</td>
<td>69 (23.4)</td>
<td>48 (10.3)</td>
<td></td>
</tr>
<tr>
<td>Separated, Widowed/divorced</td>
<td>40 (5.3)</td>
<td>15 (5.1)</td>
<td>25 (5.4)</td>
<td></td>
</tr>
<tr>
<td>Not Reported</td>
<td>9 (1.2)</td>
<td>2 (0.7)</td>
<td>7 (1.5)</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
<td>.008</td>
</tr>
<tr>
<td>&lt; Some college</td>
<td>181 (23.8)</td>
<td>83 (28.1)</td>
<td>98 (21.1)</td>
<td></td>
</tr>
<tr>
<td>Some college (&lt;than 4 yrs.)</td>
<td>125 (16.5)</td>
<td>59 (20.0)</td>
<td>66 (14.2)</td>
<td></td>
</tr>
<tr>
<td>College/ University degree (4 years)</td>
<td>305 (40.2)</td>
<td>102 (34.6)</td>
<td>203 (43.8)</td>
<td></td>
</tr>
<tr>
<td>Graduate or professional education</td>
<td>138 (18.2)</td>
<td>49 (16.6)</td>
<td>89 (19.2)</td>
<td></td>
</tr>
<tr>
<td>Not Reported</td>
<td>10 (1.3)</td>
<td>2 (0.7)</td>
<td>8 (1.7)</td>
<td></td>
</tr>
<tr>
<td>Household Income</td>
<td></td>
<td></td>
<td></td>
<td>.706</td>
</tr>
<tr>
<td>Less than $25,000</td>
<td>154 (20.3)</td>
<td>69 (23.4)</td>
<td>85 (18.3)</td>
<td></td>
</tr>
<tr>
<td>$25,000-$50,000</td>
<td>179 (23.6)</td>
<td>68 (23.1)</td>
<td>111 (23.9)</td>
<td></td>
</tr>
<tr>
<td>$50,001-$75,000</td>
<td>132 (17.4)</td>
<td>56 (19.0)</td>
<td>76 (16.4)</td>
<td></td>
</tr>
<tr>
<td>$75,001-$100,000</td>
<td>90 (11.9)</td>
<td>38 (12.9)</td>
<td>52 (11.2)</td>
<td></td>
</tr>
<tr>
<td>$100,001-$125,000</td>
<td>50 (6.6)</td>
<td>22 (7.5)</td>
<td>28 (6.0)</td>
<td></td>
</tr>
<tr>
<td>$125,001-$150,000</td>
<td>31 (4.1)</td>
<td>9 (3.1)</td>
<td>22 (4.7)</td>
<td></td>
</tr>
<tr>
<td>More than $150,000</td>
<td>57 (7.5)</td>
<td>23 (7.8)</td>
<td>34 (7.3)</td>
<td></td>
</tr>
<tr>
<td>Not Reported</td>
<td>66 (8.7)</td>
<td>56 (12.1)</td>
<td>56 (12.1)</td>
<td></td>
</tr>
<tr>
<td>Opinion about: the portion-size of SSB in restaurants</td>
<td></td>
<td></td>
<td></td>
<td>.860</td>
</tr>
<tr>
<td>Too small</td>
<td>115 (15.2)</td>
<td>41 (13.9)</td>
<td>74 (15.9)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td><strong>the portion-size of food in restaurants</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Too small</td>
<td>83 (10.9)</td>
<td>31 (10.5)</td>
<td>52 (11.2)</td>
<td></td>
</tr>
<tr>
<td>Just right</td>
<td>440 (58.0)</td>
<td>170 (57.6)</td>
<td>270 (58.2)</td>
<td></td>
</tr>
<tr>
<td>Too large</td>
<td>171 (22.5)</td>
<td>61 (20.7)</td>
<td>110 (23.7)</td>
<td></td>
</tr>
<tr>
<td>No opinion or not reported</td>
<td>65 (8.6)</td>
<td>33 (11.2)</td>
<td>32 (6.9)</td>
<td></td>
</tr>
</tbody>
</table>

| **the NYC sugary-drink portion cap policy** |       |        |        |        |
| Strongly against       | 210 (27.7) | 72 (24.4)  | 138 (29.7) |       |
| No opinion             | 97 (12.8)  | 39 (13.2)  | 58 (12.5)   |       |
| Strongly in favor      | 222 (29.2) | 66 (22.4)  | 156 (33.6)  |       |
| Never heard of policy or not reported | 230 (30.3) | 118 (40.0) | 112 (24.1) |       |

Note: BMI (703 x weight (lbs) / [height (in)]^2); Categorical variables were compared using Chi Square tests and continuous variables were compared using Independent T-tests;
a Values expressed as n (%) unless otherwise noted.
b The boldface p-values are those that are <0.05, i.e. those that were significant.
Table 2. Beverage purchasing and consumption patterns

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>All participants</th>
<th>Participants who purchased at least one SSB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Barclays</td>
<td>MSG</td>
</tr>
<tr>
<td>All beverages, number purchased</td>
<td>1.52 (1.39, 1.65)</td>
<td>1.80 (1.55, 2.05)</td>
</tr>
<tr>
<td>SSB, number purchased</td>
<td>0.23, (0.18, 0.28)</td>
<td>0.26 (0.18, 0.33)</td>
</tr>
<tr>
<td>Proportion of participants who purchased at least 1 SSB, n (%)</td>
<td>82 (17.7)</td>
<td>58 (19.7%)</td>
</tr>
<tr>
<td>All beverages, ounces purchased (oz)</td>
<td>13.33 (11.13, 15.52)</td>
<td>15.56 (13.33, 17.80)</td>
</tr>
<tr>
<td>All beverages, ounces consumed (oz)</td>
<td>12.20 (10.09, 14.30)</td>
<td>14.36 (12.21, 16.51)</td>
</tr>
<tr>
<td>SSB ounces purchased (oz)</td>
<td>2.50 (0.57, 4.43)</td>
<td>4.74 (2.79, 6.70)</td>
</tr>
<tr>
<td>SSB ounces consumed</td>
<td>2.06 (0.17, 3.94)</td>
<td>4.40 (2.48, 6.32)</td>
</tr>
</tbody>
</table>

<sup>1</sup>Values expressed as mean (95% CI) unless otherwise noted; <sup>2</sup>compared using Mann-Whitney Test; <sup>d</sup>using Chi-Square tests; <sup>4</sup>Univariate GLM controlling for sex, ethnicity, race, marital status, education, household income, BMI and age.
### Table 3. Comparison of event experience among all participants and participants who purchased SSB

<table>
<thead>
<tr>
<th>5-point scale</th>
<th>All Participants (N=759)</th>
<th>Participants who purchased SSB (N=140)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>Madison Square Garden</td>
</tr>
<tr>
<td>Overall Arena experience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1= Poor</td>
<td></td>
<td>6 (0.8)</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>4 (0.5)</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>50 (6.6)</td>
</tr>
<tr>
<td>4</td>
<td>215 (28.5)</td>
<td>75 (25.7)</td>
</tr>
<tr>
<td>5 = Excellent</td>
<td>480 (63.6)</td>
<td>190 (65.1)</td>
</tr>
<tr>
<td>Beverage enjoyment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1= Did not like it at all</td>
<td></td>
<td>11 (1.9)</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>24 (4.2)</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>95 (16.7)</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>138 (24.3)</td>
</tr>
<tr>
<td>5= Liked it a lot</td>
<td>301 (52.9)</td>
<td>116 (52.7)</td>
</tr>
<tr>
<td>Satisfaction with the size of beverage ordered</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1=Not at all</td>
<td></td>
<td>68 (12.0)</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>58 (10.2)</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>164 (28.9)</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>148 (26.1)</td>
</tr>
<tr>
<td>5 = Extremely satisfied</td>
<td>129 (22.8)</td>
<td>51 (9.0)</td>
</tr>
<tr>
<td>Satisfaction with the price of beverage ordered</td>
<td>1=Not at all</td>
<td>2</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>------------</td>
<td>---</td>
</tr>
<tr>
<td>131 (23.6)</td>
<td>45 (8.1)</td>
<td>86 (15.5)</td>
</tr>
<tr>
<td>94 (17.0)</td>
<td>30 (5.4)</td>
<td>64 (11.6)</td>
</tr>
<tr>
<td>175 (31.6)</td>
<td>78 (14.1)</td>
<td>97 (17.5)</td>
</tr>
<tr>
<td>80 (14.4)</td>
<td>34 (6.1)</td>
<td>46 (8.3)</td>
</tr>
<tr>
<td>74 (13.4)</td>
<td>26 (4.7)</td>
<td>48 (8.7)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Food enjoyment</th>
<th>1= did not like it at all</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5= Liked it a lot</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 (2.8)</td>
<td>3 (0.8)</td>
<td>8 (2.0)</td>
<td>(2.2)</td>
<td>(0.0)</td>
<td>2 (3.5)</td>
</tr>
<tr>
<td>11 (2.8)</td>
<td>5 (1.3)</td>
<td>6 (1.5)</td>
<td>1 (1.1)</td>
<td>0 (0.0)</td>
<td>1 (1.8)</td>
</tr>
<tr>
<td>89 (22.4)</td>
<td>32 (8.1)</td>
<td>57 (14.4)</td>
<td>14 (15.1)</td>
<td>5 (13.9)</td>
<td>9 (15.8)</td>
</tr>
<tr>
<td>99 (24.9)</td>
<td>40 (10.1)</td>
<td>59 (14.9)</td>
<td>24 (25.8)</td>
<td>18 (50.0)</td>
<td>6 (10.5)</td>
</tr>
<tr>
<td>187 (47.1)</td>
<td>55 (13.9)</td>
<td>132 (33.2)</td>
<td>52 (55.9)</td>
<td>13 (36.1)</td>
<td>39 (68.4)</td>
</tr>
</tbody>
</table>

\[a\] Comparison with Chi Square tests unless otherwise noted; \[b\] Exact test used due to violation of Chi square assumption (expected frequency < 5).
Figure 1. Flow chart of numbers of participants interviewed and who purchased sugar sweetened beverages at the Barclays Center and Madison Square Garden between March 2014 and June 2014.
Figure 2. Ounces of SSB purchased and consumed (adjusted mean ± SE) by participants at MSG and Barclays. Participants purchased and consumed significantly more SSB at MSG compared with Barclays.
Appendices

List of Appendices
1. Appendix A. Point-of-Purchase Data and Customer Satisfaction
2. Appendix B. Featured food and casual dining restaurants in the Barclays Center and Madison Square Garden in 2014
3. Appendix C. Methodology for assigning caloric value to menu items
4. Appendix D. Characteristics of arena goers who purchased at least one SSB
5. Appendix E. Unadjusted and Adjusted Univariable GLM Explaining Ounces of SSBs Beverages Purchased Among All Participants and Among Participants Who Purchased at Least 1 SSB: Main Effect of Arena
Appendix A Point-of-Purchase Data and Customer Satisfaction

Barclays/MSG Survey

Keep track of the number of refusals you get between surveys.

<table>
<thead>
<tr>
<th>Refusals</th>
</tr>
</thead>
</table>

Arena Location:
___ Barclays
___ MSG

(Make sure that the person just attended the planned event) Hello, I am a research interviewer working with New York University School of Medicine on a study about your experience at the arena tonight. I’d like to ask you a few questions.

Q1. On a scale of 1-5, with 1 being poor and 5 being excellent, how would you rate your overall experience at the arena?

1  2  3  4  5

Beverages

Q2. Did you order any beverages for yourself at the arena? Include anything you had to drink, such as soda, water, juice, beer, liquor and other beverages.

[Yes]  [No]

(IF Q2=No, skip to Q14)

Q3. How many beverages in total, including refills?

1  2  3  4  5  6  7  8  9  10

Beverage 1

Q4. I am going to ask you about each type of beverage you ordered, one at a time. What was the first type of beverage you ordered for yourself?

[Beer]  [Juice]  [Sparkling water/seltzer]
[Regular soda]  [Hot tea]  [Water]
<table>
<thead>
<tr>
<th>Diet soda</th>
<th>Iced tea</th>
<th>Wine</th>
<th>Coffee</th>
<th>Liquor/mixed drink</th>
<th>Other</th>
</tr>
</thead>
</table>

Q5. How many [Q4 answer] did you order for yourself at the game?

1  2  3  4  5  6+

Q6. Where did you order it from?

<table>
<thead>
<tr>
<th>Hawker/Vendor in stands</th>
<th>Concession stand</th>
<th>Restaurant</th>
<th>Bar</th>
<th>Deli</th>
<th>Private box/Suite</th>
<th>Coffee Shop</th>
<th>Fast food</th>
<th>Other</th>
</tr>
</thead>
</table>

Q7. What size was it?

<table>
<thead>
<tr>
<th>No size/one size</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
<th>Extra Large</th>
<th>Bottle</th>
<th>Don’t know</th>
</tr>
</thead>
</table>

Q8. How many ounces was it?

8  12  16  20  25  40  Other

Q9. How many calories do you think it had?


Q10. On a scale of 1 to 5, how much did you like it? *(1-I did not like it at all, to 5-I liked it a lot)*

1  2  3  4  5
Q11. What was the next type of beverage you had?
Nothing .............................. [Skip to Q148]

[Beer] [Juice] [Water]
[Regular soda] [Hot tea] [Wine]
[Diet soda] [Iced tea] [Other]
[Coffee] [Liquor/mixed drink]

(Repeat Q4-Q11 for up to 10 drinks)

Q12. Overall, for the beverages you ordered, what percent did you drink? You can say 100%, 75%, 50%, 25%, or 0%.

[100%] [75%] [50%] [25%] [0%]

Q13. On a scale of 1 to 5, from 1 being not at all to 5 being extremely, how satisfied were you overall with ...

...the price of the beverage(s) you ordered for yourself? 1 2 3 4 5 N/A

...the size of the beverage(s) you ordered for yourself? 1 2 3 4 5 N/A

(Skip to Q15)

Q14. Why did you not order a beverage?

[Not thirsty] [Too expensive] [Did not think they would taste good]
[They were too big] [They were too small] [There were no healthy options]
[Other]

Food Items

Q15. Did you order food for yourself at the arena?

[Yes] [No]
(If Q15=No, skip to Q25)

Q16. How many food items did you order? (note: different food types are separate items)

1  2  3  4  5  6  7  8  9  10

Food Item 1

Q17. I am going to ask you about each item you ordered, one by one. Let's start with the first food item you ordered for yourself at the game. What was it?

[Burger]  [Fries]  [Pizza]
[Candy bar]  [Frozen yogurt]  [Popcorn]
[Chicken/wings]  [Hot dog]  [Pretzel]
[Chips (bag)]  [Ice cream]  
[Deli Sandwich]  [Nachos]  [Other]

Q17a. How many did [Q17 answer] you order for yourself at the arena?

1  2  3  4  5  6+

Q18. Where did you order it from? (restaurant, food establishment, hawker/vendor in stands)

[Hawker/Vendor in stands]  [Concession stand]  [Restaurant]
[Bar]  [Deli]  [Private box/Suite]
[Coffee Shop]  [Fast food]  
[Other]  

Q19. What size was it?

[No size/One size]  [Small]  [Medium]
[Large]  [Extra Large]  [Don’t know]
Q20. How many calories do you think it had?

Q21. On a scale of 1 to 5, how much did you like it? *(1-I did not like it at all, to 5-I liked it a lot)*

1  2  3  4  5

Q22. What was the next food item you ordered for yourself?
Nothing ........................................... [SKIP to Q23]

[Burger]  [Fries]  [Pizza]
[Candy bar]  [Frozen yogurt]  [Popcorn]
[Chicken/wings]  [Hot dog]  [Pretzel]
[Chips (bag)]  [Ice cream]
[Deli Sandwich]  [Nachos]
[Other]

(Repeat Q17–Q21 for up to 10 food items)

Q23. Overall, for the food items, what percent did you eat? You can say 100%, 75%, 50%, 25%, or 0%.

[100%]  [75%]  [50%]  [25%]  [0%]

Q24. On a scale of 1 to 5, from 1 being not at all to 5 being extremely, how satisfied were you overall with ...

...the price of the food item(s) you ordered for yourself?

1  2  3  4  5  N/A

...the size of food item(s) you ordered?

1  2  3  4  5  N/A

(Skip to Q26)
Q25. Why did you not order food?

[Too expensive] [Did not think it would taste good]
[Portions are too big] [Portions are too small]
[Not hungry] [There were no healthy options]
[Other]

Q26. The next two questions are about portion sizes at restaurants in general.

a) Food portion sizes are.... Too Small Just Right Too Large No opinion
b) Beverage portion sizes are... Too Small Just Right Too Large No opinion

Q27. Have you heard about the regulation in New York City to cap on the size of sugary beverages being served in restaurants? This means sugary beverages greater than 16oz. could not be served at restaurants, but you can buy as many drinks as you like.

[Yes] [No]

Q28. Are you in favor of or against this regulation in New York City?

[In favor] [Against] [No opinion]

Q29. How strongly do you feel (Q28) this regulation?

[Strongly] [Somewhat] [No opinion]

Demographics
Now I have just a few background questions

Q30. What is your age? ________________

Q31. Sex

[Male] [Female]
Q32. How tall are you?

Feet: [4] [5] [6] [7] [Refused]

Q33. What is your weight?

____ LBS

Q34. Which of the following are you trying to do about your weight?

[Lose weight] [Gain weight] [Stay the same] [Not trying to do anything]

Q35. Are you Hispanic, Latino/a, or of Spanish origin?

[Yes] [No]

Q36. What race(s) do you consider yourself to be? (check all that apply)

[White] [Black or African American] [Asian/Pacific Islander]
[Other]

Q37. What is the highest level of education you completed?

[< High school] [High school or GED] [Vocational training]
[Some college (less than 4 years)] [College/university degree (4 years)]
[Graduate or professional education]

Q38. What is your current marital status?

[Never married] [Married] [Not married, living with significant other]
[Separated] [Divorced/widowed]

Q39. What is your annual household income? (from all sources)
[Less than $25,000]  [25,000-$50,000]  [50,001-$75,000]
[$75,001-$100,000]  [$100,000-$125,000]  [$125,001-$150,000]
[More than $150,000]

Interviewer Initials: ____

Optional comment
Appendix B. Featured food and casual dining restaurants in the Barclays Center and Madison Square Garden in 2014

<table>
<thead>
<tr>
<th>Barclays Center</th>
<th>Madison Square Garden</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abigael's Brooklyn</td>
<td>16 Handles Frozen Yogurt</td>
</tr>
<tr>
<td>Avlee Greek Kitchen</td>
<td>Backstage Bar</td>
</tr>
<tr>
<td>Brooklyn Bangers &amp; Dogs</td>
<td>Bar at The Garden</td>
</tr>
<tr>
<td>Brooklyn Burger</td>
<td>Bar Madison</td>
</tr>
<tr>
<td>Buffalo Boss</td>
<td>Bridge Pub</td>
</tr>
<tr>
<td>Calexico</td>
<td>Carlos &amp; Gabby's Kosher Mexican Grill*</td>
</tr>
<tr>
<td>David's K Deli</td>
<td>Carnegie Deli</td>
</tr>
<tr>
<td>Fatty 'Cue BBQ</td>
<td>Casa Nonna Pizza</td>
</tr>
<tr>
<td>Fresco's by Scotto</td>
<td>Chicken &amp; Fries</td>
</tr>
<tr>
<td>Habanas</td>
<td>Daily Burger by Drew Nieporent</td>
</tr>
<tr>
<td>Junior's Restaurant</td>
<td>Delta Sky360' Club</td>
</tr>
<tr>
<td>Junior's, Blue Marble &amp; More</td>
<td>Event Bar</td>
</tr>
<tr>
<td>L&amp;B Spumoni Gardens</td>
<td>Farley's (bar)</td>
</tr>
<tr>
<td>Metro PCS Upper Pavilion</td>
<td>Garden Market (hot dogs &amp; snacks)</td>
</tr>
<tr>
<td>Nathan's</td>
<td>Garden Pub</td>
</tr>
<tr>
<td>Paisano's Butcher Shop</td>
<td>Healthy At The Garden (gluten free)</td>
</tr>
<tr>
<td>WFAN Boomer &amp; Carton Kitchen</td>
<td>Hill Country Barbecue Market</td>
</tr>
<tr>
<td></td>
<td>Ice Cream-Soft Serve</td>
</tr>
<tr>
<td></td>
<td>La Esquina Nachos</td>
</tr>
<tr>
<td></td>
<td>Lobster Shrimp Roll by Aquagrill</td>
</tr>
<tr>
<td></td>
<td>Sausage Boss by Andrew Carmellini</td>
</tr>
<tr>
<td></td>
<td>Senzai Sushi</td>
</tr>
<tr>
<td></td>
<td>Simply Chicken by Jean-Georges</td>
</tr>
</tbody>
</table>


Appendix C. Methodology for assigning caloric value to menu items.

In 2014, the MenuStat.org online nutritional database included nutritional information for 25,278 menu items served in 82 of the largest chain restaurants in the USA (http://www.menustat.org/#/about). The full list of the 82 restaurants included in MenuStat in 2014 is available on the MenuStats website (http://www.menustat.org)\(^1\). All caloric values for menu items from 2014 were downloaded from the MenuStat website. Any duplicate menu items listed as having the same portion size and caloric value and served at the same restaurant were removed from the analysis dataset.

The following process was followed to identify the total caloric content of menu items purchased and reported in the survey.

A search of the 2014 MenuStat database was conducted by food category and using the verbatim name of each menu item reported in the survey. For example, a search for the menu item “Burger” was limited to items coded as “entrees”, and listed as burger, while the search for the menu item “cake” was limited to the “dessert” category and all items names as a type of cake.

Menu items were excluded from the data listing for the following reasons:

Menu items assigned with one of the following features: “On the Kids Menu”, “Limited Time Offer”, “Regional”, “Shareable”, and “Combo Meal”.

Represented more than a single menu item

Items bundled with side orders such as a side salads, coleslaw, fries, chips, rice or drinks.

For items listed in the MenuStat database, the caloric values for each menu item was derived by calculating the mean caloric value and caloric distribution for all matching menu items from the 2014 database. A total of 54 different menu items (excluding drinks) were purchased by arena goers, of which 10 (18.5%) were not listed in the MenuStat database. For these items (Buffet, Candy bar, M&Ms, Twizzlers, Cotton Candy, Dessert, Rice pudding, Popcorn, Sushi, Pretzels) we extracted the corresponding caloric value found in the USDA National Nutrient Database for Standard Reference, Release 28 (2015)\(^2\).

Caloric values were assigned to each menu item according to the corresponding portion size category (no size, small, medium, large and extra-large). The mean caloric value for each item was computed, along with the
caloric values associated with given percentiles of distribution. The caloric value for each menu item portion size category was assigned using the following coding conventions:

No Size = mean caloric value
Small = 25th percentile caloric value
Medium/ no portion size option selected = 50th percentile caloric value
Large = 75th percentile caloric value
Extra-large = 90th percentile caloric value

5. The caloric value given to the menu item “buffet meal” (1187 kcal) was based on the assumption that the participant consumed a salad, entrée, topping and dessert. The caloric value for these menu categories were derived from values computed by Bleich et al., in their analysis of caloric trends in US chain restaurants based on the 2014 MenuStat database.

6. The caloric value for the menu item “Dessert” (400 kcal) was assigned using the value reported by Bleich and colleagues based on the 2014 MenuStat database.

References


## Appendix D. Characteristics of arena goers who purchased at least one SSB

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total N=140</th>
<th>Madison Square Garden (n = 58)</th>
<th>Barclays Center (n = 82)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Male</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Age, years, Mean (SD)</strong></td>
<td>33.3 (12.1)</td>
<td>33.2 (11.3)</td>
<td>33.6 (13.0)</td>
<td>.840</td>
</tr>
<tr>
<td><strong>BMI, Mean (SD)</strong></td>
<td>27.00 (5.69)</td>
<td>26.31 (5.25)</td>
<td>27.42 (5.92)</td>
<td>.286</td>
</tr>
<tr>
<td><strong>Hispanic, Latina/o, Spanish</strong></td>
<td>31 (22.1)</td>
<td>16 (27.6)</td>
<td>15 (18.3)</td>
<td>.192</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>43 (30.7)</td>
<td>24 (41.4)</td>
<td>19 (23.2)</td>
<td>.080</td>
</tr>
<tr>
<td>Black or African American</td>
<td>72 (51.4)</td>
<td>24 (41.4)</td>
<td>48 (58.5)</td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>5 (3.6)</td>
<td>1 (1.7)</td>
<td>4 (4.9)</td>
<td></td>
</tr>
<tr>
<td>Some other race, more than one race</td>
<td>11 (7.9)</td>
<td>5 (8.6)</td>
<td>6 (7.3)</td>
<td></td>
</tr>
<tr>
<td>Not reported</td>
<td>9 (6.4)</td>
<td>4 (6.9)</td>
<td>5 (6.1)</td>
<td></td>
</tr>
<tr>
<td><strong>Marital Status</strong></td>
<td></td>
<td></td>
<td></td>
<td>.379</td>
</tr>
<tr>
<td>Married</td>
<td>32 (22.9)</td>
<td>12 (20.7)</td>
<td>20 (24.4)</td>
<td></td>
</tr>
<tr>
<td>Never married</td>
<td>83 (59.3)</td>
<td>34 (58.6)</td>
<td>49 (59.8)</td>
<td></td>
</tr>
<tr>
<td>Not married, living with significant other</td>
<td>17 (12.1)</td>
<td>10 (17.2)</td>
<td>7 (8.5)</td>
<td></td>
</tr>
<tr>
<td>Separated, divorced or widowed</td>
<td>5 (3.6)</td>
<td>1 (1.7)</td>
<td>4 (4.9)</td>
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</tr>
<tr>
<td>Not Reported</td>
<td>3 (2.3)</td>
<td>1 (1.7)</td>
<td>2 (2.4)</td>
<td></td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td></td>
<td></td>
<td></td>
<td>.147</td>
</tr>
<tr>
<td>&lt; Some college</td>
<td>40 (28.6)</td>
<td>20 (34.5)</td>
<td>20 (24.4)</td>
<td></td>
</tr>
<tr>
<td>Some college (&lt;than 4 yrs.)</td>
<td>36 (25.7)</td>
<td>18 (31.0)</td>
<td>18 (22.0)</td>
<td></td>
</tr>
<tr>
<td>College/ University degree (4 years)</td>
<td>45 (32.1)</td>
<td>13 (22.9)</td>
<td>32 (39.0)</td>
<td></td>
</tr>
<tr>
<td>Graduate or professional education</td>
<td>17 (12.1)</td>
<td>7 (12.1)</td>
<td>10 (12.2)</td>
<td></td>
</tr>
<tr>
<td>Not reported</td>
<td>2 (1.4)</td>
<td>0</td>
<td>2 (2.4)</td>
<td></td>
</tr>
<tr>
<td><strong>Income</strong></td>
<td></td>
<td></td>
<td></td>
<td>.653</td>
</tr>
<tr>
<td>Less than $25,000</td>
<td>32 (22.9)</td>
<td>14 (24.1)</td>
<td>18 (22.0)</td>
<td></td>
</tr>
<tr>
<td>$25,000-$50,000</td>
<td>26 (18.6)</td>
<td>12 (20.7)</td>
<td>14 (17.1)</td>
<td></td>
</tr>
<tr>
<td>$50,001-$75,000</td>
<td>25 (17.9)</td>
<td>10 (17.2)</td>
<td>15 (18.3)</td>
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</tr>
<tr>
<td>$75,001- 100,000</td>
<td>16 (11.4)</td>
<td>6 (10.3)</td>
<td>10 (12.2)</td>
<td></td>
</tr>
<tr>
<td>$100,000-$125,000</td>
<td>7 (5.0)</td>
<td>4 (6.9)</td>
<td>3 (3.7)</td>
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</tr>
<tr>
<td>$125,001-$150,000</td>
<td>7 (5.0)</td>
<td>4 (6.9)</td>
<td>3 (3.7)</td>
<td></td>
</tr>
<tr>
<td>More than $150,000</td>
<td>8 (5.7)</td>
<td>6 (10.3)</td>
<td>2 (2.4)</td>
<td></td>
</tr>
<tr>
<td>Not reported</td>
<td>19 (13.6)</td>
<td>2 (3.4)</td>
<td>17 (20.7)</td>
<td></td>
</tr>
</tbody>
</table>

Note: BMI (703 x weight (lbs) / [height (in)]²); Categorical variables were compared using Chi-Square tests and continuous variables were compared using Independent T-tests. °Values expressed as n (%) unless otherwise noted; bExact test used due to violation of Chi-square assumption (expected cell count < 5).
### Appendix E. Unadjusted and Adjusted Univariable GLM Explaining Ounces of SSBs Beverages Purchased Among All Participants and Among Participants Who Purchased at least 1 SSB: Main Effect of Arena

<table>
<thead>
<tr>
<th></th>
<th>Unadjusted Model</th>
<th>Adjusted Model</th>
<th>Unadjusted Model</th>
<th>Adjusted Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β Coefficient</td>
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\(^a\) Primary outcome; \(^b\) 2.24 and -11.03 less ounces than MSG; \(^c\) 1.86 and 6.89 less ounces than male; \(^d\) Reference group. The boldface p-values are those that are <0.05, i.e. those that were significant.
Chapter 6. Manuscript 3

“Evaluating a Portion Cap Policy on Sugar-Sweetened Beverages: a Randomized Controlled Restaurant Dining Trial.”

Abstract

**Objective:** To determine the impact of limiting the portion-size of sugar-sweetened beverages (SSB), and offering free SSB refills on food, beverage and SSB calories purchased and consumed during a simulated restaurant dining experience.

**Methods:** This randomized restaurant laboratory study was conducted in Boston between January 2015 and August 2015. Adults (n=359) participating in pseudo focus-groups were randomized to one of four conditions: either SSB portion option (Current restaurant portions or 16 oz portions) plus either SSB refill option (free or the option to purchase). Menu item weights recorded pre- and post-dinner meal were used to calculate calories ordered and consumed.

**Results:** Adjusted GLM analysis found no main effect of SSB menu conditions on food, beverage, and SSB calories ordered and consumed (all $p>.05$). Poisson regression showed a significant effect of SSB menu condition on number of SSB ordered ($p=.048$). The 16 oz SSB portion, free refills condition had a 1.29 times higher rate of ordering SSB refills compared to current restaurant SSB portion purchase refills conditions.
Conclusions: Offering a portion-limited 16 oz SSB did not influence total calories purchased or consumed at a dinner meal. Offering free refills of 16 oz SSB increased the likelihood of ordering SSB refills.

Trial Registration: ClinicalTrials.gov Identifier, NCT04197063, https://clinicaltrials.gov/ct2/show/NCT04197063?term=Sugar-Sweetened+Beverage+Portion+Limit%3A+A+Dining+Lab+RCT&draw=2&rank=1
Introduction

Little progress has been made in achieving the Healthy People 2020 ("Healthy People 2020. (2018). Washington, DC") goal of reducing the proportion of children, adolescents, and adults who are obese in the US (Hales, 2020; Hales CM, 2020). Numerous features of the food environment contribute to the complex challenges associated with reducing the prevalence of obesity, especially aspects that influence food choices. Recently, much attention has focused on the contribution of sugar-sweetened beverages (SSB) to an unhealthy eating pattern (Malik et al., 2019; Micha et al., 2017; US DHHS & USDA, 2015) and implementing public health policies aimed at reducing SSB consumption to improve the food environment and promote healthier beverage choices (Young & Nestle, 2012).

SSBs are high in calories, devoid of any meaningful nutritional value, and the largest source of added sugar in diet in the United States (Drewnowski & Rehm, 2014). Furthermore, consumption of SSB is associated with obesity (Malik, Pan, Willett, & Hu, 2013) and other adverse metabolic and cardiovascular health outcomes (Johnson et al., 2009). Despite a gradual decline in the total energy consumed from SSB from 2003 to 2016 in the US (Marriott, Hunt, Malek, & Newman, 2019), obesity rates remain at a 40-year high. Simultaneously, large-sized SSB portions have become a societal norm and are commonly offered in casual dining and fast food restaurants (Young & Nestle, 2012). Additionally, marketing and pricing promotions continue to
influence food choices and discourage healthy eating behaviors by incentivizing consumers with inexpensive super-sized portions, large-sized drinks bundled with value meals and free beverage refills (Bennett et al., 2020; Powell, 2013).

In 2012, the New York City (NYC) Department of health attempted to implement an SSB portion cap regulation limiting the portion size for “sugary-beverages” sold at food establishments in NYC to 16 ounces. An SSB portion cap policy would restrict the size of SSBs sold, but still allow consumers the freedom to purchase SSBs. Based on the principles of behavioral economics, such a policy changes the food “choice architecture” and eliminates the opportunity to purchase large-sized SSB (Sunstein, 2014). The policy is based on the premise that people have the tendency to accept the status quo and thereby nudges people to purchase smaller-sized SSB and make a healthier beverage choice (Roberto & Pomeranz, 2015; Samuelson & Zeckhauser, 1988). Eventually, the NYC courts overturned the regulation and since this time no other city has enacted an SSB portion cap policy.

There is very little scientific evidence documenting the impact of SSB portion cap policies. There are a limited number of SSB portion-size behavioral interventions (Flood, Roe, & Rolls, 2006; John, Donnelly, & Roberto, 2017; Wilson, Stolarz-Fantino, & Fantino, 2013) and simulation studies (Cleghorn et al., 2019; M. Crino et al., 2017; Elbel, Cantor, & Mijanovich, 2012; Liu, 2014; Wang & Vine, 2013) showing the potential benefits of an SSB portion limit
policy. In addition, a recent meta-analysis found that serving SSB in larger size containers was associated with a significant increase in the energy intake (Hollands et al., 2015). It is unknown if a portion-size cap policy would have a positive influence on SSB energy intake in a restaurant setting. It is also unclear how consumers will respond when offered free-refills in combination with an SSB portion-size cap.

To test this, a randomized controlled study was designed to examine the effect of a 16 oz portion-size cap policy in a simulated dining setting. The experiment examined the counter-effect of a likely marketing promotion, offering free SSB refills on energy intake at a dinner meal. We hypothesized that in the 16 oz SSB portion cap plus the option to buy refills condition, participants will order fewer calories during the dinner meal compared to those in the current restaurant portion (control), free refill conditions. In addition, we hypothesized that there would be no difference in post-meal hunger ratings between any of the SSB menu conditions (see Figure 1, study scheme and hypothesized outcome).

*INSERT FIGURE 1 HERE*

**Methods**

**Study Design**
This randomized, controlled lab-based restaurant study was conducted at the restaurant and eating behavior lab in the Landmark Center in Boston, Massachusetts between January 2015 and August 2015. To conceal the purpose of the study, participants were invited to a dinner meal to participate in a pseudo consumer market research focus group investigating dining and restaurant preferences. Participants were seated alone at restaurant-style dining table and after providing written consent were randomized on an 1:1:1:1 basis using a computer-generated code, to one of four SSB menu conditions. Participants were provided with dinner menus offering identical food choices, with the exception that the portion size of the SSB listed on the menu varied according to their SSB menu condition as follows:

1) current SSB restaurant portions plus free refills
2) current SSB restaurant portions with the option to purchase refills
3) 16 oz SSB portion limit plus free refills
4) 16 oz SSB portion limit with the option to purchase refills.

The institutional review boards at Harvard’s School of Public Health (IRB #: 14-2926) approved the protocol and at Rutgers Health Sciences IRB (IRB #: Pro2019001933) approved the statistical analysis plan. The study was retrospectively registered on clinical trial.gov (ClinicaTrials.gov Identifier, NCT04197063).
Participants

Adults (over 18 years) were referred by friends and recruited via flyers and advertising on Craigslist from the greater Boston/Cambridge area. Eligible participants were able to speak and read English but were excluded if they reported severe food allergies. To standardize pre-meal hunger, participants were instructed not to eat for approximately 2.5 hours prior to the 5:30 pm focus group.

Dinner meal SSB menu condition

Study participants were instructed to imagine that they were eating out at a real restaurant and to order a dinner meal that they would typically eat in a restaurant. They were given menus offering an assortment of healthy and unhealthy menu items from two local restaurants (Yard House and Panera) (Appendix A. SSB Menu conditions). To minimize influencing the menu selection of others, participants ordered their meal silently by circling their food choices directly on the paper menu rather than ordering out loud. Menus differed according to the participant's randomization assignment. All menus offered a choice of a variety of beverages including: soda (Coke, Cherry Coke, Diet Coke, Sprite, Fresca, Barq's Root Beer, Dr. Pepper, ginger ale), bottled water, lemonade, juice, and milk. For the "current SSB restaurant portions" conditions, the size of SSB were listed as small, medium, large and contained 16 oz, 21 oz, and 32 oz ounces, respectively. While the 16 oz SSB portion limit
condition offered soda described as “one size,” small, and contained 16 oz. In the “free refills” conditions, waitstaff used scripting to ask participants on at least one occasion if they would like to order anything else or if they wanted a “free refill.” SSB were served chilled with ice and its own straw. All participants were given a $45 credit to spend on the dinner meal. They were informed that all menu items were discounted by 70% and the cost of the meal would be deducted from the credit and they would receive the balance of money that was not spent after they returned to the lab the following evening. The only restrictions were that participants ordered at least one menu item and to prevent over-ordering, were not allowed to take home any uneaten food.

**Focus group and dinner meal**

After menu orders were place trained research team members led scripted focus groups while participants recorded their responses to questions about their restaurant and dining preferences on electronic devices. At the end of focus group, participants were served their dinner meal and subsequently completed electronic questionnaires collecting information on participant characteristics (age, BMI, ethnicity, race, marital status, education and income). The length of the study visit, including focus group and dinner meal was approximately two hours. The participants’ level of hunger before the dinner meal and level of fullness after the dinner meal were assessed with a 7-point Likert-like scale asking the following questions: “Before eating this meal,
how hungry were you?” (1=Not at all hungry, 7=Extremely hungry) and “Now that the meal is complete, how full do you feel?” (1=Not at all full, 7=Extremely full).

Food and beverage menu items were measured (in grams) by trained research assistants prior to eating and after completing the dinner meal to allow for the calculation of total calories purchased and total calories consumed. The energy content of menu items was obtained from the restaurant’s websites at the time of the study.

**Post-study meal procedures**

On the following day, participants were asked to return to the Lab. Weight and height were measured, and participants were debriefed as to the purpose of the study and received any money remaining from the $45 credit that they did not spend on the dinner meal.

**Sample size/ power**

Because no prior studies measured the effect of an SSB portion size limit policy on SSB intake in a restaurant setting, the power calculation utilized the effect size derived from a similarly designed experiment examining the effect of calorie labeling on eating behaviors (Roberto, Larsen, Agnew, Baik, & Brownell, 2010). A target sample size of at least 137 participants per SSB menu condition (n=548 total) was needed to obtain 80% power to detect a statistically
significant difference and a Cohen’s $d$ effect size of 0.34 using two-sided test with an alpha level of 0.05.

**Analysis**

Statistical analyses were performed using SPSS Version 26 (SPSS Inc, Chicago, IL). Data were assessed for outliers and normality was tested using Levene’s test/Shapiro-Wilk tests and a visual inspection of histograms and normal plots. The assumption of normality was tenable for all continuous outcomes examined with parametric testing. The demographic and socioeconomic characteristics of participants were summarized using descriptive statistics. Due to the premature termination of study an one-way ANOVA test was used to compare continuous variables (age and BMI) for significant differences across the four SSB menu conditions. Categorical variables were compared using either Chi-square test statistics for comparisons of proportions (for sex, race, ethnicity, marital status) or Kruskal Wallis test (KW test) statistic for education and income. The participants’ ratings of their level of hunger and fullness were compared for differences in pre-meal and post-meal hunger between the four beverage conditions using KW test statistics.

For the unadjusted models, univariate ANOVA tests were used to assess for significant differences in the primary endpoints, total food and beverage calories (1) ordered and (2) consumed at the dinner meal between
SSB menu conditions. Additional univariate ANOVA tests were conducted to compare the effect of SSB menu condition on the following secondary endpoints: total food calories, total beverage calories and total SSB calories ordered and consumed. Adjusted univariate GLM tests were performed controlling for income, the only baseline characteristics found to be statistically significantly different between SSB menu conditions. Chi $\chi^2$ test was used to identify any differences in the number of participants who ordered SSB (yes or no) between menu conditions. Finally, a Poisson regression models to compare the number of SSBs ordered. Post-hoc SIDAK multiple comparison correction was used to test differences between pairs of conditions due to uneven group sizes.

There were no systematic patterns of missing data identified and imputations were not performed. Statistical significance was set at $p<0.05$ for all tests.

Results

Of the 484 adults approached for this study, 359 (74.2%) were randomized; 93 were assigned to current SSB restaurant portions plus free refills; 96 were assigned to the current SSB restaurant portions with the option to purchase refills; 82 were assigned to 16 oz SSB portion limit with the option to purchase refills; and 88 were assigned to the 16 oz SSB portion limit plus free refills condition (Figure 2). Overall, 45.1% of the participants ordered at
least one SSB and there were no significant differences in the proportion of participants who ordered SSB between SSB menu conditions (p= .480).

**Characteristics of the Four SSB Menu Conditions**

Participants were mean age 34.80 (SD =15.33) years, 53.7% female, a mean BMI of 25.9 (SD =6.3), and a median annual income bracket of $30,000-$39,999 (Table 1). The characteristics of the participants were well balanced across the four SSB menu conditions with the exception of a statistically significant difference in income by SSB menu condition (H(3) =8.359, p=.039), with 10.8% of participants in the current SSB restaurant portions free refill condition reporting a household income of greater than $60,000 compared with 23.9% to 27.5% of the participants in the remaining conditions.

**Pre-meal hunger levels were measured to confirm that the participants’ perceptions of hunger were standardized among SSB menu conditions and were screened as candidate covariate for the univariate GLM analyses. The overall rating of pre-dinner hunger was (mean± SEM) 4.95± .080 (on a 7-point scale). There were no statistically significant differences in hunger between**
SSB menu conditions, (p=.977), thus hunger was not included as a covariate in analysis model. Additionally, there were no significant differences in participates’ rating of post-dinner level of fullness (p=.592).

**Total Calories Ordered and Consumed**

There was no significant main effect of SSB menu condition on the primary outcome total food and beverage calories ordered and consumed (all >.05) at the dinner meal in the unadjusted analysis or in the adjusted analysis after controlling for income (Table 2).

INSERT TABLE 2 HERE

Among secondary outcomes, the Poisson analysis demonstrated a significant main effect of SSB menu condition on the number of SSB ordered (Wald $X^2(3)=7.913$, $p = .048$). The 16 oz SSB portion limit free refill menu condition ordered a mean (SE), 0.66 (0.07), number of SSB compared with the current restaurant portions no free refills condition 0.40 (0.07), and was a significant predictor of ordering a greater number of servings of SSB ($b=.257$, S.E.=.094, $P<.006$). After controlling for income, the 16 oz SSB portion limit free refill condition was shown to be 1.29 (95% CI, 1.076, 1.555) times more likely to order refills than the current restaurant SSB portion no free refill group.
Discussion

This randomized controlled restaurant dining study did not detect a difference between SSB menu condition and food, beverage or SSB calories ordered or consumed during a simulated restaurant dining experience. This study was unique in that it was designed to test the effect of implementing a smaller, 16 oz SSB size portion as the default option in restaurants, while concurrently examining the influence of offering free refills on SSB calorie consumption. The results of this study demonstrated that the 16 oz SSB portion limit plus free refills condition was associated with ordering a significantly greater number of servings of SSB compared with the current restaurant portions condition with the option to purchase refills. This finding provides preliminary evidence that if a public health policy was implemented restricting the portion size of SSB in restaurants to 16 oz, marketing counteractions such as offering free refills have the potential to diminish the health benefits from such a policy.

This intervention is based on a behavioral economic approach that assumes people accept the status quo and would purchase the healthier default option (Roberto & Kawachi, 2014; Samuelson & Zeckhauser, 1988). Although other behavioral (Flood et al., 2006; John et al., 2017; Wang & Vine, 2013) and simulation studies (Cleghorn et al., 2019; M. Crino et al., 2017; Michelle Crino, Sacks, & Wu, 2016; Elbel et al., 2012; Liu, 2014) have predicted the effectiveness of an SSB portion limit policy there are several factors that
may have contributed to the present study not detecting a main treatment effect of the SSB portion limit menus condition on energy ordered and consumed at a dinner meal. First, the study was prematurely stopped when the principle investigator (CR) moved her research lab to another university. The original power calculation estimated that 548 participants were needed. However, the study only randomized approximately 66% of this target, leading to an underpowered analysis, particular for the primary outcomes. Second, the observed power for primary outcome was approximately 28%. Thus, it is also possible that parameters used to calculated the sample size (e.g., anticipated effect size, sample variance) may have contributed to an underestimation of the necessary number of participants needed for this study. Finally, the premature discontinuation of the study was associated with a small imbalance in the number of participants randomized to each condition and also may have further exacerbated the baseline imbalance in participants’ income, which was related to main effect of SSB menu condition on the primary outcomes.

To our knowledge, to date, no randomized controlled intervention has examined the effectiveness of an SSB portion limit policy in a restaurant laboratory setting. Although the present study failed to demonstrate the effectiveness of such a policy on energy consumption at a dinner meal, this study confirmed the feasibility of utilizing a similar setting for future studies testing SSB portion limit policies. Particularly, participant response and participation rates were high, research waitstaff were well-trained, the menu
was well-received, given that it offered popular food items from local restaurants, menu items were weighted pre- and post-dinner meal, which yielded reliable energy estimates, and affordable pricing incentivized the purchase of a typical dinner meal, while allowed participants to receive a small stipend from the unused money. Furthermore, because this study aimed to test a proposed obesity prevention policy, the study design incorporated components intended to control for factors associated with food choice or meal purchasing decisions (Leng et al., 2017). For example, to minimized the social influence of meal purchasing decisions on nearby dinners, participants were seated alone and silently ordered their meals (Herman, Roth, & Polivy, 2003). While pre-meal food intake was restricted by instructing participants to refrain from eating for the same length of time prior to the start of the focus group, thus hunger levels were equalized between SSB menu conditions (Suzuki, Simpson, Minnion, Shillito, & Bloom, 2010).

If an SSB portion size limit regulation was implemented, it is possible that food service establishments would respond with marketing and pricing promotions meant to influence dining and food choice decisions and prevent the loss of revenue. This study found that the 16 oz SSB portion limit plus free refills condition consumed slightly more calories from SSB compared with the current restaurant SSB portions menu conditions with no refills, but the difference was not statistically different. Yet this study demonstrated that the likelihood of ordering a free refill of SSB was 29.4% greater in the 16 oz SSB
portion limit plus free refill condition compared with the current restaurant SSB portions conditions with no option to purchase refill. Very few studies have examined an SSB portion size restriction policy and to the best of our knowledge only John and colleagues (John et al., 2017) conducted a behavioral laboratory experiment that examined the impact of free refills of sugary-drinks. Similarly, they found that the majority of participants (79.6%) who were offered free refills obtained one. Furthermore, while their study did not detect a significant increase in beverage calories between the 16 oz cup size and the 16 oz cup plus refills groups, the overall analysis found when participants were offered free refills of all drink sizes, they consumed 20.1% more calories compared with the no refill groups. Together, these preliminary findings reinforce the importance of understanding the impact of an SSB portion limit policy, along with offering free refills in a real-world restaurant setting.

Limitations and strengths.

There were several limitations to this study. As previously noted, the primary analysis for this study was underpowered, thus we cannot draw any definitive conclusions about these study results.

In addition, although this study may be representative of participants in the Boston-Cambridge metropolitan area, the generalizability of this study to other populations, geographical regions, or settings (a natural restaurant or other retail settings where SSB are sold) is unknown. Finally, while this study
took steps to minimize social influences on ordering, it is possible that participants may have observed larger-size beverage portions at nearby tables and this may have influenced decisions to order SSB refills. The strengths of this study include that it was a randomized controlled study designed to test for casual inferences. Participant bias was minimized by using a pseudo-focus group to conceal the purpose of the study and thus it was unlikely that the pseudo-focus group influenced participants’ SSB beverage consumption behaviors at the dinner meal. In addition, the assessment of the energy content of the food and beverages ordered and consumed was highly reliable as it was derived from the actual weight of menu items prior to and after the dinner meal.

**Conclusion**

These findings demonstrated the feasibility and acceptability of examining the impact of SSB portion limit policy and offering free refills using a restaurant dining laboratory intervention. Although the study was not adequately powered to demonstrate a strong SSB portion size effect, the trend in caloric intake from SSB was in the expected directions. Furthermore, this study importantly confirmed the negative impact of offering free SSB refills on caloric intake at a dinner meal. These data and previous research suggest that such a policy may be an effective tool for reducing SSB consumption but adequately powered confirmatory studies are still needed. Additionally, future studies should identify
and study the effect of marketing promotions that may offset the health benefits of an SSB portion size limit policy.

References


Crino, M., Sacks, G., & Wu, J. (2016). A Review of Population-Level Actions Targeting Reductions in Food Portion Sizes to Address Obesity and


# Tables

## Table 1. Characteristics of the Participant

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</table>

Household Income²  

<table>
<thead>
<tr>
<th>Income Level</th>
<th>&lt; $20,000</th>
<th>$20,000 - $39,999</th>
<th>$40,000 - $59,000</th>
<th>&gt; 60,000</th>
<th>Not Reported</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45 (48.4)</td>
<td>34 (35.4)</td>
<td>27 (30.7)</td>
<td>136 (37.9)</td>
<td>0</td>
</tr>
<tr>
<td>&lt; $20,000</td>
<td>23 (24.7)</td>
<td>26 (27.1)</td>
<td>24 (29.5)</td>
<td>20 (20.7)</td>
<td>92 (25.6)</td>
</tr>
<tr>
<td>$20,000 - $39,999</td>
<td>15 (16.1)</td>
<td>12 (12.5)</td>
<td>14 (15.9)</td>
<td>52 (14.5)</td>
<td>0</td>
</tr>
<tr>
<td>&gt; 60,000</td>
<td>10 (10.8)</td>
<td>23 (24.0)</td>
<td>21 (23.9)</td>
<td>22 (26.8)</td>
<td>76 (21.2)</td>
</tr>
<tr>
<td>Not Reported</td>
<td>0</td>
<td>1 (1.0)</td>
<td>0</td>
<td>2 (2.4)</td>
<td>3 (0.8)</td>
</tr>
</tbody>
</table>

BMI (703 x weight (lbs.) / [height (in)]²); Categorical variables were compared using Chi Square omnibus test; Kruskal-Wallis test for Income and education; continuous variables were compared using ANOVA; VALUES expressed as n (%) unless otherwise noted;

²Differences were identified between participant characteristics and treatment condition: P=.039.
Table 2. Food, beverage and SSB consumption patterns: effect of beverage menu condition

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Current Restaurant SSB Portions</th>
<th>16 oz SSB Portion Limit</th>
<th>P value of comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total food and beverage calories, ordered consumed</td>
<td>2425.06 (121.34)</td>
<td>2654.29 (123.73)</td>
<td>.529</td>
</tr>
<tr>
<td></td>
<td>1591.50 (76.82)</td>
<td>1748.50 (77.64)</td>
<td></td>
</tr>
<tr>
<td>Total food calories, ordered consumed</td>
<td>2239.53 (118.60)</td>
<td>2499.64 (120.52)</td>
<td>.361</td>
</tr>
<tr>
<td></td>
<td>1429.78 (75.53)</td>
<td>1603.50 (77.12)</td>
<td></td>
</tr>
<tr>
<td>Total beverage calories, ordered consumed</td>
<td>168.98 (15.92)</td>
<td>152.88 (16.25)</td>
<td>.262</td>
</tr>
<tr>
<td></td>
<td>107.19 (11.86)</td>
<td>120.13 (12.10)</td>
<td></td>
</tr>
<tr>
<td>SSB ordered, yes, n (%)</td>
<td>42 (45.2%)</td>
<td>45 (51.1%)</td>
<td>.480c</td>
</tr>
<tr>
<td>Number of SSB</td>
<td>0.49 (0.07)</td>
<td>0.66 (0.07)</td>
<td>.048d</td>
</tr>
<tr>
<td>Total SSB kcal, ordered consumed</td>
<td>129.98 (15.69)</td>
<td>111.70 (16.02)</td>
<td>.372</td>
</tr>
<tr>
<td></td>
<td>84.01 (11.43)</td>
<td>85.17 (11.67)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviation: Sugar-sweetened beverages (SSB); a Data shown as adjusted marginal mean (SE), unless otherwise specified; b Between group comparisons tested with GLM adjusting for income; c Chi $X^2$ used for between group comparisons; d Poisson loglinear model used for between group comparison adjusting for income
Figures

Figure 1. Randomization schematic showing randomization assignment from least to most restrictive SSB menu condition and hypothesized outcome.
Figure 2. Flow diagram of the study: participant recruitment, screening, randomization and data analysis
### Appendix A. Current Restaurant SSB Menu and 16 oz SSB Portion Limit Menu

#### Boston Dining

<table>
<thead>
<tr>
<th>Appetizers</th>
<th>Entrée Salads</th>
<th>Menu</th>
<th>Sandwiches</th>
<th>Dessert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fried Calamari</td>
<td>Avocado, pear, corn, cheddar, jalepeno, tortilla strips, tomato, beans, citrus salad, fried onions, cilantro, &amp; chipotle ranch</td>
<td>Roasted Turkey Melt</td>
<td>Salted Caramel Butterscotch Pudding</td>
<td></td>
</tr>
<tr>
<td>Fried Chicken Strips</td>
<td>BBB Chichnea</td>
<td>Swiss, pickled jalapenos &amp; mayo on garlic French bread with fries</td>
<td>Topped with house made whipped cream, chocolate cookie crumble and malonaise sauce</td>
<td></td>
</tr>
<tr>
<td>Chicken Nachos</td>
<td>Spicy pinto beans, cheddar, jack, red &amp; green sauce, tomato, cilantro, onion, guacamole, sour cream</td>
<td><strong>New York Steak</strong></td>
<td>Mini Trifle Sampler</td>
<td></td>
</tr>
<tr>
<td>Onion Ring Tower (V)</td>
<td>BBQ Chicken</td>
<td>(prepared to your specifications) roasted romaine, dijon &amp; garlic aioli on garlic French bread with BBQ au jus &amp; fries</td>
<td>Mini serving of our lemon soufflé cake, peach apple cobbler and chocolate soufflé cake</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Four Cheese (V)</td>
<td>Grilled Chicken &amp; Avocado</td>
<td>Cheese souffle cake</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>Fresh tomato sauce, feta, ricotta, mozzarella &amp; parmesan</td>
<td></td>
<td>Served warm with vanilla ice cream</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>Margherita (V)</td>
<td>Blackened Chicken Torta (V)</td>
<td>Mini Lemon Soufflé Cake</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>Roasted roma tomatoes, mozzarella &amp; fresh basil</td>
<td>Pepper jack, cheddar, blackberry, grilled avocado, dijon, mayonnaise, arugula &amp; romaine</td>
<td>With fresh raspberries and house made whipped cream</td>
<td>2.10</td>
</tr>
<tr>
<td></td>
<td>Pepperoni &amp; Mushroom</td>
<td>Roasted Turkey Club</td>
<td>Mac and Cheese*</td>
<td>2.10</td>
</tr>
<tr>
<td></td>
<td>Fresh tomato sauce, crinkles mushrooms &amp; mozzarella</td>
<td>Swiss, avocado, applewood smoked bacon, tomato, lettuce &amp; mayo on toasted sourdough or wheat with fries</td>
<td>Mac &amp; Cheese*</td>
<td>2.10</td>
</tr>
<tr>
<td></td>
<td>Grilled Burgers</td>
<td>Roast Beef Dip</td>
<td>Over caramel and raspberry sauce with house made whipped cream</td>
<td>1.20</td>
</tr>
<tr>
<td>Your choice of potato or wheat bun. Fries can be substituted for salad</td>
<td><em>Cheese</em></td>
<td>Fresh Fruit</td>
<td>A selection of grapes, pineapples, cantaloupe, and honey dew</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td><em>BBQ Bacon Cheddar</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lettuce, tomato, red onion, garlic aioli &amp; cheddar cheese with fries</td>
<td></td>
<td>Beverages</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Applewood smoked bacon, rum BBQ sauce &amp; garlic aioli with fries</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Turkey Burger</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>House made, roasted roma tomatoes, mozzarella &amp; garlic aioli with fries</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Rosen Crusted Gorgonzola</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Marinated roasted crimi mushrooms, caramelized onions &amp; baby spinach with fries</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chopped Salad</td>
<td>Garden’s* Burger (V)</td>
<td><strong>Roasted Cauliflower (V)</strong></td>
<td></td>
<td>2.10</td>
</tr>
<tr>
<td></td>
<td>Avocado, tomato, bacon, corn, cilantro, cucumber, onion, tomatoes &amp; bloody Mary vinaigrette</td>
<td>Beer battered, roasted with BBQ sauce</td>
<td><strong>Bottle Water</strong> (1 liter)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.38</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fizz &amp; Fruitydog</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lemonsade</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Orange Juice</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Milk</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.70</td>
</tr>
</tbody>
</table>

*Vegetarian options available. Chicken or beef substitutions made from soy, wheat, peas proteins, vegetables and ancient grains.

**Notes:**
- Salted Caramel Butterscotch Pudding: Topped with house made whipped cream, chocolate cookie crumble and malonaise sauce.
- Mini Trifle Sampler: Mini serving of our lemon soufflé cake, peach apple cobbler and chocolate soufflé cake.
- Cheese Soufflé Cake: Cheesecake with fresh raspberries and house made whipped cream.
- Mac & Cheese*: Mac and Cheese topped with bacon, applewood smoked bacon, and mixed greens on garlic French bread with fries.
- Roasted Cauliflower (V): Roasted cauliflower topped with roasted garlic & basil aioli.
- Fizz & Fruitydog: Fizz & Fruitydog is a refreshing and tasty beverage option.

---

*Only certain or any of raw or undercooked ingredients may be cross-contaminated with other ingredients in the kitchen area.*
# Boston Dining

## Appetizers

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fried Calamari</td>
<td>$3.30</td>
</tr>
<tr>
<td>with spicy tomato sauce &amp; tartar sauce</td>
<td></td>
</tr>
<tr>
<td>Fried Chicken Stripes</td>
<td>$3.00</td>
</tr>
<tr>
<td>Maple Dijon &amp; buttermilk ranch sauce</td>
<td></td>
</tr>
<tr>
<td>Chicken Nachos</td>
<td>$3.60</td>
</tr>
<tr>
<td>Spicy pinto beans, cheddar, jack, red &amp; green sauce, tomato, cilantro, onion, guacamole, sour cream</td>
<td></td>
</tr>
<tr>
<td>Onion Ring Tower (V)</td>
<td>$2.70</td>
</tr>
<tr>
<td>Beer battered, dusted with parmesan, with chipotle and buttermilk ranch dipping sauce</td>
<td></td>
</tr>
<tr>
<td>California Roll</td>
<td>$3.60</td>
</tr>
<tr>
<td>Crispy rice, crab, tomatoes, avocado, cucumber, sesame, wasabi, nori, miso, soy, cilantro</td>
<td></td>
</tr>
<tr>
<td>Lettuce Wraps</td>
<td>$3.60</td>
</tr>
<tr>
<td>Steamed tofu, zine nuts &amp; green onions with three dipping sauces. Chicken $3.60 or shrimp $4.20 or sidekick &amp; cream mushroom $5.60</td>
<td></td>
</tr>
</tbody>
</table>

## Starter Salads

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caesar</td>
<td>$2.10</td>
</tr>
<tr>
<td>Shredded parmesan &amp; herbs</td>
<td></td>
</tr>
<tr>
<td>Classic Ranch (V)</td>
<td>$1.80</td>
</tr>
<tr>
<td>Idaho &amp; Boston lettuce, tomatoes, carrots, sweet corn, jack, cheddar, croutons &amp; buttermilk ranch</td>
<td></td>
</tr>
<tr>
<td>Mixed Green Goddess (V)</td>
<td>$2.10</td>
</tr>
<tr>
<td>Tomatoes, cucumbers, carrots, leeks, croutons &amp; balsamic vinegar</td>
<td></td>
</tr>
<tr>
<td>Chopped Salad</td>
<td>$2.40</td>
</tr>
<tr>
<td>Avocado, tomatoes, bacon, corn, cilantro, cucumbers, salad, onions &amp; bloody mary vinegar</td>
<td></td>
</tr>
</tbody>
</table>

(V): Vegetarian  * Vegetables option available. Chicken or beef substitute made from soy, wheat, pea proteins, vegetables and ancient grains

## Salads

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>BBQ Chicken</td>
<td>$3.20</td>
</tr>
<tr>
<td>Avocado, pinto beans, corn, cheddar, jack, tortilla strips, tomato, beans, citrus blue, fried onions, cilantro &amp; chipotle ranch</td>
<td></td>
</tr>
<tr>
<td>Pizzas</td>
<td>$3.20</td>
</tr>
<tr>
<td>BBQ Chicken</td>
<td>$2.80</td>
</tr>
<tr>
<td>Mozzarella, cilantro, red onions, smoked gouda &amp; BBQ sauce</td>
<td></td>
</tr>
<tr>
<td>Four Cheese (V)</td>
<td>$3.80</td>
</tr>
<tr>
<td>Fresh tomato sauce, fontina, ricotta, mozzarella &amp; parmesan</td>
<td></td>
</tr>
<tr>
<td>Margherita (V)</td>
<td>$3.60</td>
</tr>
<tr>
<td>Roasted roma tomatoes, roasted garlic, mozzarella &amp; French basil</td>
<td></td>
</tr>
<tr>
<td>Pepperoni &amp; Mushrooms</td>
<td>$3.90</td>
</tr>
<tr>
<td>Fresh tomato sauce, crumbled mushrooms &amp; mozzarella</td>
<td></td>
</tr>
</tbody>
</table>

## Grilled Burgers

Your choice of potato or wheat bun. Fries can be substituted for salad

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Classic Cheese</strong></td>
<td>$3.20</td>
</tr>
<tr>
<td>Lettuce, tomato, red onion, garlic aioli &amp; cheddar cheese with fries</td>
<td></td>
</tr>
<tr>
<td><strong>BBQ Bacon Cheddar</strong></td>
<td>$3.60</td>
</tr>
<tr>
<td>Applewood smoked bacon, rum BBQ sauce &amp; garlic aioli with fries</td>
<td></td>
</tr>
<tr>
<td>Turkey Burger</td>
<td>$3.30</td>
</tr>
<tr>
<td>House made, roasted roma tomatoes, mozzarella &amp; garlic aioli with fries</td>
<td></td>
</tr>
<tr>
<td><strong>Pepper Crusted Gorgonzola</strong></td>
<td>$3.60</td>
</tr>
<tr>
<td>Herbed seared crumbled mushrooms, caramelized onions &amp; baby spinach with fries</td>
<td></td>
</tr>
<tr>
<td>Garden® Burger (V)</td>
<td>$3.30-</td>
</tr>
<tr>
<td>Garden® is on all burgers. Chicken or beef substitutes made from soy, wheat, pea proteins, vegetables and ancient grains</td>
<td></td>
</tr>
<tr>
<td>$3.60</td>
<td></td>
</tr>
<tr>
<td>Roasted Cauliflower (V)</td>
<td>$2.10</td>
</tr>
<tr>
<td>Zatar, spicy tahini</td>
<td></td>
</tr>
<tr>
<td>Hummus (V)</td>
<td>$2.10</td>
</tr>
<tr>
<td>Topped with olive oil &amp; kalamata olives with your choice of crispy flatbread or baked pita</td>
<td></td>
</tr>
<tr>
<td>Crispy Brussels Sprouts &amp; Ripped Potatoes (V)</td>
<td>$2.10</td>
</tr>
<tr>
<td>Matt vinegar aioli</td>
<td></td>
</tr>
</tbody>
</table>

## Menu

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roasted Turkey Malt</td>
<td>$3.20</td>
</tr>
<tr>
<td>Swiss, pickled jalapenos &amp; mayo on garlic French bread with fries</td>
<td></td>
</tr>
<tr>
<td><strong>New York Steak</strong></td>
<td>$3.60</td>
</tr>
<tr>
<td>(prepared to your specifications) roasted roma tomatoes, djon &amp; garlic aioli on garlic French bread with BBQ au jus &amp; fries</td>
<td></td>
</tr>
<tr>
<td>Grilled Chicken &amp; Avocado</td>
<td>$4.20</td>
</tr>
<tr>
<td>Swiss, lettuce, tomato &amp; mayo on onion poppy seed bun with fries</td>
<td></td>
</tr>
<tr>
<td>Blackened Chicken Tarta (V)</td>
<td>$4.50</td>
</tr>
<tr>
<td>Pepper jack, cheddar, cajun, blackened chicken, chipotle, mayo, cumin crema</td>
<td></td>
</tr>
<tr>
<td>Roasted Turkey Club</td>
<td>$3.60</td>
</tr>
<tr>
<td>Swiss, avocado, applewood smoked bacon, tomato, lettuce &amp; mayo on toasted sourdough or wheat with fries</td>
<td></td>
</tr>
<tr>
<td>Roast Beef Dip</td>
<td>$3.60</td>
</tr>
<tr>
<td>Swiss on garlic French bread with au jus, horseradish cream or fries</td>
<td></td>
</tr>
<tr>
<td><strong>Seared Ahi Steak</strong></td>
<td>$4.20</td>
</tr>
<tr>
<td>Seared rare, spinach, Swiss, tomatoes, caramelized onions &amp; peppercorn aioli on grilled rye with fries</td>
<td></td>
</tr>
</tbody>
</table>

## Sandwiches

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salted Caramel Butterscotch Pudding</td>
<td>$1.80</td>
</tr>
<tr>
<td>Topped with house made whipped cream, chocolate cookie crumble and melon ice cream</td>
<td></td>
</tr>
<tr>
<td>Mini Trio Sampler</td>
<td>$2.70</td>
</tr>
<tr>
<td>Mini serving of our lemon souffle cake, peach apple cobbler and chocolate souffle cake</td>
<td></td>
</tr>
<tr>
<td>Mini Chocolate Souffle Cake</td>
<td>$1.20</td>
</tr>
<tr>
<td>Served warm with vanilla ice cream</td>
<td></td>
</tr>
<tr>
<td>Mini Lemon Souffle Cake</td>
<td>$1.20</td>
</tr>
<tr>
<td>With fresh raspberries and house made whipped cream</td>
<td></td>
</tr>
<tr>
<td>Macadamia Nut Cheesecake</td>
<td>$2.10</td>
</tr>
<tr>
<td>Over caramel and raspberry sauce with house made whipped cream</td>
<td></td>
</tr>
<tr>
<td>Fresh Fruit</td>
<td>$1.20</td>
</tr>
<tr>
<td>A selection of grapes, pineapple, cantaloupe and honey dew</td>
<td></td>
</tr>
</tbody>
</table>

## Beverages

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soda</td>
<td>$0.80</td>
</tr>
<tr>
<td>Small, medium</td>
<td></td>
</tr>
<tr>
<td>Coke, cherry coke, diet coke, sprite, fanta, hanky's root beer, dr pepper, seagram's ginger ale</td>
<td></td>
</tr>
<tr>
<td>Bottled Water</td>
<td>$2.39</td>
</tr>
<tr>
<td>(1) size</td>
<td></td>
</tr>
<tr>
<td>Fiji &amp; Pellegrino, Minute Maid</td>
<td></td>
</tr>
<tr>
<td>Lemonade</td>
<td>$0.70</td>
</tr>
<tr>
<td>Apple, orange, ocean spray cranberry</td>
<td></td>
</tr>
<tr>
<td>Juice</td>
<td>$0.70</td>
</tr>
<tr>
<td>Milk</td>
<td>$0.70</td>
</tr>
<tr>
<td>1% milk</td>
<td></td>
</tr>
</tbody>
</table>

**Contains (or may contain) nut or unknowned ingreidents. Consuming raw or undercooked meats, poultry, seafood, shellfish or eggs may increase your risk of food borne illnesses, especially if you have certain medical conditions.**

---

**Email:** bostondining617@gmail.com  
**Phone:** (617) 384-0613
Chapter 7. Summary, Conclusion and Recommendations for Future Research

This dissertation research evaluated a proposed public health policy aimed at limiting the portion size of SSB in food service establishments and thereby reducing consumption of SSB. The research strategy adopted a totality of evidence approach (Sherman, 2017; Center for food safety and Applied Nutrition, 2009) and sought to evaluate the available evidence in the scientific literature, along with results from an experimental study and real-world evidence study. The dissertation presents a synthesis of this evidence in the form of three independent manuscripts; a scoping review mapping out obesity prevention efforts in young children, and empirical evidence generated from two studies using different study designs, study populations and research settings. The first study, “The Real-world SSB Limit Policy Study” (Real-world Study) leveraged a natural experiment and examined the impact of a 16 oz SSB portion cap policy in large sporting arenas during professional men’s and women’s basketball games. While the SSB Portion Limit Dining Lab RCT (Dining Lab RCT) examined the effectiveness of the SSB portion cap policy using a randomized study design in a dining laboratory setting. Each component of this dissertation provides complementary evidence intended to fill the evidence gaps and inform SSB portion size policy implementation decisions.
Manuscript one, “Early childhood obesity prevention efforts through a life course health development perspective: A scoping review,” presented a broad overview of current obesity prevention efforts across the early life course and multiple levels and domains of influences. The review specifically focused on identifying obesity prevention efforts in children six years old given that the prevalence of obesity increases considerably once children start to attend elementary school and continues to increase through adulthood (Hales, Fryar, Carroll, Freedman, & Ogden, 2018a). The existing evidence from obesity prevention interventions, regional programs, and policy studies were mapped and we found that very few studies examined community and societal public health policy initiatives. The largest body of policy evidence was generated from SSB portion cap simulation model studies that consistently predicted that such a policy would reduce SSB consumption and thus be an effective public health strategy to promote healthier beverage choices. Overall, the scoping review reinforced the benefits of intervening early in the life-course to influence eating behaviors, food choices, establish social norms to modify the trajectory of health. Furthermore, the scoping review importantly identified critical knowledge gaps in food policy research and underscored the importance of substantiating the effectiveness of obesity prevention public health policies.

Following the scoping review, a conceptual framework was developed illustrating the underlying mechanism by which a portion size restriction policy prevents overconsumption of SSB and hinders an energy imbalance. The
framework was adapted from Steenhuis and Vermeer’s portion size framework of intervention opportunities for reducing portion sizes and energy intake (Steenhuis & Vermeer, 2009). Its development was further informed by the scoping review and a subsequent review of the portion-size policy literature. This framework theorizes that multiple levels (Individual, interpersonal, community and societal) and domains (behavioral, physical and socio-cultural environment) of influence, comprised of distal and proximal modifiable factors, interact and play a role in the availability, affordability, and accessibility of SSB, and influence SSB consumption patterns (Hunter et al., 2018; Leng et al., 2017; Maas et al., 2012).

The Real-world Study, evaluated a natural experiment and successfully demonstrated the effectiveness of a 16 oz SSB portion cap policy in a real-world setting. The study cross-sectional observational study was conducted at two sporting arenas in the NYC area and took advantage of a 16 oz SSB portion size cap that was voluntarily implemented at Barclays while MSG (the comparison arena) did not impose any portion-size restriction. Results generated from non-randomized controlled designed studies have been ranked as lower quality evidence compared to results from an RCT (Guyatt et al., 2011). Considering that this study is the only real-world study examining an SSB portion cap restriction, these data provide policymakers with persuasive real-world evidence of the portion size effect in a large arena and the results
may be generalizable to other similar sporting arenas (Green & Glasgow, 2006; Burford et al., 2012).

In contrast, the Dining Lab RCT, utilized a randomized, single-blinded study design, recruited local community members, and was conducted in a highly controlled environment in an eating behavior and restaurant dining lab. Nevertheless, the Dining Lab RCT failed to confirm the causal effect of 16 oz SSB portion cap restriction on reducing caloric intake from SSB at a dinner meal. Importantly, this study identified that offering free SSB refills with smaller-sized SSB may reduce the corresponding SSB portion size cap effect.

There are several explanations for the conflicting findings related to the effectiveness of an SSB portion cap restriction shown in the Dining Lab RCT and the Real-world Study. The primary reason for these divergent results is likely due to the early discontinuation of the Dining Lab RCT study. This event produced a primary outcome analysis that was underpowered due to the smaller than required number of study participants. Although an examination of the trends in the adjusted marginal means for total SSB kcals ordered and consumed revealed that caloric values were consistently, numerically higher for the current restaurant SSB portions compared to 16 oz SSB portion cap condition, and for the free refill conditions compared to the option to purchase refills, these patterns were not statistically significant. These trends in the expected direction provide preliminary evidence suggesting that the outcome
of a larger, properly powered SSB portion cap restaurant dining study may be very different.

Another possible explanation for the conflicting findings may be that although both studies applied behavioral economic theories, they may not have been equally impacted by the status quo bias. Both studies assume that when consumers are faced with a decision, they predictably choose the status quo alternative (Samuelson & Zeckhauser, 1988). Samuelson argued that in a controlled experiment the participants are less aware that there is a choice; therefore, the status quo choice may be stronger in real-world setting compared to a randomized controlled study.

A complementary explanation for the different study results is that the choice to purchase and consume a beverage in a restaurant setting versus at a sporting arena is differentially influenced by independent external psychological, physical and socio-economic factors. While little is known about the mechanism of food choice decisions at sporting events (Smith, Signal, Edwards, & Hoek, 2017), it is possible that the volume of SSB consumed in the Real-world Study was moderated by unmeasured external factors present during the basketball games, at a sporting arena. Thus, portion size effect in the Real-world Study uniquely reflects distal-level influences (e.g., changes to the beverage portion options at the point-of-purchase) on individual event-goes present within the arena’s physical and sociocultural environment (Cohen & Lesser, 2016). Other examples of potential moderators of SSB choice and
consumption in a sporting arena include: societal influences such as attitude towards SSB and beliefs about the appropriateness of smaller-sized SSB sold at sporting events, or as a new social norm; priming through subtle exposure to SSB advertisements within the stadium (Thaler, 2008) and a “proximity effect” (Hollands et al., 2019) produced by the stadium’s physical facility, whereby the far distance between the SSB concession stand and the spectator’s seat presents a physical and psychological deterrent and a disincentivize to purchase food and beverages, especially if it means missing out on an opportunity to watch the basketball match.

In contrast, in the Dining Lab RCT unmeasured proximal behavioral moderators may have exerted a stronger influence on the participant’s dinner meal and beverage choice, along with the decision to purchase SSB refills. For example, beliefs about beverage choice intentions prior to ordering, and the participants control over healthy eating habits may have contributed to beverage choice and the participants subsequent decision to order an SSB refill (Ajzen, 1991). Thus, the contribution of any number of unmeasured distal factors in the Real-world Study and proximal factors associated with the Dining Lab RCT is unknown and provides an alternative explanation for the discordant results found between these studies.

A further probable explanation for the inconsistent findings may have been related to the different types of social interactions that typically occur in a restaurant setting compared to a sporting arena. Food choice and how much
food is consumed are influenced by the ambience and social context of a meal, with larger meals consumed by customers exposed to more desirable ambience, and while in the presence of others (De Castro, 1997; Seo, 2020; Stroebele & De Castro, 2004; Weber, King, & Meiselman, 2004). In the Dining Lab RCT participants were seated alone and ate their meals alone in a quiet environment. Conversely, in the Real-world Study, the physical surrounding was a loud sporting arena full of distractions. Although, the social context of the arena-goers is unknown, it is plausible that most of the participants were not seated alone at the sporting events.

**Conclusion**

There is unanimous agreement among national (ODPHP, 2018; The National Institute for Health and Care Excellence, 2015) and international (WHO, 2015) organizations and the scientific community (AMA, 2017; Fidler Mis et al., 2017; Obesity Society, 2018) of the individual and societal health benefits of reducing SSB consumption. The evidence from this body of work, combined with previous simulations and behavioral studies provides credible support for the potential effectiveness of a public health policy limiting the portion size of SSB and improving SSB consumption behaviors. The results of this dissertation highlight the importance of generating confirmatory scientific evidence, along with conducting complementary evaluations of the
effectiveness and scalability of an SSB portion cap policy in a variety of populations and settings.

**Recommendations for Future Research**

SSB portion cap policy research is an understudied discipline and there is a critical need to fill in the gaps in the scientific evidence. At the most basic level, the contradictory results from this dissertation research highlight the need to conduct a dining SSB portion cap lab RCT in an adequately powered study sample. A future Dining Lab RCTs could also be expanded to quantify the impact of social, psychological, behavioral and environmental moderators of SSB choice, SSB consumption and portion size control in a restaurant setting.

This dissertation identified several relevant areas of concern and SSB policy-related research questions that required further study (IOM, 2010). First, the findings of the Real-world SSB limit study should be replicated and the generalizability of the results should be explored. Future follow-up studies could be designed with a dual focus:

1) to gain a better understanding of typically eating behaviors and moderators of SSB choice and consumption in sporting arenas

2) to examine the broader strength of an SSB portion-size effect in other real-world sporting arenas, across a variety of geographically locations and participant populations
For example, studies could also be conducted in various age-groups and across a variety of socio-economic backgrounds to investigate if there are individual-level or community-level differences in an SSB portion-size effect at sporting events held at local high schools, community and state-wide tournaments or even minor league baseball games.

Second, there is a notable lack of policy evaluations conducted using natural experiments. Data from natural experiments is highly desirable and provides researchers and policy makers with useful real-world evidence to support the assessment of the effectiveness of a public health policy. Future research studies could examine the effectiveness of an SSB portion size restriction in a real-word restaurant or food-service establishment using “administrative data”, collected for business bookkeeping purposes instead of for research, such as customer bills, sales records, wholesale purchases data, along with commercial point-of-sale or proprietary retail scanner data (National Academies of Sciences, Engineering, and Medicine, 2020).

Potential settings for a natural experiment could be a set of similar restaurants offering unique portion sizes of SSB; alternatively, a before and after study conducted in a restaurant or restaurant chain that has undergone a change in the portion size of the SSB listed on the menu. The research study could be designed to examine the respective SSB portion size effect by comparing customer SSB sales and wholesale purchasing data as outcome measures.
It would also be beneficial to gain a better understanding of stakeholder perception and acceptance of portion size restriction policies. Although we did not identify an association between an SSB portion limit conditions and customer/ event satisfaction, the NYC sugar-beverage portion size cap regulation was highly controversial and was met with strong opposition from residents and businesses who objected to creating a “nanny state” (IOM, 2010). Qualitative research studies could be conducted to develop a thorough understanding of the perspective of the stakeholders and acceptable of the SSB portion limit policy, along with the rationale behind all major objections. This information would assist policy makers to develop strategies for a successful implementation of such a policy.

Several additional future research topics include, examining the impact of social context on the effectiveness of SSB portion size limit; identifying the most cost-effective SSB portion cap size (i.e., 12 oz, 16 oz, 20 oz) and quantifying the cost of implementing the respective SSB portion limit policy; and identify and study the counteracting effects of marketing promotions and price promotions on SSB consumption in real-world settings. Finally, future research should utilize a multi-component approach and examine the effectiveness of an SSB portion cap study in combination with other public health initiatives aimed at reducing consumption of SSB, such as combining an SSB portion size cap with nutritional labels or posting the caloric value of SSB on restaurant menu and menu boards.
References


Barlow, S. E. (2007). Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent...


Crino, M., Sacks, G., & Wu, J. (2016). A Review of Population-Level Actions Targeting Reductions in Food Portion Sizes to Address Obesity and


Hu, F. B. (2013). Resolved: there is sufficient scientific evidence that decreasing sugar-sweetened beverage consumption will reduce the prevalence of obesity and obesity-related diseases. *Obes Rev, 14*(8), 606-619. doi:10.1111/obr.12040


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Comparison with Previous Studies. *Obes Facts*, 10(6), 674-693. doi:10.1159/000484566


Sherman RE, Davies KM, Robb MA, Hunter NL, Califf RM. Accelerating development of scientific evidence for medical products within the


consumption in a meal-testing environment. *Appetite, 42*(1), 115-118. doi:10.1016/j.appet.2003.10.001


doi:10.1016/j.amepre.2018.02.017