Title

Relationship Between Sugar Sweetened Beverage Consumption and Academic Performance Among Elementary and Middle School Children

Author

Haftoglou, Soultana

Publication Date

2015

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA

Los Angeles

Relationship between sugar-sweetened beverage consumption and academic performance among elementary and middle school children

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Public Health

by

Soultana Haftoglou

2015

ABSTRACT OF THE DISSERTATION

Relationship between sugar-sweetened beverage consumption and academic performance among elementary and middle school children

by

Soultana Haftoglou

Doctor of Philosophy in Public Health

University of California, Los Angeles, 2015

Professor May C. Wang, Co-Chair

Professor William J. McCarthy, Co-Chair

Background: Sugar-sweetened beverage (SSB) consumption has markedly increased in the last three decades among U.S. children and adolescents aged 2-18 years. The health effects of SSBs have mostly been examined in the context of obesity, and other metabolic disorders but little is known about how SSBs affect cognitive function. Evidence from animal and human studies suggests that high-fructose corn syrup and sucrose, found in large quantities in SSBs, may have adverse effects on the hippocampus, the learning and memory center of the brain. Nutritional insults to the hippocampus impair cognitive function and may negatively affect children's academic performance (AP). **Purpose:** The objectives were to examine the association between SSB consumption and AP in school-aged children, and identify modifiable food-related family behaviors associated with high SSB consumption.

Methods: Data were obtained from an evaluation of a district wide multi-component school-based intervention which followed 238 fourth and fifth grade students annually from 2006 to 2009. Repeated measures analysis using mixed-effects models was conducted to examine the association between SSB consumption and AP measured by Math and English test scores; race, gender, grade level, mother 's education, mother's employment, intervention level and physical activity were controlled for. Mediation analysis was conducted to determine if family meal behaviors, namely the frequency with which children assist in meal preparation and have dinner with their family, mediate the association between socio-demographic variables and SSB consumption. **Results:** SSB consumption was inversely associated with English z-score ($p<0.05$); for every 24-ounces of soda consumed per day, English z-score decreased by 0.19 standard deviation units (3-4% of the mean). African American children had dinner together with their family less frequently than White children ($p<0.01$) and that as frequency of eating family dinner increased, SSB consumption decreased ($p<0.05$ among African Americans). Furthermore, African-American children assisted with meal preparation significantly more frequently than White children ($p<0.01$) but assisting with meal preparation was not significantly related to SSB consumption. **Conclusion**: SSB consumption is inversely associated with English but not math test score. The association between sociodemographic characteristics and SSB consumption is partially mediated by family meal behaviors. Future studies should explore how SSB consumption may affect cognitive function throughout the life-course and provide a clearer understanding of the biological mechanisms by which SSB consumption may influence AP.

The dissertation of Soultana Haftoglou is approved by:

Ondine S. von Ehrenstein

Charlotte G. Neumann

Catherine M. Crespi

Thomas S. Weisner

William J. McCarthy, Committee Co-Chair

May C. Wang, Committee Co-Chair

University of California, Los Angeles

2015

DEDICATION

To my father, whose gentleness has been a great source of inspiration for me!

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

ACKNOWLEDGEMENTS

This journey would not have been possible without the support and encouragement of family, friends, colleagues and everyone who believed in me! I would like to first thank my multi-disciplinary committee, Drs. May Wang, Bill McCarthy, Ondine von Ehrenstein, Charlotte Neumann, Kate Crespi and Tom Weisner for their expertise and insightful comments that challenged me and helped me think outside of the box. I feel fortunate to have had such a supportive committee - you have all been a great source of encouragement and inspiration and have each helped carve my professional path in a special way. I would also like to extend a special thank you to the statistical consulting team at the UCLA Academic Technology Services, particularly to Drs. Andy Lin and Joni Ricks, for their eternal patience in assisting me with data management and analysis.

To my wonderful friends and colleagues, who were there for me during challenging times to wipe the tears away, give comforting hugs, and encourage me to keep my chin up and proceed with grace - this would not have been possible without your love and support and I am eternally grateful for your true friendship! You all know who you are but just to name a few: Tabashir Nobari, Taline Marcarian, Mellissa Withers, Jenny Ramirez, Amy Wang, Hannah Husby, Erin Murphy, Demetra Bastas, Wayna Cariaga, Dr. Wolf, Jen Gough, Carmen Ayala and Maribel Martinez. Lastly, a very special thank you to my loving parents and my brother who have been putting up with me and my aspirations for a long time and have supported me every step of the way!

CURRICULUM VITAE

Education

1999-2001	MPH, Epidemiology, University of Illinois at Chicago
1992-1996	B.S., Biology, University of California in Irvine

Professional Experience

2013-present	Health Consultant, USC Early Childhood Education Center
2013	Teaching Assistant for course in Contemporary Health Issues, UCLA Fielding School of Public Health, Department of Epidemiology
2013	Teaching Assistant for course in Anatomy & Physiology, UCLA School of Nursing
2010	Health Educator, Network for a Healthy California, UCLA Fielding School of Public Health
2009-2010	Program Coordinator, Healthy Habits Youth Mentoring Program, Cedars-Sinai Medical Center
2008-2010	Health Educator and Promotora Trainer, UCLA Department of Family Medicine
2007-2009	Research Assistant, UCLA Fielding School of Public Health, Department of Health Services
2007	Graduate Student Researcher, UCLA, Department of Community Health Sciences
2002-2004	Research Assistant, University of Salamanca, Department of Public Health and Preventive Medicine

Publication (Peer-reviewed)

Toth Z, Yan XX, Haftoglou S, Ribak CE, Baram TZ. Seizure-induced neuronal injury: vulnerability to febrile seizures in an immature rat model. J Neurosci. 1998 Jun 1;18(11):4285-4294.

Presentations

2009	Plenty of fish in the sea, but are they safe enough to eat? The benefits of omega-3 supplementation. Poster presentation. American Public Health Association annual meeting.
2008	The Mediterranean diet paradox; a systematic review of childhood obesity trends among European Mediterranean countries. Oral presentation. American Public Health Association annual meeting.

Chapter 1. INTRODUCTION

Description of the problem

Sugar-sweetened beverage (SSB) consumption has markedly increased in the last three decades among children and adolescents ages 2-18 years living in the United States. Between 1977 and 2001, energy intake from SSBs more than doubled in this age group (Popkin and Nielsen 2003; Nielsen and Popkin 2004; Wang, Bleich et al. 2008; RWJF 2009). Recent data from the National Health and Nutrition Examination Survey (NHANES) for 2009-2010 indicate that children and adolescents consume on average, 155 calories (12-14 ounces) per day from SSBs, making up about 8% of their daily caloric intake (Kit, Fakhouri et al. 2013). More specifically, adolescents ages 12-19 have the highest SSB intake (more than 10% of daily caloric intake), compared to any other age group (Kit, Fakhouri et al. 2013).

The high consumption of SSBs by children and adolescents has raised concern in light of the obesity epidemic as diets high in added sugar have been associated with increased risk of obesity in numerous studies (Malik, Pan et al. 2013; Te Morenga, Mallard et al. 2013). The health outcomes examined in relation to SSB consumption have included obesity (DeBoer, Scharf et al. 2013; Emond, Patterson et al. 2013; Te Morenga, Mallard et al. 2013), heart disease (Ambrosini, Oddy et al. 2013; de Koning, Malik et al. 2012; Fung, Malik et al. 2009), diabetes (Malik, Popkin et al. 2010; Schulze, Manson et al. 2004), gastrointestinal distress (Jones, Butler et al. 2013; Beyer, Caviar et al. 2005), fatty liver disease (Bray 2013; Maersk, Belsa et al. 2012), and other metabolic disorders (Aeberli, Hochuli et al. 2013; Kosova, Auinger et al. 2013; Le, Frye et al. 2012; Aeberli, Hochuli et al. 2011) among both children and adults.

In making dietary recommendations for children and adults ages 2 years and older, the *Dietary Guidelines for Americans* 2010, the Institute of Medicine's (IOM) Healthy People 2020, the American Heart Association (Lloyd-Jones, Hong et al. 2010; Gidding, Lichtensein et al.

2009) and the American Academy of Pediatrics (Gidding, Dennison et al. 2006) recommend that intake of added sugars should be limited. In the *Dietary Guidelines for Americans* 2010, added sugars are defined as "caloric sweeteners that are added to foods during processing, preparation, or consumed separately", including sucrose (table sugar), high-fructose corn syrup (HFCS), honey, molasses, and other syrups (Bray, Nielsen et al. 2004). In 2009, the American Heart Association (AHA) published for the first time, specific recommendations limiting the amount of added sugars consumed daily by children and adults (Johnson, Appel et al. 2009). The AHA statement suggested that daily intake of added sugars should be limited to 6 teaspoons for women, 9 teaspoons for men, and 3-5 teaspoons for children. As a reference, a 12-oz serving of soda (~150 calories) contains about 10 teaspoons of sugar so the added sugar from this drink alone is at least double AHA's recommended daily amount for children. Although many food items that are consumed daily contain added sugars, including desserts and sugary snacks, cereals, bread and yogurt, SSBs are the largest single source of added sugars in the American diet (Lakhan and Kirchgessner 2013; Gross, Ford et al. 2004; Tappy, Le et al. 2010; Bray, Nielsen et al. 2004; Marriott, Olsho et al. 2010; Popkin, Armstrong et al. 2006).

SSBs include sodas, fruit-flavored drinks (excluding 100% fruit juice), sports drinks, energy drinks, sweetened tea, soy/rice/bean drinks, and other non-alcoholic beverages that contain added sugars (Wang, Bleich et al. 2008). In fact, almost all the calories in SSBs come from added sugars. The sugar in SSBs is composed of almost equal parts glucose and fructose, generally in the form of HFCS or sucrose. In the United States, HFCS is the sweetener of choice in most SSBs (Popkin and Nielsen 2003; Bray, Nielsen et al. 2004; Ludwig 2009).

Because fructose metabolism is a less efficient process than glucose metabolism (Tappy and Le 2010), it has been suggested that excessive intake of fructose may result in metabolic perturbations contributing to adverse chronic health effects observed to be related to high consumption of SSBs (Tappy, Le et al. 2010; Hochuli, Aeberli, et al. 2014; Aeberli, Hochuli et al. 2011; Vos and Lavine 2013). In addition, there is growing evidence from experimental animal studies indicating that high intake of fructose may also result in cognitive impairment of the hippocampus, the memory center of the brain (Stranahan, Norman et al. 2008; Tappy, Le et al. 2010; Stephan, Wells et al. 2010; Page, Chan et al. 2013). Among U.S. children ages 4-18, the major source of fructose is SSBs (Marriott, Cloe et al. 2009; Jones, Butler et al. 2013), leading some researchers to suggest that high SSB consumption may adversely affect cognitive function (Agrawal and Gomez-Pinilla 2012), and consequently, academic performance (AP) in American children and adolescents. However, to-date, little is known about the effects of SSB consumption on AP in children.

While normal cognitive function is essential for learning, it is important to note that AP is also influenced by sociodemographic factors such as race/ethnicity, and parent's education level and employment status (Crosnoe and Schneider, 2010; Baum 2004; Muller, Riegle-Crumb et al. 2010; Riegle-Crumb 2006; Rushton and Jensen, 2006; Kao and Thompson 2003; Weis et al. 2013; Childs and McKay 2001). For example, children from lower socioeconomic status (SES) and some ethnic minority families tend to perform less well academically (Garcia Bacete and Rosel Remirez 2001; Crosnoe and Schneider 2010; Muller,Riegle-Crumb et al. 2010; Riegle-Crumb 2006; Rushton and Jensen, 2006; Kao and Thompson 2003). Lower SES families tend to have fewer financial resources and more limited social networks (Garcia Bacete and Rosel Remirez 2001; Crosnoe and Schneider 2010; Dominguez and Watkins 2003), which may decrease learning opportunities and compromise student AP (Bradley and Corwyn 2002).

SES and race/ethnicity are associated not only with AP but also with SSB consumption, with children from lower SES and/or ethnic minority families having a higher mean consumption of SSBs (Ogden, Kit et al. 2011; Park, Sherry et al. 2012; Richmond, Spadano-Gasparro et al. 2013; Totland, Lien et al. 2013; Wijtzes, Jansen et al. 2013; Han and Powell 2013; Kit, Fakhouri et al. 2013; Beck, Patel et al. 2013). Hence, any investigation of the contribution of SSB consumption to AP must consider the potential confounding effects of sociodemographic factors. Further, any effort to design a behavioral intervention to reduce SSB consumption among lower socioeconomic and ethnic minority children must identify behavioral factors amenable to change; one such factor is family meal behaviors.

The literature suggests that family meal behaviors, such as how frequently children assist with meal preparation and have dinner with their family, greatly influence children's SSB consumption (Larson, Story et al. 2006; Larson, Neumark-Sztainer et al. 2007; Larson, Fulkerson et al. 2013). Specifically, greater involvement in meal preparation (Larson, Story et al. 2006) and higher frequency of family dinner (Larson, Neumark-Sztainer et al. 2007; Larson , Fulkerson et al. 2013) are associated with lower SSB consumption. Moreover, studies have reported racial/ethnic and SES differences in family meal behaviors including less frequent family meals among lower income families compared to higher income families (Neumark-Sztainer, Hannan et al. 2013). While examining the association between sociodemographic factors and SSB consumption is useful in identifying children at risk of increased SSB consumption, what is lacking in the literature is a better understanding of how family meal behaviors may explain how these racial/ethnic and SES differences in SSB consumption arise. From a public health perspective, it is essential to examine the potential mediating effects of family behaviors in the association between sociodemographic factors and SSB consumption in order to more effectively address high SSB consumption in lower SES and/or ethnic minority families.

Additional behavioral risk factors commonly identified in the literature to be associated with SSB consumption include diet quality (Yamada, Murakami et al. 2008; Ranjit, Evans et al. 2010; Collison, Zaidi et al. 2010; Mathias, Slining et al. 2013), physical activity (Ranjit, Evans et al. 2010; Chen and Wang, 2013) and TV watching (Olafsdottir, Eiben et al. 2013; Barr-Anderson, Larson et al. 2009). Children who have a higher quality diet rich in fruits and vegetables (Yamada, Marakami et al. 2008) and low in unhealthy snacks (Ranjit, Evans et al. 2010; Collison, Zaidi et al. 2010; Mathias, Slining et al. 2013), have a lower intake of SSBs. Further, it has been suggested that children with lower levels of physical activity (Ranjit, Evans et al. 2010; Chen & Wang, 2013) and higher levels of exposure to television (Olafsdottir, Eiben et al. 2013; Barr-Anderson, Larson et al. 2009) may have higher consumption of SSBs. Because these behavioral factors have also been found to be associated with AP **(**Taras, 2005; Florence, Asbridge et al. 2008; Davidson, Hargrave et al. 2013; Roberts, Freed et al. 2010; London and Castrechini, 2011; Donnelly and Lambourne, 2011; Coe, Peterson et al. 2013; Shin 2004; Kirkorian, Wartella et al. 2008; Schmidt and Vandewater, 2008; Johnson, Cohen et al. 2007**)** their potential confounding effects should be considered when examining the association between SSB consumption and AP.

Purpose of the study

The motivation for this study stems from reports of poor AP among children of lower SES and ethnic minority families, particularly African American and Latino (Garcia Bacete and Rosel Ramirez 2001; Crosnoe and Schneider 2010; Muller, Riegle-Crumb et al. 2010; Riegle-Crumb 2006; Rushton and Jensen 2006; Kao and Thompson 2003), and research showing that SSBs may have detrimental effects on the hippocampus (the memory center of the brain) resulting in impaired cognitive function (Page, Chan et al. 2013; van der Borght, Köhnke et al. 2011; Djordjevic, Bursać et al. 2013; Francis and Stevenson 2013).

This is one of the first studies to investigate the relation between SSB consumption and AP in elementary and middle school children while controlling for potential confounders, namely, parent's education, race/ethnicity, family meal behaviors, overall diet quality and physical activity. Using data from a three-year evaluation study of a district wide multi-approach school nutrition intervention implemented from 2006 to 2009, this study aims to:

1) Examine the association between SSB consumption and academic performance in 238 fourth and fifth graders who were unevenly exposed to a nutrition intervention; and

2) Identify modifiable food-related family behaviors associated with high SSB consumption in children.

Dissertation overview

Following this introductory chapter, Chapter 2 provides a review of the literature on SSB consumption, cognitive function, AP, and their correlates; presents the research questions and hypotheses that were investigated in this study; and highlights biological mechanisms by which sugar metabolism may influence cognitive function and AP. Chapter 3 describes the study design, the methods used to collect the data and the analytic approach to address the research questions and hypotheses. Chapter 4 reports the results for this study including repeated measures and mediation analyses. Lastly, Chapter 5 discusses the main findings and public health implications of the study.

Chapter 2. LITERATURE REVIEW

This chapter begins with a historical background of the development of SSBs and an overview of SSB consumption trends. It then presents a critical evaluation of the research on the effects of SSB consumption on cognitive function and academic performance (AP) followed by a discussion on plausible biological mechanisms indicating how sugar metabolism may influence cognitive function and AP. The chapter concludes with an examination of the current knowledge of social and behavioral factors associated with SSB consumption and AP and a presentation of this study's research questions and hypotheses.

Historical perspectives of SSB consumption

The history of SSBs has its roots in natural mineral waters which have been praised for their healing powers for thousands of years (Wolf, Bray et al. 2008; Petraccia, Liberati et al. 2006). Natural mineral waters were perceived to be of superior quality due to their mineral content and natural carbonation, which were believed to aid in healthy digestion (Petraccia, Liberati et al. 2006). In the U.S., as doctors began to prescribe natural mineral waters for their reputed medicinal properties, pharmacists and chemists were looking for ways to re-create these carbonated waters in the lab and in the 1760s the first imitation carbonated beverage (soda) was developed (Wolf, Bray et al. 2008; Riley 1958). By the 1830s, fruit and herb flavors, along with sugar, were added to these carbonated drinks to enhance their palatability; these drinks were widely sold at pharmacies equipped with soda fountains (Wolf, Bray et al. 2008; Riley 1958). Soda fountains became even more popular during the prohibition era as many people turned to soda as an alternative to alcohol (Hiatt, Sine et al. 2009). In 1886, an American pharmacist produced a soda fountain syrup by combining two stimulants, the coca leaf containing cocaine and the kola nut containing caffeine, and Coca-Cola was created and consequently promoted as a brain tonic (Wolf, Bray et al. 2008). During these early years, soda was considered a novelty treat reserved for special occasions or therapeutic uses.

It was not until 200 years after the invention of soda that sports and energy SSBs came into existence. The first sports drink, Gatorade, was developed in 1965 to replenish water and electrolytes that college athletes lost in sweat during vigorous exercise, particularly in hot weather (Galaz 2013). The latest addition to the plethora of already existing SSBs is energy drinks which generally contain multiple stimulants, including caffeine; the effects of such drinks have not been studied in children. Red Bull was the first energy drink to make it to the U.S. market in 1997 (Galaz 2013) and has been promoted as a beverage that enhances mental alertness and boosts energy. Through persuasive marketing strategies, sports and energy drinks have become increasingly popular among children and adolescents since their inception (Committee on Nutrition and the Council on Sports Medicine and Fitness, 2011).

Traditionally, beet or cane sugar was used to sweeten SSBs. In the early 1970s, as the price of sugar was increasing, high fructose corn syrup (HFCS) was commercially introduced to the U.S. food and beverage industries (Warner 2011). HFCS could be produced cheaply through a refinement process of corn sugar so it began to be increasingly used in SSBs. Currently, almost all SSBs are made with HFCS (Welsh, Lundeen et al. 2013; Bray 2010; Popkin and Nielsen 2003; Ludwig 2009). Since the advent of HFCS, beverage manufacturers have been able to provide larger portion sizes at lower cost to value-driven consumers (Welsh, Lundeen et al. 2013). The average portion size of SSBs in the 1950s was 6.5 ounces (Jacobson 2005). After the introduction of HFCS in the 1970s it more than doubled to 13.6 ounces; by the 1990s it was 21 ounces (Welsh, Lundeen et al. 2013; Nielsen and Popkin, 2004) and currently 64-ounce SSBs are widely available (Young and Nestle 2003). Between 1977 and 2001, SSB consumption increased by 135% (Nielsen and Popkin 2004), although recently, it has declined (Kit, Fakhouri et al. 2013). The increase in SSB consumption can be primarily attributed to the increased affordability, accessibility and heavy marketing of SSBs (Bray 2008; Drewnowski and Specter 2004; Story and French 2004).

According to a recent report by the Yale Rudd Center for Food Policy and Obesity (2014), in 2013, beverage companies spent $866 million in advertising for SSBs; regular soda accounted for about half of that spending, followed by energy drinks (20%), sports drinks (15%), fruit-flavored drinks (9%) and other SSBs (8%). The same report also indicated that between 2010 and 2013, beverage companies increased SSB advertising spending on Spanish-language TV by 44% and some SSBs, such as 7UP, were exclusively advertised on Spanish-language TV. In addition, brands such as Red Bull were disproportionately marketed to African American youth, who saw more than twice as many TV advertisements for SSBs than White youth. Beverage companies have been getting more creative by advertising on social media websites capitalizing on children's increasing use of computer and mobile technologies (Welsh, Lundeen et al. 2013; Harris, Schwartz et al. 2011). Furthermore, in light of the health risks associated with SSB consumption, particularly soda, beverage companies are shifting their marketing strategies to promote what they encourage the public to perceive as healthier beverage options, including fruit-flavored vitamin water, sports drinks, and caffeinated energy drinks (Welsh, Lundeen et al. 2013). Some of the effects of these marketing practices are reflected in recent statistics which indicate that although soda consumption has been decreasing among children in the last 10 years, consumption of other SSBs, such as sports and energy drinks, has increased in the same time period (Kit, Fakhouri et al. 2013). Importantly, SSB advertisements may also appeal to children's innate preference for excessive sweetness (Mennella, Finkbeiner et al. 2014).

Within the historical context of SSB consumption, it is also important to understand how children's taste preferences evolve over time and how environmental influences may help shape dietary preferences and behaviors. Prior to the domestication of animals (and using their milk for human consumption) and long before infant formula was developed, human breast milk was the only nutrient-rich and life-sustaining substance infants relied on for survival and healthy development (Short 2006). Infants are born with an innate taste preference for sweetness which creates a natural affinity for their mother's sweet-tasting milk (Mennella, Finkbeiner et al. 2014). According to Mennella et al (2014), this biologically hard-wired sweet preference gets magnified during childhood which results in heightened preference for intensely sweet foods and beverages. The authors reported that children 5-10 years of age preferred higher concentrations of sugar in water than adults. Furthermore, a study by Nickelson et al (2014), estimated that 94% of preschool children consumed flavored milk, which is considered intensely sweet since 8 ounces of chocolate milk usually contain at least 6 teaspoons (~100 calories) of sugar. Frequent exposure to intensely sweet processed foods and beverages, which are heavily marketed to children, may solidify and enhance children's preference for sweet foods and beverages, particularly SSBs, which contain large amounts of sugar.

Mennella et al (2014), further point out that ingesting something sweet activates the pleasure-generating areas of the brain, which overlap with the brain circuitry involved in drug addiction. In addition, sweet-tasting foods and beverages induce pain-reducing mechanisms that are only observed during childhood (Mennella, Finkbeiner et al. 2014). If children have greater affinity for intense sweetness, which leads to enhanced hedonic and analgesic sensations, then addiction may be a concern and should be carefully examined in future studies, as it is beyond the scope of this dissertation. In conclusion, the inherently strong preference for sweet-tasting foods that humans are born with can be further shaped by the degree to which environmental influences promote or limit access to intensely sweet processed foods and beverages. SSBs are intensely sweet (Bray 2008) and along with satisfying children's sweet tooth, they may also produce feelings of happiness and reduce pain sensations which may make them attractive thirst quenchers to children. Although taste preference is considered the most important determinant of food choices (McCarthy 2014), it may lead to poor dietary choices, particularly among children who may not have the knowledge and ability to independently make healthy dietary choices. In summary, reduced cost, increased availability and effective marketing strategies, in combination with an innate preference for excessive sweetness, have contributed to increased consumption of SSBs among children in the last three decades.

SSB consumption patterns and trends among children

SSBs generally contain little or no nutritional value (Schulze, Manson et al. 2004) and are considered empty calories derived almost exclusively from sugar in the beverage. Wang et al (2008) reported that among children and adolescents, sodas comprised more than half of all calories from SSBs and for adolescents alone, sodas made up about two thirds of all SSB consumption. Studies have consistently reported that boys consume more SSBs than girls and that SSB consumption increases with age among children ages 2-19 (Ogden, Kit et al. 2011; Kit, Fakhouri et al. 2013; Miller, Mckinnon et al. 2013). The latest data from NHANES for 2009-2010 (Kit, Fakhouri et al. 2013) indicate that among children ages 6-11, boys consumed 15% more calories from SSBs than girls (128 vs 108 calories, respectively) and among those ages 12-19, boys consumed 37% more calories from SSBs than girls (278 vs 175 calories, respectively), adjusting for total caloric intake. The American Heart Association recommends that children limit their daily intake of added sugars from all food and beverage sources to 50-80 calories. According to NHANES for 2009-2010 (Kit, Fakhouri et al. 2013), children currently consume at least 2-4 times this amount of sugar from SSBs alone.

Although recent studies report that SSB consumption has been decreasing among children since 2004 (Beck, Patel et al. 2013; Kit, Fakhouri et al. 2013; Han and Powell 2013), intake levels are still higher than recommended and racial/ethnic disparities persist, particularly among low SES groups (Beck, Patel et al. 2013; Kit, Fakhouri et al. 2013; Han and Powell 2013). In addition, while the gap in SSB consumption between White and ethnic minority children has narrowed in the last decade, intake levels among African American and Latino children continue to be greater than that of White children (Kit, Fakhouri et al. 2013). In a serial cross-sectional study using data from the 2003-2009 California Health Interview Survey, Beck et al (2013) reported that among children ages 6-11 years, Latinos (OR=1.46, 95% CI=1.18, 1.81) and African-Americans (OR=1.54, 95% CI=1.08, 2.21) had higher odds of SSB consumption, compared to Whites.

The literature further suggests that children whose mothers are less educated consume more SSBs than children whose mothers have higher levels of education (Totland, Gebremariam et al. 2013; Wijtzes, Jansen et al. 2013) and children whose mothers are employed consume more SSBs than children whose mothers are not employed (Hawkins, Cole et al. 2009; Bauer, Hearst et al. 2012; Datar, Nicosia et al. 2014). In a study by Beck et al (2013), the authors reported that children whose parents had attained a college education had lower odds of SSB consumption compared to children whose parents had less than a high school education (OR=0.66, 95% CI=0.55, 0.79). To summarize, boys (compared to girls), older children (compared to younger), ethnic minorities, particularly African Americans and Latinos (compared to Whites), children whose mothers are less educated (compared to more educated) and children whose mothers are employed (compared to not employed), consume more SSBs.

Physiologic effects of sugar on cognitive function

Glucose is the major nutrient for the brain and is the fuel used by neurons (Hover 1994). The human brain makes up approximately 2% of the body's weight yet it consumes 20-25% of the basal metabolic energy (energy expended when body is at rest) and about 50% of the total glucose that the body uses per day, making it the primary glucose consumer in the body (Peters 2011; Whitney and Rolfes 2011; Le Coutre and Schmitt 2008). A child's developing brain requires more energy than the adult brain; for example, among children ages 6-12 years, at least 30-45% of the basal metabolic energy is utilized by the brain (Le Coutre and Schmitt 2008). In general, the brain gets access to glucose after the body has digested the simple and complex carbohydrates ingested from a meal. Simple carbohydrates are simple sugars made up of one (e.g. fructose, glucose, galactose) or two sugar molecules (e.g sucrose). Complex carbohydrates are made up of chains of three or more sugar molecules and break down to glucose more slowly; examples are dietary fiber (e.g. from whole grains) and starches (e.g. from potatoes).

Globally, the sugars found in SSBs are sucrose or HFCS. In the United States today, HFCS is the main non-diet sweetener used in SSBs. Sucrose and HFCS are composed of two monosaccharides, glucose and fructose, but in sucrose the two molecules are bound together while in HFCS they are unbound (Figure 2.1) (Rizkalla 2010). Sucrose comes from cane or beet sugar and contains a 50:50 ratio of fructose to glucose while HFCS comes from corn starch and is enzymatically made into 42%-55% fructose with the remaining 45% -58% being glucose and other sugars (Rizkalla 2010). HFCS was first manufactured in Japan in the 1960s and became popular as a cheap sweetener and preservative in the United States in the 1970s (Bray, Nielsen et al. 2004; Cordain, Boyd Eaton et al. 2005). Currently, Americans consume more HFCS per capita than any other country (Goran, Ulijaszek et al. 2013). The rapid increase in the use of HFCS in the U.S. food supply has resulted in an increase in fructose consumption which has doubled over the past three decades (US Department of Agriculture-Economic Research Service 2013). Further, in the U.S., the major source of fructose in the diet is SSBs (Stanhope and Havel 2008; Tappy, Le et al. 2010).

Fructose in food is a public health concern because its consumption has been linked to metabolic conditions including obesity, dyslipidemia, type 2 diabetes and fatty liver disease (Basciano, Federico et al. 2005; Vos and Lavine 2013). It also appears to have a role in cognitive function as discussed in the following section.

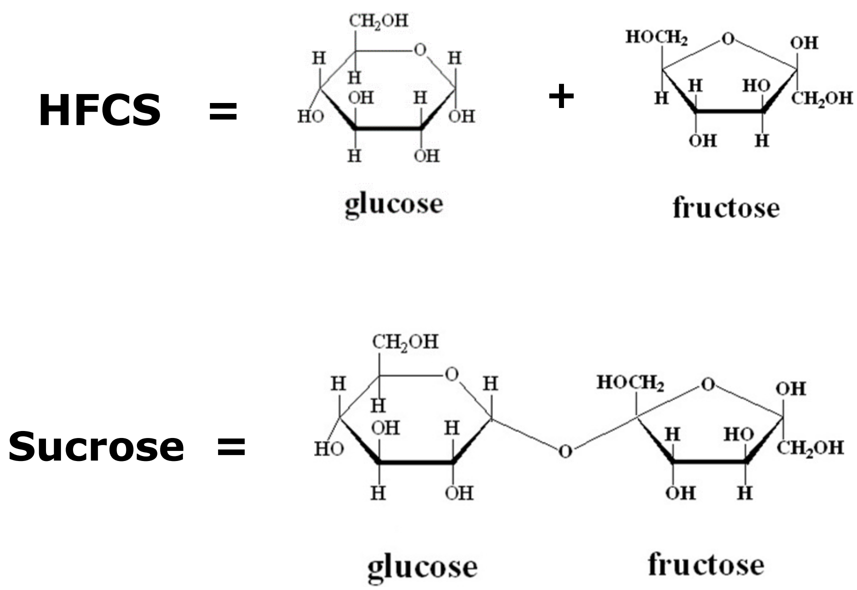


Figure 2.1: Molecular structure of HFCS and Sucrose
(HFCS is composed of unbound glucose and fructose molecules while sucrose is composed of glucose and fructose molecules bound together by an oxygen molecule)

Role of fructose metabolism in cognitive function

A major concern with the high consumption of SSBs is with the amount of fructose consumed (Wu, Giovannuci et al. 2004; Dekker, Su et al. 2010; Stanhope, Schwarz et al. 2013; Bray 2013). Fructose is naturally found in small amounts in fruits and vegetables and it is easily metabolized by the liver in small quantities along with the vitamins and enzymes that the fruits and vegetables contain (Gaby 2005; Tappy, Le et al. 2010). However, currently, the primary source of fructose among U.S. children and adolescents is SSBs (Jones, Butler et al. 2013; Marriott, Cloe et al. 2009). Specifically, data from NHANES indicate that between 1977 and 2004 the average intake of naturally occurring fructose from fruits and vegetables decreased while fructose intake from added sugars increased from 42g/day to 51g/day among children ages 7-10 years (Jones, Butler et al. 2013; Marriott, Cloe et al. 2009).

A study by Page et al (2013) examined the effects of glucose and fructose on cerebral blood flow (blood supply to the brain in a given time) among healthy adults. In this blinded cross-over study, participants were given either 75 grams (300 calories) of glucose or fructose in 10 ounces of flavored water, followed by a functional MRI to evaluate cerebral blood flow in various brain regions. The authors reported that fructose reduced cerebral blood flow in the hippocampus. These findings are striking because a 16-20 ounce SSB, such as an energy drink or soda, contains about 75 grams of sugar so the participants did not ingest an unrealistically high amount of sugar.

Although in the Page et al (2013) study the drinks contained exclusively glucose or fructose and most SSBs contain approximately equal amounts of both in the form of HFCS or sucrose, laboratory estimates of the composition of HFCS in popular drinks indicated that sodas such as Coke, Pepsi, and Sprite contained about 65% fructose and 35% glucose (Ventura, Davis et al. 2011). In concurrence, a more recent study by Walker et al (2014), replicated

Ventura's study and used three different laboratory methods to examine the sugar profile of SSBs made with HFCS and reported that many popular SSBs contained up to 63% fructose and 37% glucose. If SSBs are the leading source of added sugars in the American diet (Miller, McKinnon et al. 2013) and almost all SSBs contain HFCS, then SSBs are the major source of fructose, possibly even more so than previously estimated, since the Ventura and Walker studies highlight that many popular SSBs may contain up to 65% fructose.

Chronic reduction of cerebral blood flow to the hippocampus as a result of high fructose consumption, as indicated in the Page et al (2013) study, may result in neurodegeneration, neuronal death and memory impairment (Daulatzai 2012; Pappas, De la Torre et al. 1996). Brain chemistry alterations that may be triggered from chronic SSB consumption may result in compromised memory and AP, and may also play a role in the clinical manifestation of diseases, such as Alzheimer's, later in life (Lakhan and Kirchgessner 2013).

According to the National Scientific Council on the Developing Brain (2006), a child's developing brain is particularly susceptible to adverse impacts on the formation of its basic circuits. Hence, children's developing brains may be more vulnerable to the effects of fructose metabolism and they may be more adversely affected both in the short- and long-term if they consume excessive amounts of SSBs. According to Georgieff (2007), the brain's susceptibility to nutritional insults likely outweighs its plasticity, so nutritional insults during growth and development may still result in brain dysfunction, even after correcting that nutritional insult. In a recent review, Nyaradi et al (2013) reported that the timing of nutritional insults can significantly affect brain development especially during sensitive developmental periods. One of the critical times of brain development is during adolescence, during puberty, when brain and cognitive maturation take place, particularly, major developments in the pre-frontal cortex

(Nyaradi, Li et al. 2013; Yurgelun-Todd 2007; Steinberg 2005; Lenroot and Giedd 2006; Blakemore, Burnett et al. 2010). The pre-frontal cortex is responsible for concentration, reasoning, problem solving, attention, speed of information processing and memory retrieval (Yurgelun-Todd 2007; Steinberg 2005; Rugg, Fletcher et al. 1996) so any impairment in that brain structure would also have a negative effect on cognitive function.

Effect of fructose from SSBs on cognitive function in animal studies

Evidence for the role of fructose from SSBs on cognitive function is available from experimental animal studies, which have identified harmful brain chemistry alterations and disruption of normal function of brain structures, such as the hippocampus, as a result of being exposed to SSBs (van der Borght, Köhnke et al. 2011; Djordjevic, Bursać et al. 2013; Francis and Stevenson 2013). Specifically, rats that were chronically exposed to fructose (ranging from 10-60% fructose solution) experienced hippocampal inflammation and reduction in hippocampal neurogenesis. Animal studies can be informative in advancing understanding of brain function under diverse conditions and allow us to extend the results to humans because the rat and human brain are functionally and anatomically similar due to their comparable brain glucose consumption, controlling for brain size (Blin, Ray et al. 1991).

Effect of SSBs on cognitive function and academic performance in human studies

The animal studies discussed above suggest that fructose may affect cognitive function through several biological mechanisms. However, there is minimal evidence from epidemiologic and experimental studies to support the role of SSBs in academic performance. While SSBs are high in fructose, they have, to some extent, replaced milk as a beverage in children and adolescents. Hence, it could be argued that any decline in academic performance may be due to changes in overall diet quality or other confounding factors. To-date, only four epidemiologic studies have examined the association between SSB consumption and AP or cognitive function. Two cross-sectional studies in the U.S. reported an inverse association between SSB consumption and AP in late elementary and/or middle school children (Edwards, Mauch et al. 2011; Park, Sherry et al. 2012). Two longitudinal studies (Nyaradi, Li et al. 2013; Nyaradi, Foster et al. 2014) in Australia also found an inverse association between SSB consumption and AP when examining SSB consumption as part of overall diet quality in a cohort of children that were followed from birth to age 17. Edwards et al. (2011), reported that among 800 sixth-grade students, those who consumed less than or equal to 12 ounces of SSBs per day had significantly higher mean math and reading standardized test scores compared to those who consumed more than 12 ounces of SSBs per day, after controlling for important covariates, such as gender, SES, TV watching and physical activity. Unlike the Edward's study that used a smaller sample from one school district in Texas, Park and colleagues used a larger and nationally representative sample of 16,000 US high-school students who participated in the national Youth Risk Behaviors Survey. They found that drinking soda at least once a day was associated with poorer self-reported grades even after adjusting for potential confounders such as race/ethnicity, milk and 100% juice intake, fruit and vegetable consumption, TV watching, physical activity and sleep duration. Specifically, compared to students who reported receiving mostly As, those receiving mostly Bs, mostly Cs, and mostly D/Fs had 1.26 (CI=1.08, 1.47), 1.66 (CI=1.38, 1.99) and 2.19 (CI=1.67, 2.87) higher odds of consuming soda, respectively. While Edwards et al. examined a variety of SSBs, Park et al. only evaluated soda consumption, may not accurately reflect the magnitude of SSB consumption because the literature reports that although soda consumption may be decreasing, consumption of other SSBs is increasing among youth (Han and Powell 2013; Kit, Fakhouri et al. 2013). Furthermore, both of these studies dichotomized SSB consumption which limits understanding of the variation of SSB consumption.

While the two cross-sectional studies examined SSB consumption independently, the two longitudinal studies examined it as part of a diet quality index (Nyaradi, Hickling et al. 2013) or pattern (Nyaradi, Foster et al. 2014). In the first study, Nyaradi et al (2013) found that among a birth cohort of 2,868 children, there was a significant inverse association between SSB consumption during the first year of life and cognitive outcomes (assessed via picture vocabulary and nonverbal reasoning ability tests) at age 10, after adjusting for a range of potential confounding factors including sociodemographic characteristics, language stimulation at age three and maternal mental health distress. In the second study, the same authors found that a Western diet, which included high intakes of SSB consumption, at age 14 was associated with poorer levels of cognitive performance (measured via computerized cognitive assessments) at age 17, after adjusting for gender, total energy intake, maternal education, family income and father's presence in the family. Measures of AP varied across the four studies; three used objective measures such standardized tests and computerized cognitive tests while Park et al used self-reported grades, which may not accurately represent children's AP. Lastly, the findings of these four studies indicate that SSB consumption may have short- and long-term effects on cognitive function and those effects should be further explored in order to gain better understanding of the mechanisms by which SSB consumption may influence cognitive function.

Conceptual framework for understanding the effect of SSB consumption on AP

The scant literature examining the association between SSB consumption and AP does not offer any explanation for how SSB consumption may affect AP. There are various plausible mechanisms by which SSB consumption may directly or indirectly influence cognitive function and, consequently, AP. The proposed conceptual framework uses established biological theory and empirical evidence to delineate biological mechanisms by which sugar metabolism in the brain and body may influence cognitive function. These mechanisms include: (1) disruption of energy homeostasis as a result of high blood sugar levels; (2) metabolic dysfunction as a result of fructose overloading the liver and contributing to fatty liver disease; and (3) chronic low-grade inflammation as a result of high intake of glucose and fructose, and are discussed in the following paragraphs.

Energy homeostasis

The brain functions optimally when it receives a slow and constant supply of glucose, its principal metabolic fuel (Dwyer 2002). Any imbalance in the glycemic flow (resulting in too high or too low blood glucose levels) may disrupt energy homeostasis and brain function (Bellisle 2004). SSBs contain a high carbohydrate (sugar) content in liquid form so they are consumed and digested at much faster rates than solid food (de Graaf 2011; de Koning, Malik et al. 2012). What this means is that the body may be exposed to large quantities of sugar in a short amount of time resulting in a rapid increase in blood glucose levels. The effect of a food on blood glucose levels is better understood in the context of glycemic index and glycemic load.

The glycemic index (GI) of a food indicates how quickly its consumption raises blood sugar levels. It is measured by taking a portion of a particular food item that contains 50 grams of carbohydrates and measuring the increase in blood glucose that follows its consumption (Benton and Stevens 2008; Venn and Green 2007). While the GI is calculated independently of the quantity of food consumed, the glycemic load (GL) is like a weighted version of the GI because it includes information about the amount of carbohydrate ingested from a particular food (Liese, Schulz et al. 2005; Micha, Rogers et al. 2010). Thus, GL provides a more informed estimate of the impact of varying amounts of food on blood glucose levels (Benton and Stevens 2008). It has been reported that children who eat a meal with a low GL display better memory and attention in the classroom than children who consume a high GL meal because the former condition results in a slow and sustained release of glucose in the blood (Benton, Maconie et al. 2007). In rat studies, rapid and large amounts of cellular energy production and depletion caused disturbances in energy homeostasis which could lead to mental and metabolic disorders (Gomez-Pinilla 2008).

Metabolic dysfunction

As mentioned earlier, sucrose and HFCS are composed of glucose and fructose. While glucose can be utilized directly by the brain and almost all other body organs, fructose needs to be converted into glucose (Tappy and Le 2010). This metabolic process takes place in the liver, depleting hepatic ATP (energy source of liver cells), and contributing to the development of fatty liver disease and metabolic dysfunction (Le, Frye et al. 2012; Tappy and Le 2010; Sevastiavona, Santos et al. 2012; Bray 2013; Aeberli, Hochuli et al. 2013; Jin, Le et al. 2012; Hochuli, Aeberli et al. 2014). Furthermore, while glucose in the blood signals the pancreas to release insulin and transport glucose from the bloodstream to the cells (Tappy, Le et al. 2010) where the glucose gets converted to ATP (energy) (Cha, Wolfgang et al. 2008; Lane and Cha 2009), fructose does not elicit insulin release (Teff, Elliott et al. 2004).

Studies in humans and animals suggest that metabolic dysfunction that results from fructose metabolism may adversely affect cognitive function (Ross, Bruggeman et al. 2012; Stephan, Wells et al. 2010; Page, Chan et al. 2013; Simopoulos 2013). In a recent study by Ross et al (2012), rats that were fed a high fructose diet developed fatty liver disease, which was linked to impaired hippocampal-dependent memory function.

The hippocampus is the memory center of the brain and any acute or chronic insult to that part of the brain has negative consequences on memory and learning. Molteni et al (2002), reported that rats that were exposed to a high-fat, high-sugar diet had reduced hippocampal levels of brain-derived neurotrophic factor (BDNF) which is involved in learning and memory (Kanoski and Davidson 2011). Other studies further show that the liver's capacity to release IGF-1, a hormone pertinent for the growth and repair of hippocampal neurons (Ross, Bruggeman et al. 2012) is inhibited by fructose-induced fatty liver disease.

Chronic inflammation

Nutritionally deficient diets can exert immediate and long-term adverse effects on the brain (Bourre, 2006; Greenwood and Winocur 2005; Lakhan and Kirchgessner 2013), including inflammation (Sonnenburg and Sonnenburg 2014; Myles 2014). The Western diet, which is rich in refined sugars and other carbohydrates and fats and low in fruits and vegetables, has been found to be associated with pro-inflammatory markers (Sonnenburg and Sonnenburg 2014; Myles 2014). In a randomized controlled crossover trial among adults, Aeberli et al (2011) found that even low to moderate intake of SSBs led to perturbations in glucose and lipid metabolism and an increase in inflammation.

One possible mechanism may involve the formation of Advanced Glycated End products (AGEs) (Seneff, Wainwright et al. 2011) when proteins are exposed to high levels of glucose and fructose. AGEs take part in a vicious cycle of inflammation and generation of reactive oxygen species, which leads to neurodegeneration and blood-brain-barrier dysfunction (Ramasamy, Vannucci et al. 2005; Glass, Saijo et al. 2010; Wan, Chen et al. 2014). When the hippocampus is exposed to chronic low-grade inflammation resulting from nutritional insults, it may endure damage and volume loss (Wärnberg, Gomez-Martinez et al. 2009) leading to compromised cognitive function.

Lastly, a more novel mechanism by which diet may influence cognition is via gut-brain communication (Mayer 2011; Cryan and Dinan 2012) and the integrity of the blood-brain barrier (BBB) (Banks 2012). The gut communicates with the brain through neurons, endocrine (hormone) cells and immune cells present in the gut (Mayer 2011; Cryan and Dinan 2012). Any perturbations in the gut-to-brain signaling, such as disruption of homeostasis as a result of chronic SSB consumption, may have adverse effects on cognitive function, including learning and memory (Matsumoto, Kibe et al. 2013; Mayer 2011). In addition, many gastrointestinal hormones, such as ghrelin, leptin and insulin, influence attention, learning, memory, and other aspects of cognition (Banks 2012). These hormones cross the BBB to exercise their effects on the central nervous system but their transport may be impaired if the integrity of the BBB has been compromised as a result of metabolic dysfunction (i.e., increased triglycerides) from SSB consumption (Kanoski, Zhang et al. 2010; Banks 2012).

Perturbations in metabolic function are linked to neuronal cell death (Mergenthaler, Lindauer et al. 2013). Chronic fluctuations in energy homeostasis through continuous exposure to the aforementioned effects of SSB consumption may result in chronic energy disruption and metabolic dysfunction adversely affecting a child's learning, memory and concentration, all of which contribute to AP.

Behavioral factors influence SSB consumption

In addition to the sociodemographic (i.e., race/ethnicity and SES) differences in SSB consumption that were discussed earlier, there are also behavioral factors that are associated with SSB consumption, including diet quality, family meal behaviors, physical activity and TV watching.

Dietary variables influence SSB consumption

Children's and adolescents' dietary choices may be influenced by their home and school environment, their peers, the presence of establishments in their neighborhoods that sell primarily healthy or unhealthy foods and beverages, and their level of exposure to food and beverage advertisements. Optimal nutrition contributes to proper growth during the critical developmental stages of childhood and adolescence. Consuming healthful foods, such as fruits and vegetables, has been found to be negatively associated with SSB consumption (Yamada, Murakami et al. 2008). On the contrary, snack intake, which includes consumption of high-fat, high-sugar, processed food items, such as candy, cookies, and chips, has been found to be positively associated with SSB consumption (Ranjit, Evans et al. 2010; Collison, Zaidi et al. 2010; Mathias, Slining et al. 2013).

Studies have demonstrated that children's eating patterns may change over time with marked declines in dietary quality as they transition into adolescence (Lytle, Seifert et al. 2000; Demory-Luce, Morales et al. 2004). For example, fruit and vegetable consumption decreases while SSB consumption increases between childhood and adolescence (Lytle, Seifert et al. 2000). It is possible that adolescents' increased independence in decision making and food purchasing contributes to this trend. Dietary behaviors established in childhood generally continue into adulthood so exposing children early on to nutritious foods and encouraging them to adopt healthy eating patterns may contribute to healthier dietary choices in the future.

Family meal behaviors influence SSB consumption

It has been established that the home food environment is very influential in the development of children's lifelong dietary attitudes and behaviors (Arcan, Neumark-Sztainer et al. 2007; Haerens, Craeynest et al. 2008; Larson, Neumark-Sztainer et al. 2008; Rosenkranz and Dzewaltowski 2008; Vereecken, Haerens et al. 2010). The literature suggests that children consume most SSBs at the home setting (Wang, Bleich et al. 2008; Briefel, Wilson et al. 2009). A recent study using a national representative sample of school-aged children reported that, on a given day, 21-49% of elementary- and 31-43% of middle-school children reported consuming an SSB at home (Dodd, Briefel et al. 2013). Since children do not have a lot of financial autonomy, the food and beverage items that they consume at home or when eating out, are usually purchased by their families. Parents can positively influence children's dietary patterns through selection and preparation of healthy food items, modeling healthful eating behaviors, and encouraging children to participate in meal preparation and in family meals (Arcan et al, 2007; Hammons & Fiese, 2011; Larson et al, 2012; Larson et al, 2006; Chu et al, 2013; Wijtzes et al, 2013; Fulkerson et al, 2014).

Two longitudinal studies by Larson et al (2007, 2013), reported that having frequent family meals during adolescence was a significant predictor of more shared meals and lower intake of SSBs in adulthood, which indicates that dietary habits that are established in childhood may be carried throughout the lifespan. Recent studies by Neumark-Sztainer et al (2013, 2014) have highlighted that the nutritional quality and frequency of family meals varies by sociodemographic characteristics. Specifically, the investigators examined secular trends in family meals from 1999-2010 among middle- and high-school youth from diverse socioeconomic and racial/ethnic backgrounds (Neumark-Sztainer, Wall et al. 2013). They reported that having family dinner at least five times per week decreased (from 46.9% in 1999 to 38.8% in 2010, $p<0.001$) among low income families while it increased (from 55.8% in 1999 to 61.3% in 2010, p=NS) among higher income families, over time, widening the disparity that already existed between lower and higher income households. Furthermore, in 2010, a smaller proportion (41%) of African-American youth reported having frequent (at least 5 times a week) family meals compared to 51% of White, 46% of Hispanic and 43% of Asian youth (Neumark-Sztainer, Wall et al. 2013). The dietary quality of these family meals was further assessed through a parent questionnaire (Neumark-Sztainer, MacLehose et al. 2014). African-American parents scored significantly lower in the overall healthfulness of their family dinner, primarily because they were more likely to serve SSBs and fast-food items, compared to other racial/ethnic groups.

Although parents can serve as positive or negative role models for food choices during mealtimes, most studies suggest that frequent family meals are associated with diets of higher nutritional quality in children and adolescents (Woodruff and Hanning 2009; Gillman, Rifas-Shiman et al. 2000; Burgess-Champoux, Larson et al. 2009; Fulkerson, Larson et al. 2014). One of the challenges to frequent family meals is finding time and coordinating schedules between children's school and other activities and parents' work obligations and other commitments. Further, with increasingly more mothers entering the workforce, the traditional division of labor with the woman as the homemaker and the man as the breadwinner has dissipated, especially among the 60% of American families where both parents are employed (US Census Bureau 2012).

Historically, women have carried most of the responsibility for feeding the family, including food purchasing and preparation (Cunningham and Green 1974; DeVault 1994). Although gendered division of labor has been declining since the 1980s (Cunningham 2008), working women continue to spend more time with household chores than men, including meal planning, shopping and preparation (Coltrane 2000; Harnack, Story et al. 1998). Additionally, according to the Pew Research Center analysis of data from the U.S. Census Bureau, in 2011, mothers were the sole or primary source of income in 40% of U.S. households with children under age 18. About 63% of the aforementioned households are headed by single mothers who are disproportionally Black or Hispanic, have generally achieved less than or equal to a high-school education and earn the lowest income of all families (compared to single-father or dual-parent incomes).

Maternal education has been found to be inversely associated with the quality of children's diet (Cribb, Jones et al. 2011) and the healthfulness of family meals (Neumark-Sztainer, MacLehose et al. 2014). Further, research indicates that children whose mothers work are less likely to engage in family dinner (Neumark-Sztainer, Hannan et al. 2003; Bauer, Hearst et al. 2012) and more likely to drink primarily sweetened beverages between meals (versus other beverages) compared to children whose mothers have never been employed (Hawkins, Cole et al. 2009). Competing demands and time constraints are some of the potential reasons that reduce working mothers' participation in meal planning and food preparation (Rosenkranz and Dzewaltowski 2008; Morin, Demers et al. 2013). In addition, lower levels of education and lower incomes may contribute to families' poorer food choices (Devine, Jastrin et al. 2006) as they may gravitate toward more affordable but unhealthy food items, which, as mentioned earlier, are disproportionately marketed to these populations. Consequently, children may be exposed to less healthful quick-meal options, such as processed foods and SSBs. This is an indication that in order for interventions targeting the home food environment to be effective in reducing SSB consumption, there needs to be better understanding of the challenges (i.e., social, cultural, economic) that low income minority populations face that may hinder them from making healthier food choices and having more frequent family meals.

A potentially enjoyable and effective way to help children establish healthy dietary behaviors early on and to participate more frequently in family meals may be to encourage them to get involved in meal preparation (Larson, Story et al. 2006). Cross-sectional studies suggest that greater involvement in meal preparation is associated with lower intake of SSBs (Larson, Story et al. 2006) and better diet quality (Chu, Storey et al. 2014) among children and adolescents. In focus group discussions, working parents expressed their interest in involving their children in meal preparation but were concerned that it might be more time consuming and messy (Fulkerson, Larson et al. 2011). In a study of 3,699 adolescents from a Midwestern school district, Larson et al (2006) reported that frequent involvement with meal preparation was significantly associated with the following sociodemographic characteristics: being female, Asian, in middle school (versus high school), having low SES and frequent family meals. In summary, family meal behaviors vary by sociodemographic factors and warrant further research in order to better understand how they contribute to SSB consumption.

Physical activity and TV watching influence SSB consumption

The literature suggests that SSB consumption is associated with physical activity although studies have been primarily cross-sectional and findings have been mixed (Ranjit, Evans et al. 2010; Chen and Wang 2013). For example, Ranjit et al (2010) found that among adolescents, the association between SSB consumption and organized physical activity (i.e., participating in a sports team) varied by type of SSB. More specifically, soda consumption was negatively associated while flavored and sports SSBs were positively associated with organized physical activity, particularly among boys. In a study of a nationally representative sample of high school students, Park et al (2012) reported that adolescents who adhered to the Physical Activity Guidelines for Americans' recommendation of exercising a minimum of 1 hour daily at least 5 days a week had higher odds of consuming SSBs, particularly sports drinks, compared to those who exercised less than 5 days a week. A more recent study by Chen et al (2013) reported a non-linear association between SSB consumption and physical education (PE) in 8^{th} grade students, but there was a significant positive association between SSB consumption and PE participation only among students who participated in PE three or more days per week, especially in schools with vending machines. The authors hypothesized that children who had access to SSBs at school were more likely to consume those beverages to quench their thirst after PE. These findings could possibly reflect the effect of the heavy marketing of flavored and sports SSBs as healthier alternatives to soda to rehydrate when participating in sports or vigorous physical activity.

Children are exposed to advertisements for unhealthy foods and beverages through various types of media but television continues to be the primary medium used for marketing such products (Boyland and Halford 2013; Story and French 2004). Television commercials that promote unhealthy food and drink choices may have long-term effects on children's dietary behaviors because dietary patterns are primarily influenced and established during childhood. Longitudinal studies have indicated that the number of hours of television viewing is positively associated with SSB consumption (Olafsdottir, Eiben et al. 2013; Barr-Anderson, Larson et al. 2009). Olafsdottir et al (2013) reported that among children ages 2-9, SSB consumption was 19% higher for every hour of watching TV per day, after a 2-year follow-up. Consistent with these findings, Barr-Anderson et al (2009) found that among middle and high school students, watching at least 5 hours of television per day at baseline predicted high SSB consumption after 5 years. Limiting TV watching may be beneficial in reducing SSB consumption because children may then be less likely to be exposed to persuasive commercials encouraging consumption of unhealthy snack-food items, such as SSBs. Currently, the American Academy of Pediatrics recommends no TV for children under age 2 and no more than 2 hours per day for children over age 2.

Factors influencing academic performance

Sociodemographic characteristics

Similar to SSB consumption, variables that influence AP include sociodemographic characteristics, such as SES, and dietary and physical activity behaviors. It has been reported in the literature that White children may perform better academically compared to African-American and Latino children. (Muller, Riegle-Crumb et al. 2010; Riegle-Crumb 2006; Rushton and Jensen, 2006; Kao and Thompson 2003). There does not seem to be a definitive answer as to why these racial/ethnic differences in AP are observed, but many studies lend support to economic (i.e., cannot afford access to academic resources), cultural (i.e., beliefs about educational attainment), and other environmental (i.e., poor neighborhood without a library) factors that may hinder or enhance a child's AP (Mulle, Riegle-Crumb et al. 2010; Riegle-Crumb 2006; Rushton and Jensen 2005; Breslau, Chilcoat et al. 2001; Dickens and Flynn 2001).

The literature further suggests that children who come from higher SES families may have higher AP compared to children who come from lower SES families possibly because higher SES families may have the financial ability and resources to provide necessary educational assistance to their children (Garcia Bacete and Rosel Remirez 2001; Crosnoe and Schneider 2010). For example, it has been reported that better educated parents may be more involved in their child's education and be able to more easily provide the academic resources that the child may need to excel, possibly because more highly educated parents are more likely to have better paying jobs and therefore the financial means to afford those resources (Garcia Bacete and Rosel Remirez 2001; Crosnoe and Schneider 2010). Additionally, highly educated parents may also have more knowledge, time, and ability (i.e., no language limitations) to directly help their children with academic tasks while less educated parents may not possess such qualities. Moreover, traditionally, mothers have been more engaged in their children's education, and child-rearing in general (Tan and Goldberg, 2009; Finley, Mira et al. 2008; Hoover-Dempsey and Sandler, 1997; Hoover-Dempsey, Bassler et al. 1995), although social change in the last two decades has resulted in more fathers getting involved in their children's upbringing and education (Tan and Goldberg 2009).

Findings in the literature about the effect of parental employment on children's AP are inconsistent. The evidence from some studies lends support to increasing hours of maternal employment being inversely associated with a child's AP (Baum 2004) while the evidence from others suggests that it can enhance a child's AP, if it is part-time employment (Williams and Radin 1993; Muller 1995). Results are not conclusive because the effect of maternal employment on a child's AP is different depending on the child's age, whether the mother is single or married, household income, and her level of education, among other factors (Milne, Ginsburg et al. 1986). If, as suggested by the literature, mothers are more engaged in their children's education than fathers and they work full-time then that diminishes some of the benefits that the children may derive since the mother may not be around as much to help. On the other hand, if the mother works part-time she may have more time to spend directly assisting her child with academic tasks and in general may be more involved with her child's education (Buehler and O'Brien 2011; Muller 1995), and may also be able to afford to pay for supplemental assistance (i.e., tutoring) if necessary, all of which may enhance a child's overall AP.

Diet quality

One of the keys to improving academic performance is by enhancing the quality of children's diet (Taras 2005; Florence, Asbridge et al. 2008; Bellisle 2004). Evidence from the literature suggests that healthy dietary behaviors, such as regular consumption of fruits and vegetables, are positively associated with AP (Florence, Asbridge et al. 2008). It is possible that the vitamins and minerals, particularly the antioxidants, found in fruits and vegetables maintain the integrity of healthy brain function and enhance cognitive performance (Proteggente, Pannala et al. 2002). On the contrary, consumption of snack foods rich in fat, sugar or salt, has been shown to be associated with metabolic dysfunction and neuronal injury in the hippocampus (Molteni, Barnard et al. 2002; Davidson, Hargrave et al. 2013). As mentioned earlier, if a child's brain experiences nutritional insults from a low quality diet during critical periods of development, such as during the first year of life and during adolescence, brain regions that control cognitive abilities (frontal lobes and hippocampus), such as memory and learning, may be impaired both in the short- and long-term.

Physical activity and TV watching

Physical activity and sedentary behaviors, such as TV watching, have also been reported to be associated with AP. Physical activity/fitness has been consistently found to be positively associated with AP in both cross-sectional and longitudinal studies (Kwak, Kremers et al. 2009; Chomitz, Slining et al. 2009; Roberts, Freed et al. 2010; London and Castrechini 2011; Edwards, Mauch et al. 2011; Van Dusen, Kelder et al. 2011; Donnelly and Lambourne 2011; Kibbe, Hackett et al. 2011; Rauner, Walters et al. 2013; Coe, Peterson et al. 2013; Bass, Brown et al. 2012). For example, London and Chastrechini (2011) examined the longitudinal association between physical fitness (measured by the six components of the FITNESSGRAM®) and academic achievement (measured by standardized test scores for English and Math) by following two cohorts of students from grade four to grade seven (N=1,325) and from grade six to grade nine (N=1,410) from 2002-2003 to 2007-2008 school years. Of interest, the authors found a wide fitness achievement gap the first year among students in the younger cohort. Specifically, students who passed both their fifth and seventh grade fitness tests scored, on average, 0.40 and 0.45 standard deviations above the mean in English and Math, respectively, compared to students who failed the fitness tests in both fifth and seventh grade and scored 0.28 and 0.29 standard deviations below the mean. They also reported that the relationship was stronger between fitness and the initial achievement gap than between changes in fitness and achievement over time which could indicate that a longer period of time may be necessary to fully understand trends in fitness and academic achievement.

A review by Rasberry et al (2011) covering 23 years (1985-2008) of research in physical activity/fitness and academic performance in school-aged children concluded that “there is substantial evidence that physical activity can help improve academic achievement (including grades and standardized test scores).” Some of the suggested mechanisms by which aerobic fitness potentially enhances AP include increased blood flow, and therefore oxygen, to the brain (van Praag 2009) resulting in enhanced concentration and attention (Rasberry, Lee et al. 2011) and improved memory (Erickson, Voss et al. 2011). It has also been suggested that exercise has neuroprotective effects on the brain by increasing the levels of brain-derived neurotrophic factor (BDNF), a protein responsible for neuron survival and growth, in the learning and memory regions of the brain (Phillips, Baktir et al. 2014).

While physical activity may enhance AP, sedentary behaviors, such as television (TV) watching, have been linked to poor cognitive development and AP, attention and learning difficulties and negative long-term educational outcomes (Shin, et al, 2004; Kirkorian et al, 2008; Schmidt and Vandewater 2008; Johnson, Appel et al. 2007). Entertainment TV has been particularly criticized for its content which may adversely affect children's cognitive health, while educational TV programs may have beneficial effects on learning and cognitive function (Schmidt and Vandewater, 2008). According to The Nielsen Company (2009), children ages 2-11 years watch, on average, more than a day's worth of television per week, ranging from 26-32 hours (includes TV, DVR, DVD and VCR programs), which is more than double the recommended number of hours. As mentioned earlier, the American Academy of Pediatrics recommends fewer than 2 hours of TV watching per day for children over age 2 so even if the programs are educational, children's TV exposure may need to be curtailed given current statistics.

Theoretical frameworks for understanding effect of sociodemographic and behavioral factors on SSB consumption and AP

Social-ecological theories stemming from Urie Bronfenbrenner's Ecological Systems Theory (1979) can serve as a guide in understanding the development of human behavior (i.e., SSB consumption) and individual characteristics (i.e., academic performance). A central focus of social-ecological theories is that the individual is nested within a larger ecological niche that includes family, community and society, which interact with each other to shape individual behavior and characteristics (Bronfenbrenner 1979; Davison and Birch 2001; Story, Neumark-Sztainer et al. 2002). From a social-ecological perspective, SSB consumption and AP among children may be influenced by individual, family, peer, school, neighborhood and policy factors. For example, SSB consumption and AP may be influenced by individual-level characteristics, such as gender and race/ethnicity; family-level characteristics, such as SES and family meal behaviors; and neighborhood-level characteristics such as access to healthy food and safe parks. There are also societal-level characteristics, such as local and national laws and policies that may further influence SSB consumption and AP. All these levels dynamically interact to shape individual behavior.

As discussed earlier in this chapter, family SES is considered an important contributing factor to SSB consumption and AP in children. Low SES families have also been reported to have less frequent family meals (Neumark-Sztainer, Wall et al. 2013). The lack of structured family meals may diminish meal quality, which may contribute to higher intake of SSBs among children (Woodruff and Hanning 2009; Gillman, Rifas-Shiman et al. 2000; Burgess-Champoux, Larson et al. 2009; Fulkerson, Larson et al. 2014). Low SES families also tend to live in low-income neighborhoods where fast-food advertisements and restaurants are more ubiquitous and access to healthy food items is more scarce, compared to higher income neighborhoods. It follows that in lower income neighborhoods children are more frequently exposed to and have easier access to unhealthy food items, including SSBs. Furthermore, children from ethnic minority and low SES families watch more TV than Whites (Powell, Szczypka et al. 2010; Kumanyika and Grier 2006), which exposes them to more TV commercials promoting unhealthy foods and beverages. Importantly, low-income families may be more likely to provide such unhealthy food items to their children because of their low cost.

Economic theory further explains how SES influences SSB consumption and AP. According to economic theory, the observed SES gradient in SSB consumption and AP could be attributed to cost, which is an important determinant of the quality of a good/service (Darmon and Drewnowski 2008; Andrieu, Darmon et al. 2006; Rouse and Barrow 2006). Consequently, the diet quality of low-income families may be suboptimal as fruits and vegetables are considered more costly than high-fat, high-sugar and high-salt fast foods, snacks and beverages (Schroder, Marrugat et al. 2006; Maillot, Darmon et al. 2007).

Lastly, in low-income communities the safety and quality of school and recreational infrastructures may be compromised hindering children's academic development and opportunities to be physically active. If families and communities cannot afford to offer children quality education at schools, local library and tutoring services and other educational resources, children may not be able to thrive and do as well academically. In summary, the application of social-ecological and economic theories to predictors of SSB consumption and AP can offer a comprehensive approach to understanding and addressing disparities in SSB consumption and AP.

Summary

Current intake levels of SSBs among children and adolescents are higher than recommended. Although there is extensive literature on the adverse short- and long-term health consequences of SSB consumption, the effects of SSBs on cognitive function and AP are now beginning to be explored. It is therefore essential to further investigate the relation of SSB consumption with cognitive function and AP, particularly among children and adolescents whose developing brains are sensitive to nutritional insults.

This review also highlights that although normal cognitive function is essential for learning, AP is influenced by many factors such as parent’s education, race/ethnicity, family environment, overall dietary quality and physical activity; these factors have also been reported to be associated with SSB consumption and may confound relationships between SSB and AP. Hence, it is important that these potentially confounding factors be considered in analytic efforts to estimate the independent effects of SSB intake on AP. Moreover, identifying factors that contribute to SSB consumption is an important step in the development of effective interventions that will target vulnerable populations that disproportionately consume high levels of SSBs.

Research questions and hypotheses

The primary aim of this dissertation is to determine if SSB consumption is associated with AP, using longitudinal data collected from 327 fourth and fifth grade students who were differentially exposed to a school district-wide initiative established to promote healthy eating, and followed annually for three years. To do this, this study examines associations of factors known to influence AP – parent's education, race/ethnicity, family environment, dietary quality and physical activity – with SSB consumption so as to identify potential confounders and mediators (Figure 2.2).

Research Question 1: Is SSB consumption associated with academic performance in elementary and middle school children?

> ***Hypothesis 1:*** SSB consumption is inversely associated with AP among elementary and middle school children, controlling for potential confounders such as sociodemographic characteristics (i.e., race/ethnicity, parent's education), diet quality, physical activity and TV watching.
>
> ***Hypothesis 2*:** Diet quality moderates the association between SSB consumption and AP; specifically, the effect of SSB consumption on AP is stronger at lower fruit and vegetable intake levels and at higher unhealthy snack intake levels.
>
> ***Hypothesis 3:*** Physical activity moderates the association between SSB consumption and AP; specifically, the effect of SSB consumption on AP is stronger at lower physical activity levels.

Research Question 2: Is SSB consumption associated with sociodemographic characteristics, namely race/ethnicity, and maternal education and employment? If it is, do family meal behaviors, specifically frequency of children assisting with meal preparation and having dinner with their family, mediate these associations?

> ***Hypothesis 4:*** Sociodemographic characteristics, such as race/ethnicity and maternal education and employment, are associated with SSB consumption.
>
> ***Hypothesis 5:*** Family meal behaviors, namely frequency of children assisting with meal preparation and having dinner with their family, are inversely associated with SSB consumption.
>
> ***Hypothesis 6:*** The association between sociodemographic characteristics and SSB consumption is partially mediated by family meal behaviors.

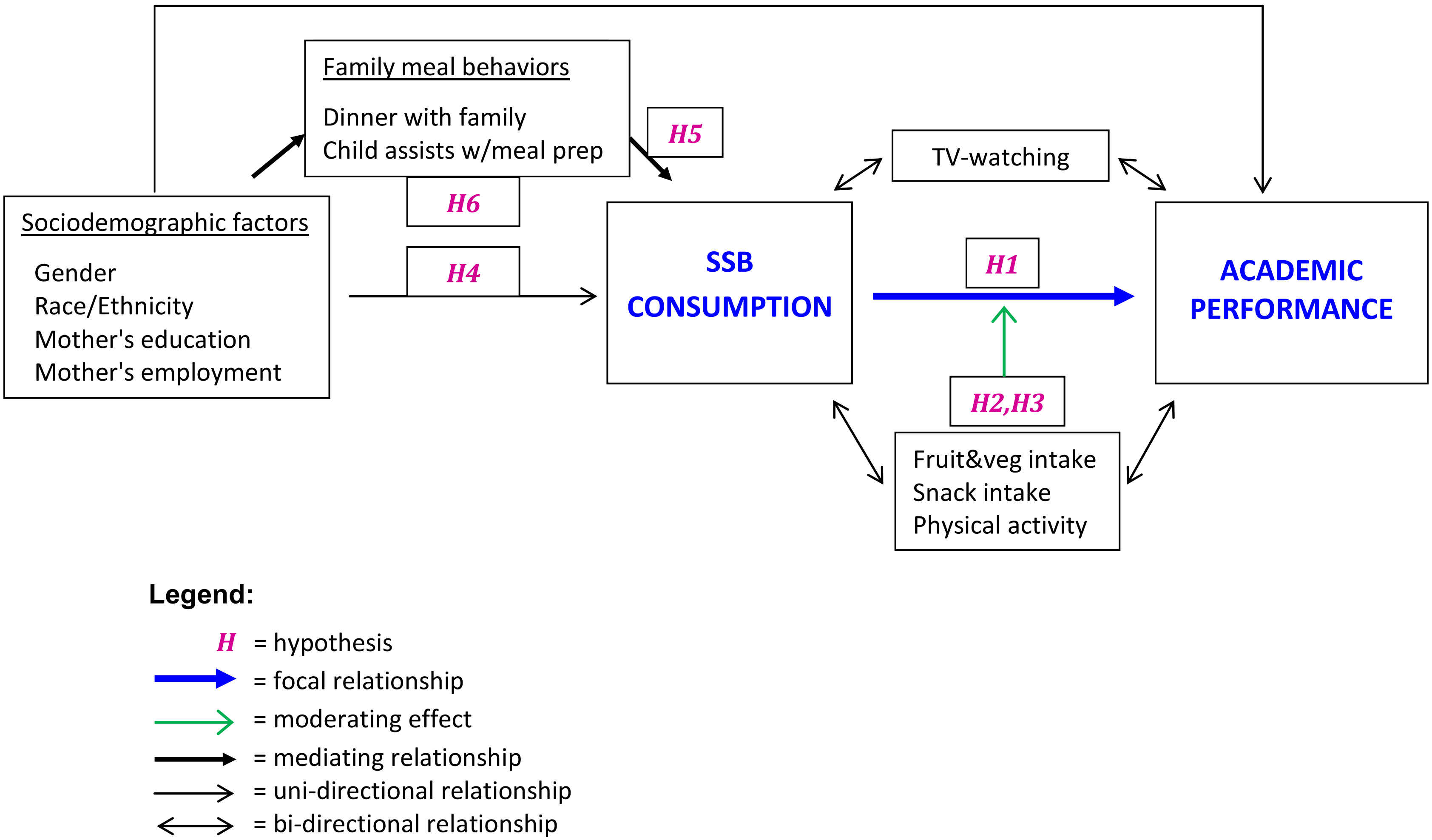


Figure 2.2: Conceptual model that illustrates the association of sugar-sweetened beverage (SSB) consumption with academic performance (AP) and potential predictors of SSB consumption and AP

Chapter 3. METHODS

This chapter describes the study design, data collection methods, the variables of interest, and the analytic approach relevant to addressing the research questions and hypotheses.

Study Design Overview

This study used data previously collected for an evaluation of the School Lunch Initiative (SLI), a school-based nutrition intervention implemented in a California medium-sized suburban public school district to improve children's dietary behaviors (Rauzon, Wang et al. 2010). Known as the School Lunch Initiative Evaluation Study (SLI Study), this evaluation gathered data on food-related aspects of the family environment, and assessed food-related knowledge, attitudes and behaviors among baseline 4th and 5th grade students, in relation to exposure to the intervention over a period of three years (Rauzon, Wang et al. 2010).

In the first year of the study, a total of 327 students from four elementary schools with contrasting levels of exposure to the intervention were enrolled in the SLI Study. Student exposure to the intervention was subsequently assessed annually by determining the student's school of attendance and the level of intervention activities implemented at each participating school; details of the data collection methods can be found elsewhere (Rauzon, Wang et al. 2010); Wang, Rauzon et al. 2010). For the present study, data from the SLI Study were used to examine the relation of SSB consumption with AP and other influential variables.

Description of the SLI Study

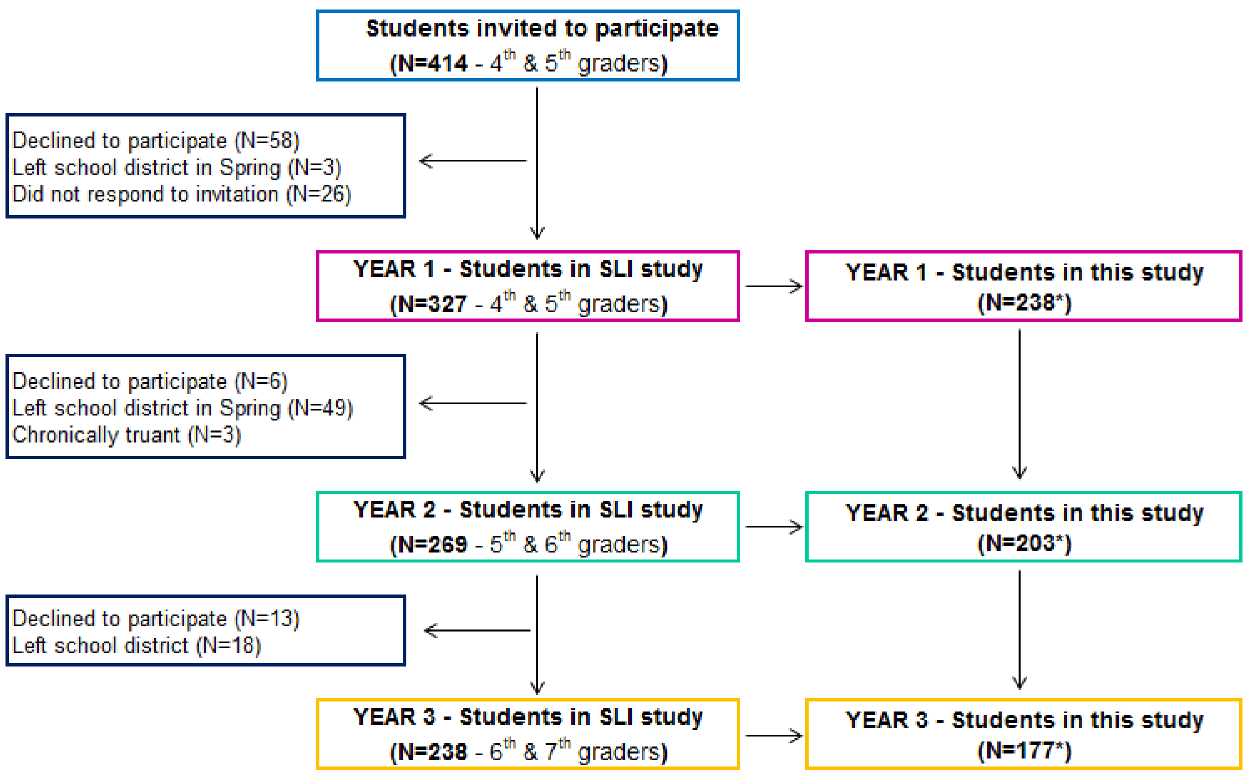
The SLI Study used an observational design that measured students' exposure to intervention activities yearly over a period of three years. Intervention activities included hands-on cooking and gardening classes, school-wide changes in food and dining services, and integration of nutrition education into the academic curriculum. The observational study design was chosen because schools were not uniformly engaged in the SLI, hence providing an opportunity to evaluate the effectiveness of varying levels of development of implementation of the various nutrition components.

In the first year of the SLI Study, all elementary schools were assessed for their level of development of SLI activities – this assessment was conducted by interviewing school staff about the types of intervention activities that were being undertaken by the school. From this assessment, the schools were ranked according to their level of development to SLI activities; the two highest- and two lowest-ranking elementary schools were selected for participation in the evaluation. All 4th and 5th graders enrolled at these four schools were invited to participate in the SLI Study and their exposure to the SLI was considered 'high' or 'low' depending on the level of development of SLI activities at the school they attended. As 5th grade students entered middle school in the second year of the study, 'medium' exposure category was added because SLI activities varied considerably among the three middle schools in the school district. Site visits and semi-structured interviews with school staff were conducted annually at each of the elementary and middle schools in order to assess students' exposure to the SLI components. This SLI Study was approved by the Committee for the Protection of Human Subjects at the University of California in Berkeley.

Participants

Four elementary schools provided a potential pool of 414 fourth and fifth grade ethnically diverse students for recruitment, of whom 327 (79%) enrolled in the study. In the second year of the study, 49 students from the original cohort had left the school district, three were chronically absent from school, and six declined to participate, leaving a sample of 269 fifth and sixth grade students. In the third year of the study, 18 students from the original cohort had left the school district and 13 declined to participate, leaving a sample of 238 sixth and seventh grade students (Rauzon, Wang et al. 2010).

For the purpose of the present study, only students with complete data for all variables of interest were included in the analyses (see Figure 3.1). Specifically, out of the original baseline sample of 327 fourth- and fifth-grade students, 238 (73%) students had complete data for the variables relevant to this study. Out of the sample of 238 students at Year 1, 198 (83%) had complete data at Year 2 and 177 (74%) had complete data at Year 3. Selection bias was examined via attrition analysis, described later in this chapter.



*The present study includes only observations with complete data on all variables of interest for each year

Figure 3.1: Participant recruitment and retention

Post-hoc power analysis

Power calculations for the original study yielded estimates suggesting that a final sample of 174 participants would be enough to detect the effect size that was expected in the outcomes of interest, which included nutrition knowledge, attitudes and behaviors (Wang, Rauzon et al. 2010. For this study, post-hoc power analysis was conducted to assess whether there was reasonable power to detect statistically significant associations among variables of interest, specifically, the effect of SSB consumption on AP. Power calculations were based on a repeated measures ANOVA (F-test), a type I error rate of 0.05, three time points, two groups, and a sample size of 200 (average sample size over three year period). SSB consumption was dichotomized into those who "ever consumed SSBs" (N=100) and those who "never consumed SSBs" (N=100) by calculating the average number of SSB consumers and non-consumers over the three year time period. Power levels were calculated for a range of effect sizes (low=0.1, medium=0.25, high=0.4), and for a correlation level of 0.8 to reflect the actual within-subject correlation of academic performance (AP) scores over time. We found that with a total sample size of N=238, we would have 33% power to detect an effect size of 0.1, 97% power to detect an effect size of 0.25 and almost 100% power to detect an effect size of 0.4.

Data collection

Data collection took place annually in the spring of each year and included administration of: (1) a student questionnaire that evaluated student knowledge and attitudes about nutrition, the home food environment, and physical activity habits, and (2) a three-day food diary that assessed student food behavior. Additionally, a 45-item questionnaire was mailed to parents in the first year to gather information about sociodemographic characteristics and the home food environment, including food purchasing and meal preparation behaviors.

The student questionnaire was developed in collaboration with and reviewed by school staff and was pretested for wording among students of the same age as the participants. It included 28 items and was administered during class time by trained research staff. The three-day food diary was previously developed for young children by the National Heart, Lung and Blood Institute Growth and Health Study (Crawford, Obarzanek et al. 1994; Wang, Rauzon et al. 2010).

In order to achieve quality food records and a high response rate, participating students were trained on a Monday to record their food intake for the following three days (Tuesday through Thursday); this 45-minute training session was conducted by research staff in the classroom. Additionally, students received daily reminders from their classroom teachers to record their food intake. On the Friday of the same week, during another 45-minute classroom session, research staff reviewed the food diary with each student individually.

Operational definitions of variables of interest

A summary of the operational definitions of all variables of interest used to address this study's research questions is shown in Table 3.1. In brief, sociodemographic variables of interest include gender, race/ethnicity, grade level and mother's education and employment. Grade level was used as a proxy for age because more than 50% of the sample was missing data on age. In the first year of the study, all children started out in elementary school (4^{th} or 5^{th} grade). In the second year, approximately half of the children were in elementary school (5^{th} grade) and the other half were in middle school (6^{th} grade) and in the third year all children were in middle school (6^{th} or 7^{th} grade). Only mother's education was used as an indicator of socioeconomic background because family income information was missing for a considerable number of students (n = 65). Further, mother's education has been linked more consistently with children's nutrition than income (Murakami, Miyake et al. 2009; Manios, Kourlaba et al. 2009;

van Ansem, van Lenthe et al. 2014). When mother's education was not reported, father's education was used.

Academic performance is the main outcome of interest and it is operationalized as the scores of the California Standardized Testing (CST) and Reporting (STAR) examinations. STAR examinations are state mandated achievement tests and take place in the spring of each year as part of the CST. The raw exam scores were converted to z-scores to allow for comparison across the years of the study since the STAR exams are different each year. Z-scores were calculated using the population (all 4-7 grade students who took the CST in the spring of 2007, 2008 and 2009 in California) means and standard deviations.

Dietary intake variables include intake of SSBs, snacks, fruits and vegetables. Sugar-sweetened beverage consumption is the main predictor variable of the focal relationship between SSB consumption and academic performance. In this study, SSBs are defined as the mean daily intake, in ounces, of any sweetened beverage that contains added sugars such as soft drinks, fruit-flavored drinks, sports drinks, and sweetened teas. Although 100% fruit juice and flavored milk were not classified as SSBs (100% fruit juice contains naturally occurring sugars and flavored milk was classified as a dairy food), both were examined as SSBs in sensitivity analyses in order to be able to report measures comparable to measures used in other studies. Fruit and vegetable intake is defined as the mean daily intake, in cups, of fruit, vegetables, 100% fruit juice, and fruit smoothies. Fruit and vegetable intake was combined into one composite variable. Snack intake is defined as the mean daily intake, in ounces, of high sugar, high fat snacks, such as candy bars, cookies, and chips, based on food diary reports. The mean daily intake of the dietary variables was calculated from the children's 3-day food records by taking the average number of ounces or cups consumed over the period of three days.

Family meal behaviors were measured by the frequency of the family eating dinner together and of the child assisting with meal preparation. Both variables were categorical but were analyzed as continuous in their role as mediators. The reason for treating the categorical mediators as continuous is explained in more detail later in the methods section.

Physical activity was defined as the frequency by which students reported playing sports, running, dancing, doing martial arts, or any activity that made them sweat or breathe hard, in or outside of school. It is a dichotomous variables with frequency of physical activity classified as 1) $\leq$ 3 days/week or 2) $>$ 3 days/week. TV watching was assessed by asking students the number of hours they watch TV (excluding video games) on a weekday. Response options were collapsed into three categories; 1) Do not watch TV, 2) $<$ 2 hours/day and 3) $\geq$ 2 hours/day. This classification permits evaluating student adherence to the American Academy of Pediatrics' guidelines that children limit TV watching to less than 2 hours per day.

The last confounder of interest is the SLI level of development. SLI level was defined as "low", "medium", and "high" depending on the degree of development of each intervention component at the schools. As described earlier, intervention components included hands-on cooking and gardening classes, school-wide changes in food and dining services, and integration of nutrition education into the academic curriculum. As an example, a school was ranked "low" on the cooking and gardening component if students were exposed to these activities for 20-26 hours per year, and "high" if exposed for 40-45 hours per year (Rauzon, Wang et al. 2010). For more details on the ranking of the various SLI components, see Appendix A.

Table 3.1. Definitions of variables used to address this study's research questions

Variable name	Variable type	Variable definition	Data source
Sociodemographics			
Gender	Dichotomous	1 = male 0 = female	Student questionnaire
Race/Ethnicity	Categorical	1 = White 2 = African American 3 = Latino 4 = Asian 5 = Mixed/Other	Student questionnaire
Grade level	Dichotomous; Year 1 = 4th, 5th Year 2 = 5th, 6th Year 3 = 6th, 7th	4th, 5th, 6th, 7th	Student questionnaire
Mother's education	Categorical	1 = $\leq$ High school 2 = Some college 3 = Bachelor's degree 4 = $\geq$ Graduate school	Parent questionnaire
Mother's employment	Categorical	1=Not employed 2=Part-time 3=Full-time	Parent questionnaire
Behavioral variables			
SSB consumption	Continuous	Average daily consumption in ounces	3-day food records
Fruit & Vegetable intake	Continuous	Average daily consumption in cups	3-day food records
Snack intake	Continuous	Average daily consumption in ounces	3-day food records
Dinner with family	Categorical	1 = $\leq$ 1 time/month 2 = 2-3 times/month 3 = 1 time/week 4 = Several times/week 5 = Every day	Parent questionnaire
Child assisting with meal preparation	Categorical	1 = $\leq$ 1 time/month 2 = 2-3 times/month 3 = 1 time/week 4 = Several times/week 5 = Every day	Parent questionnaire
Physical Activity	Categorical	1 = $\leq$ 3 days/week 2 = >3 days/week	Student questionnaire
Hours of TV watching	Categorical	1 = Don't watch TV 2 = $\leq$ 2 hours/day 3 = > 2 hours/day	Student questionnaire
Other variables			
SLI intervention	Categorical	1=Low 2=Medium 3=High	School and research study staff
Academic Performance	Continuous	Standardized test scores in math & English	California STAR exam

Analytic Plan

This section describes the analytic strategies that were employed to address this study's research questions. SAS software, version 9.3 (SAS Institute, Cary, NC) was used for all analyses. The statistical analysis plan included the following:

1. Descriptive statistics to assess the distribution of sample characteristics and other variables of interest.
2. Bivariate analyses, such as correlations and one-way ANOVA, to identify relationships between two variables.
3. Mixed effects linear modeling of repeated measures to answer research question 1, "Is SSB consumption associated with academic performance in elementary and middle school children?" using data collected annually for three years.
4. Mediation analysis to answer question 2, "Is SSB consumption associated with sociodemographic characteristics, namely race/ethnicity, and maternal education and employment? If it is, do family meal behaviors, specifically frequency of children assisting with meal preparation and having dinner with their family, mediate these associations?"
5. Regression model diagnostic tests such as outlier and collinearity diagnostics.
6. Attrition analysis to examine potential differences in participant characteristics between those who remained in the study and those who dropped out.

Descriptive statistics

Descriptive analyses were conducted for all variables selected for this study at all three time points to assess sample characteristics, variable distributions and identify potential outliers.

Means, standard deviations and ranges were calculated and histograms were examined for normality for all continuous variables, such as SSB consumption, other dietary factors, and AP. Boxplots were used to detect outliers. Frequencies and percentage distributions were calculated for categorical variables, such as sociodemographic and behavioral characteristics.

Bivariate analyses

Bivariate analysis was conducted to examine associations of each of the predictors of interest with SSB consumption and AP. Bivariate analyses included correlations between dietary intake variables and AP, and one-way analysis of variance (ANOVA) of sociodemographic and behavioral variables with SSB consumption and AP. Spearman's rather than Person's correlation coefficients were estimated for variables that were not normally distributed. In the one-way ANOVAs, pairwise comparisons tests were conducted to assess mean differences in SSB consumption and AP among the different groups of each categorical variable and Tukey-Kramer adjustment was applied to correct for multiple comparisons. The association between SSB consumption and AP was also examined through scatterplots at each of the three time points (see Appendix B).

Mixed effects linear modeling of repeated measures to answer question 1

Research Question 1: Is SSB consumption associated with academic performance in elementary and middle school children?

This section describes the analytic methods that were used to address the main research question in this study. Although bivariate analyses helped identify the magnitude and significance of associations between two variables, variable selection for the longitudinal model was primarily theory-driven and based on support from the literature. Prior to examining mixed effects models, baseline data (N=238) were assessed cross-sectionally using Ordinary Least Squares regression to determine the contribution of selected predictor variables in explaining the variation in AP.

The type of longitudinal analysis that was employed to examine the association between SSB consumption and AP is repeated measures mixed effects regression analysis since the data were collected at three time points for the same children and, therefore, not independent. One of the main advantages of using mixed effects regression to analyze longitudinal data, as opposed to repeated measures ANOVA, is that mixed effects regression modeling produces regression estimates that are robust in the presence of data missing at random whereas the repeated measures ANOVA requires that all observations have measurements at all time points (Quene and van den Bergh 2004). In other words, for repeated measures ANOVA, a single missing observation leads to dropping the case from the analysis or requires imputation of the missing data. In the mixed effects modeling, all available data can be used from each of the three time points without having to drop subjects who do not have complete data for all study years, or having to impute missing values. The PROC MIXED procedure in SAS was used to conduct all longitudinal analyses. The main predictor variable of the focal relationship was daily SSB consumption (in ounces) and the outcome variable was the two AP measures, Math and English z-scores, examined in separate models. There were 613 (N=238 at Year 1, N=198 at Year 2, and N=177 at Year 3) observations with complete data on all variables of interest in the final model.

Missing data were not imputed, instead, variables that were associated with missingness were included in the model. It appears that SSB consumption and AP predict missingness on mother's education, the variable with the most missing data. Thus, it appears that mother's education is missing at random which would warrant conducting multiple imputation but by including the variables associated with missingness, imputation is not necessary. In addition, imputing data for variables of drop-outs would most likely result in a poor imputation model because drop-out inherently implies that all the variables for an individual in a particular wave of data are missing, therefore, using non-missing variables as good predictors of the missing information in order to impute is not possible. Hence, multiple imputation was not conducted.

Two main regression models were examined, one with Math z-scores as the outcome variable and one with English z-scores as the outcome variable. An autoregressive (AR) covariance structure was used to account for the potentially higher correlation between observations that are closer together in time compared to observations that are further apart (i.e., Year 1 and Year 2 AP scores may be more highly correlated compared to Year 1 and Year 3). Based on theoretical support from the literature, the following potential confounders were included in the model: dietary variables, namely, fruit, vegetable, and snack intake; sociodemographic variables, namely, gender, race/ethnicity, grade level, and maternal education and employment; and activity behaviors, namely TV watching and physical activity; and the level of intervention which may have influenced both SSB consumption and AP. The moderating effects of diet (fruit, vegetable and snack intake) and physical activity were also assessed to determine whether different levels of diet quality and exercise exert a differential effect on the relationship between SSB consumption and academic performance.

A mixed effects linear regression model was used with subject treated as a random effect, and time and other covariates as fixed effects. Random effect variables assume different effects on the outcome over time for different participants while fixed effect variables assume the same effect on the outcome variable over time for different participants (Liu, Rovine et al. 2012). The mixed model used for estimating the association between SSB consumption and AP includes both level-1 (within-subject) predictors, such as dietary and physical activity variables, and level-2 (between-subject) predictors, such as gender and race:

$$Y_{ij} = \beta_0 + \beta_1 t_2 + \beta_2 t_3 + \beta_3 x_i + \beta_4 w_{1ij} + \beta_5 w_{2ij} + \beta_6 s_{1ij} + \beta_7 s_{2ij} + \text{interactions} + \delta_i + \varepsilon_{ij}$$

For example, for subject #1, that is male, if time=2, physical activity=everyday, and level of intervention=low, then the equation would be as follows:

$$Y_{1,2} = \beta_0 + \beta_1(1) + \beta_2(0) + \beta_3(1) + \beta_4(0) + \beta_5(1) + \beta_6(0) + \beta_7(0) + \text{interactions} + \delta_1 + \varepsilon_{12}$$

where:
Y_{ij} = academic performance
i = index for subject
j = index for time point (1, 2, or 3)
β_0 = intercept (value for Y when all predictors are zero or set at the reference group)
t_2 = indicator for time 2 (1=2nd time point, 0=otherwise; 1st time point is reference)
t_3 = indicator for time 3 (1=3rd time point, 0=otherwise; 1st time point is reference)
x_i = example of a time-invariant covariate for individual i (for example gender, 1=male)
w_{1ij} and w_{2ij} = example of a time-varying covariate that is categorical with three levels, for example, w_{1ij} =1 for being physically active everyday and 0 otherwise; w_{2ij} = 1 for being physically active 4-6 days/week and 0 otherwise; $\leq$3 days/week is reference
s_{1ij} = indicator for medium level of intervention (1=medium, 0=otherwise; low=reference)
s_{2ij} = indicator for high level of intervention (1=high, 0=otherwise; low=reference)
δ_i = subject random effect (level-2 residuals), distributed as normal N(0, σ^2)
ε_{ij} = error for subject i at time point j (level-1 residuals), distributed as normal N(0,σ^2)

Sensitivity analysis to examine the effects of flavored milk and 100% juice on AP was also conducted, as suggested by the literature (Park, Sherry et al. 2012; Fernandes 2012). Since this study is an investigation of the effects of sugar in liquid form (from SSBs) on academic performance, and flavored milk contains added sugar and 100% juice contains naturally occurring sugar, their effects were explored separately and also in combination with other SSBs which, unlike flavored milk and 100% juice, do not contain essential nutrients. Lastly, the Variation Inflation Factor (VIF) was estimated to assess multicollinearity among variables.

Mediation analysis to answer research question 2

Research Question 2: Are sociodemographic characteristics associated with SSB consumption? If they are, are the associations mediated by family meal behaviors?

Two-way analysis of variance (ANOVA) was conducted, using PROC GLM, to examine the association of categorical sociodemographic and family meal predictor variables with SSB consumption. Predictor variables included gender, race/ethnicity, mother's education and employment, frequency of having dinner with the family and frequency of the child assisting with meal preparation. Mediation analysis was conducted (as indicated by the INDIRECT macro in SAS 9.3) to test the mediating effects of family meal behaviors in the association between sociodemographic characteristics and SSB consumption. Bootstrapping was used to test mediation effects; the categorical mediators were examined as continuous variables to allow for easier interpretation of the results because having categorical predictors, with categorical mediators and continuous outcome variable would lead to coefficients in different metrics, yielding difficult to interpret results. Additionally, mediation with categorical mediators is not easily handled by currently available software. Bootstrapping provides a more accurate approach to calculating standard errors in mediation analysis, compared to the traditional delta method originally proposed by Baron and Kenny (1986), which has come under question (Zhao, Lynch et al. 2010). Since data on the mediators was only collected at baseline, for consistency purposes, OLS regression and mediation analysis were conducted using data only from Year 1 (N=245).

In the mediation test, the following associations were examined between sociodemographic predictors (X variables), family meal behaviors (M_1 and M_2) and SSB consumption (Y) (Figure 3.2):

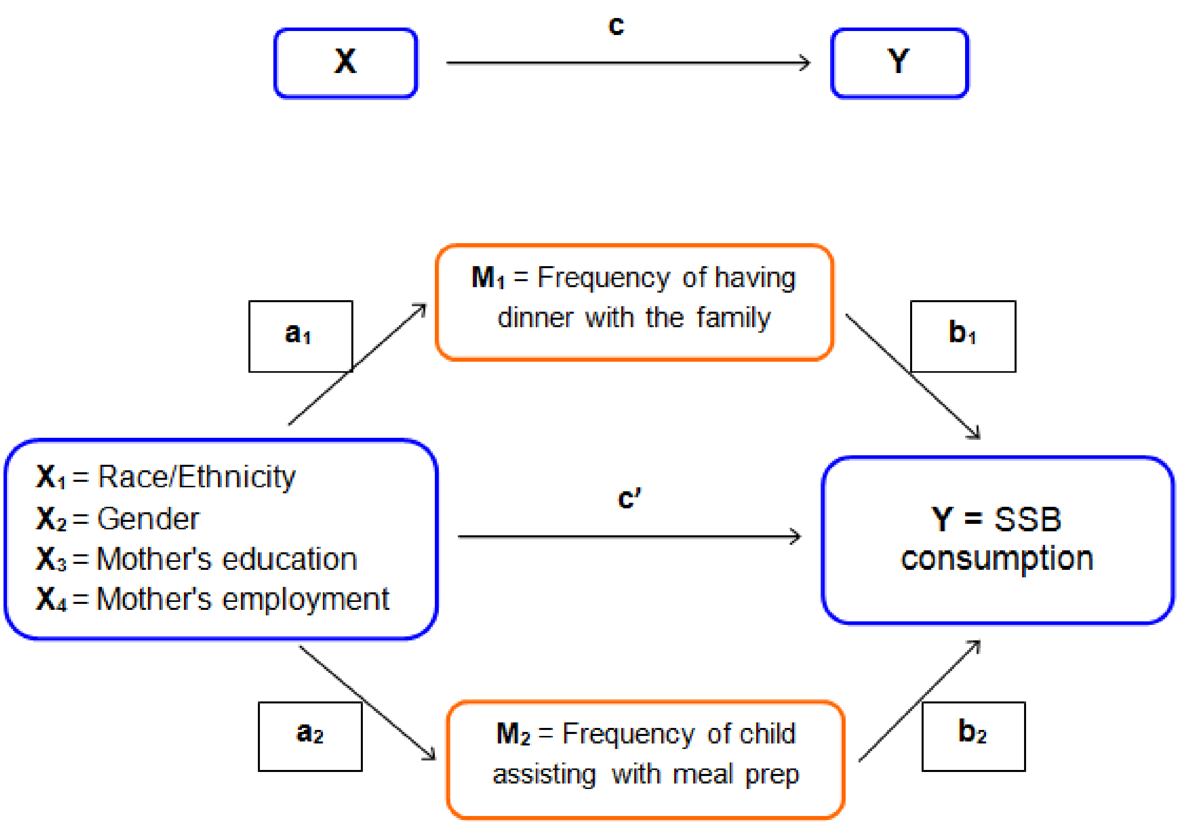
1) Sociodemographic predictors (X variables) and family meal behaviors (Mediators).

2) Family meal behaviors (Mediators) and SSB consumption (Y).

3) Sociodemographic predictors (X variables) and SSB consumption (Y).

4) Sociodemographic predictors (X variables) and SSB consumption (Y); indirect association between X and Y through M.

The potential mediating effects of family meal behaviors, namely frequency of 1) family dinner and 2) child assisting with meal preparation, were examined in the association between sociodemographic factors (gender, race/ethnicity, and maternal education and employment) and SSB consumption. Race/ethnicity, mother's education and mother's employment have more than two categories and they were dummy coded.



Legend:

X = Sociodemographic predictor variables
Y = Outcome variable
M_1 = Mediator 1
M_2 = Mediator 2
a_1 = Coefficient for direct path from X to M_1
a_2 = Coefficient for direct path from X to M_2
b_1 = Coefficient for direct path from M_1 to Y
b_2 = Coefficient for direct path from M_2 to Y
c = Coefficient for total effect of X on Y (unmediated model)
c' = Coefficient for direct effect of X on Y

Figure 3.2. Path-diagram showing each of the regressions examined in mediation analyses

Regression coefficients, bootstrapped standard errors and confidence intervals were calculated for the indirect effects of sociodemographic variables on SSB consumption through both mediators. For partial mediation to occur, the indirect effect has to be statistically significant, which may be indicated by confidence intervals that do not include zero. For example, if the coefficient of the indirect path between maternal employment and SSB consumption is significant when frequency of family dinner is tested as a mediator, then that signifies that part of the effect that maternal employment has on SSB consumption is explained through the frequency with which a family has dinner together.

Since flavored milk contains added sugars and may also be considered an SSB, sensitivity analysis was conducted to examine the mediation model with SSB including flavored milk as the outcome variable. Further sensitivity analysis including 100% fruit juice in the SSB variable (so as to assess all calorically-sweetened beverages) was also conducted.

Missing data analysis

In the analytic sample used in the mixed effects models, there were 238 participants at Year 1 and 177 participants at Year 3. The 25% reduction in sample size was a result of incomplete data on variables of interest for this study or were drop-outs, therefore, attrition analysis was conducted to determine if there were statistically significant differences in baseline characteristics between those who remained in the study (analytic sample) and those who were lost to follow up. The Mann-Whitney tests were used to examine these differences for continuous variables (SSB consumption and AP); and chi-square tests for categorical variable (sociodemographic and behavioral characteristics).

Chapter 4. RESULTS

This chapter reports the results for this study beginning with descriptive statistics to assess the distribution of sample characteristics and other variables of interest and bivariate analyses to identify relationships between pairs of variables. Subsequently, findings from repeated measures analysis and mediation analysis are presented to address this study's research questions and hypotheses.

Summary characteristics of study participants

Sociodemographic and behavioral characteristics

Descriptive statistics for the relevant sociodemographic and behavioral characteristics of the study participants at each of the three time points are presented in Tables 4.1 and 4.2. The sample size is based on the final analytic sample, which includes observations that had complete data on all the sociodemographic, dietary, and behavioral variables of interest for at least one of the three time points. At baseline, there were 238 fourth (54.6%) and fifth (45.4%) grade students that had complete data on all variables of interest. Approximately, sixty-one percent of the participants were female; 31.1% were White, 19.3% were African American, 12.2% were Latino, 8.0% were Asian/Pacific Islanders and 29.4% were of mixed or other race/ethnicity. In comparison, the proportions of Whites, African Americans, Latinos and Asians in the school district were 26.5%, 17.8%, 26.6%, and 25.4% respectively (http://www.ed-data.k12.ca.us). Nearly sixty four percent of the participants attended low-level intervention schools; 73.1% reported being physically active at least four days a week and 67.2% reported watching any television (Table 4.2). Approximately eighty-four percent of the participants' mothers reported having at least some college education; 88.7% were employed; 59.9%

reported that their children had dinner with the family every day and 50.7% reported that their children assisted with meal preparation at least once a week.

Level of intervention and frequency of physical activity and TV watching were assessed annually. In the second year of the study, 52.7% of the participants attended low-level intervention schools; 75.9% reported being physically active at least four days a week and 65.0% reported watching any television. In the third year of the study, 22.0% of the participants attended low-level intervention schools; 78.5% reported being physically active at least four days a week and 72.9% reported watching any television.

Means and standard deviations for SSB consumption, fruit and vegetable intake, and snack intake of the study participants at each of the three time points are presented in Table 4.2. Mean daily SSB consumption increased from 4.44 ounces (SD=6.20) in Year 1 to 5.49 ounces (SD=7.64) in Year 2 and remained stable at Year 3 at 5.44 ounces (SD=7.09). Mean daily fruit and vegetable intake was stable over the three years ranging from 2.20-2.27 cups per day (SD range = 1.26-1.39). Mean daily snack intake was also stable over the three years ranging from 0.93-1.04 ounces per day (SD range = 0.89-0.93).

Table 4.1. Sociodemographic characteristics of study participants

	Year 1 (N=238)	Year 2 (N=203)	Year 3 (N=177)
	%	%	%
Gender[a]			
Female	61.3	63.1	61.6
Male	38.7	37.0	38.4
Race/Ethnicity[a]			
White	31.1	32.0	33.9
African American	19.3	20.7	14.1
Latino	12.2	12.3	11.9
Asian	8.0	7.4	9.0
Mixed/Other	29.4	27.6	31.1
Grade[a]			
4th	54.6		
5th	45.4	58.6	
6th		41.4	57.1
7th			42.9
Mother's education[b]			
≤ High school diploma	15.6	14.8	15.3
Some college	24.8	25.1	20.3
Bachelor's degree	18.9	21.2	22.0
≥ Graduate school	40.8	38.9	42.4
Mother's employment[b]			
Not employed	11.3	9.4	7.9
Part-time (<40 hours/week)	39.5	40.4	42.4
Full-time (≥40hours/week)	49.2	50.3	49.7
Level of intervention[c]			
Low	63.9	52.7	22.0
Medium		5.9	32.2
High	36.1	41.4	45.8

Percentage may not add to 100% due to rounding
[a]Gender, race/ethnicity and grade were self-reported by students at baseline
[b]Mother's education and employment were self-reported by parents at baseline
[c]Degree of development of each of the three components of the intervention: hands-on cooking and gardening classes, food and dining services, and integration of nutrition education into the academic curriculum

Table 4.2. Behavioral characteristics of study participants

	Year 1 (N=238)		Year 2 (N=203)		Year 3 (N=177)	
	Mean (SD) or %	**Range**	**Mean (SD) or %**	**Range**	**Mean (SD) or %**	**Range**
SSB consumption[a,b,c] (ounces/day)	4.44 (6.20)	0-33	5.49 (7.64)	0-48	5.44 (7.09)	0-44.67
Fruit & Vegetable intake[a,b,c] (cups/day)	2.20 (1.26)	0-8.68	2.27 (1.38)	0-8.97	2.24 (1.29)	0.07-6.87
Snack intake[a,b,c] (ounces/day)	1.01 (0.94)	0-4.67	1.04 (0.89)	0-5.67	0.93 (0.93)	0-5.67
Physical activity[b,d]						
≤ 3 days/week	26.9		24.1		21.5	
> 3 days/week	73.1		75.9		78.5	
TV watching[b]						
Do not watch TV	32.8		35.0		27.1	
≤ 2 hours/day	36.1		30.5		37.9	
> 2 hours/day	31.1		34.5		35.0	
Dinner with the family[e]						
≤ 1 time/week	9.7		10.9		10.2	
Several times/week	30.4		31.2		30.1	
Everyday	59.9		57.9		59.7	
Child assisting in meal preparation[e]						
≤ 1 time/month	25.3		23.8		27.8	
2-3 times/month	24.1		24.8		23.9	
1 time/week	22.8		22.3		25.0	
Several times/week	27.9		29.2		23.3	

Percentages may not add to 100% due to rounding
SSB = Sugar-sweetened beverage
[a] Differences in means not significant; Tukey-Kramer adjustment applied for multiple comparisons
[b] Physical activity, TV watching, and intake of SSBs, fruit, vegetables and snacks were self-reported by students annually
[c] Mean daily intake of SSBs, fruit, vegetables and snacks calculated from 3-day food records
[d] Defined as frequency of participating in any physical activity (sports, dance, martial arts) that makes one sweat or breathe hard
[e] Frequency of family dinner and assisting with meal preparation were self-reported by parents at baseline

AP was assessed using Math and English standardized test scores. Mean Math z-score increased from 0.42 standard deviations (SD=1.09) above the mean in Year 1 to 0.63 standard deviations (SD=1.15) above the mean in Year 2 and 0.65 standard deviations (SD=1.06) above the mean in Year 3 (Table 4.3). The 0.21 and 0.23 standard deviation increases in Math z-score from Year 1 to Years 2 and 3 respectively translate into a 14-22 point increase in raw score (raw score range=150-600 depending on the grade level and year). Mean English z-score was fairly stable across the three years. It was 0.58 standard deviations above the mean in Year 1, 0.63 standard deviations above the mean in Year 2 and 0.58 standard deviations above the mean in Year 3; the difference between 0.58 and 0.63 standard deviations translates into just a 3 point increase in raw score (raw score range=150-600 depending on the grade level and year).

Table 4.3. Academic performance of study participants

	Year 1 (N=238)		**Year 2** (N=203)		**Year 3** (N=177)	
	Mean (SD)	**Range**	**Mean (SD)**	**Range**	**Mean (SD)**	**Range**
Math z-score[a]	0.42 (1.09)	-1.56-3.21	0.63 (1.15)	-1.72-3.55	0.65 (1.06)	-1.64-3.86
English z-score[a]	0.58 (0.97)	-1.69-3.13	0.63 (1.01)	-1.91-3.80	0.58 (0.96)	-2.19-3.57

[a] Math and English language scores obtained annually from the California STAR exam

The bar graphs in Figure 4.1, break down the types of beverages that were reported each of the three years and the percentage of each type in relation to all beverages (excluding water). The bar graphs display SSBs, flavored milk, and 100% juice in order to get a more comprehensive view of all beverages that were reported being consumed. The most frequently consumed SSBs were Sprite, Capri Sun fruit-flavored drink, and Minute-Maid lemonade. Relative to all beverages that were reported being consumed, the proportion of soda increased over time from 11% in Year 1 to 21% in Year 3; fruit-flavored drinks slightly increased from 27% in Year 1, to 29% in Year 2, but decreased to 20% in Year 3; flavored milk decreased over time from 10% in Year 1 to 5% in Year 3; 100% fruit juice decreased from 43% in Year 1, to 33% in Year 2, and increased to 39% in Year 3.

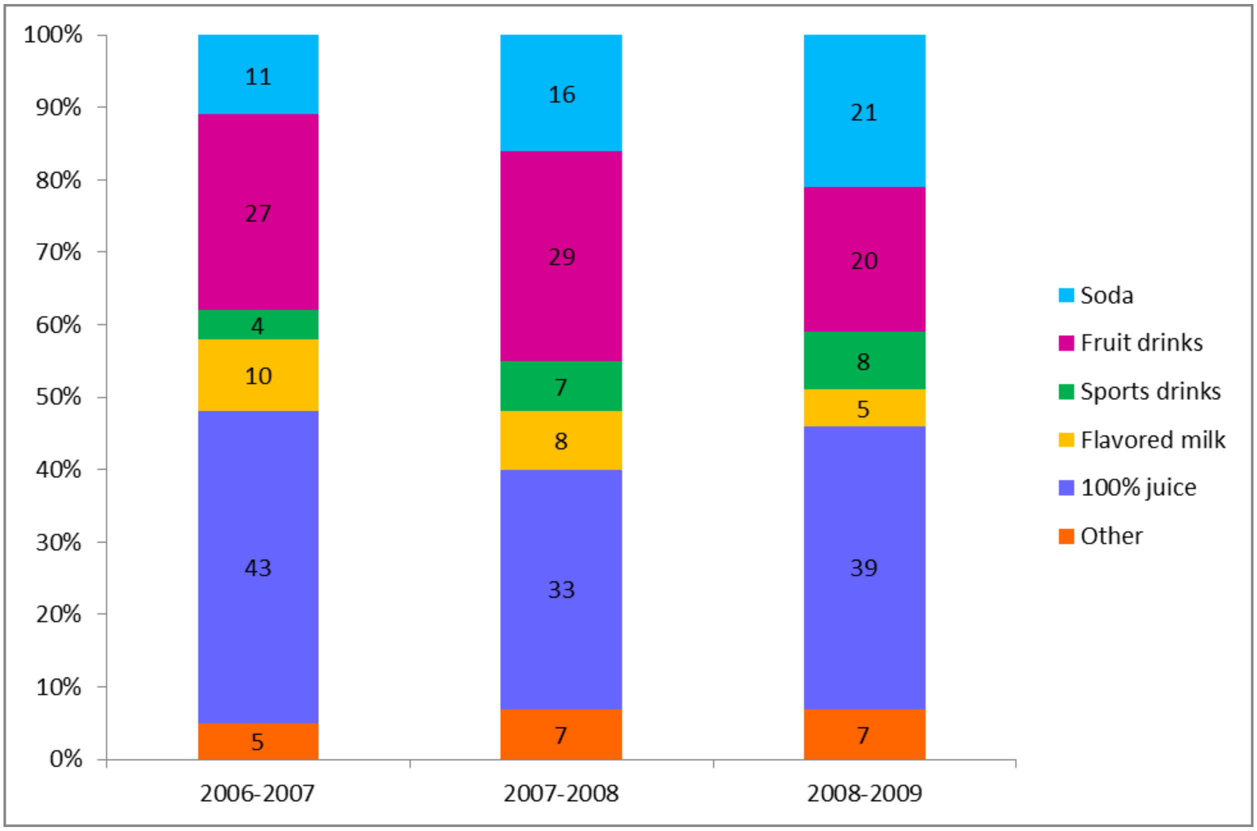


Figure 4.1. Types and proportions of beverages (excluding water) reported being consumed by study participants across the three time points

Bivariate analysis

Bivariate associations between SSB consumption, other dietary variables and AP (Math and English scores) at each of the three time points were examined via Spearman's correlation (Table 4.4). All significant correlations (r) ranged from 0.13-0.78, with most falling below 0.3. In general, dietary variables were positively correlated with each other. In year 1, fruit and vegetable intake, and snack intake were both positively associated with AP. SSB consumption was negatively associated with AP at all three time points (p<.01). Scatterplots of SSB consumption and AP further confirmed that as SSB consumption increased, AP decreased, and this trend was consistent for both Math and English scores at all three time points (see Appendix B).

Table 4.4. Spearman correlations between dietary and academic performance variables

	Math[a] (z-score)	**English**[a] (z-score)	**SSB**[b] (ounces/day)	**Fruit & Veg**[b] (cups/day)	**Snack**[b] (ounces/day)
Math	1				
Year 1					
Year 2					
Year 3					
English		1			
Year 1	0.78****				
Year 2	0.78****				
Year 3	0.79****				
SSB			1		
Year 1	-0.20**	-0.19**			
Year 2	-0.23***	-0.27***			
Year 3	-0.21**	-0.24**			
Fruit & Veg				1	
Year 1	0.13*	0.20**	0.01		
Year 2	0.04	0.03	0.03		
Year 3	0.14	0.11	-0.02		
Snack					1
Year 1	0.24***	0.28****	0.12	0.15*	
Year 2	0.13	0.11	0.22**	0.11	
Year 3	0.03	0.04	0.28***	0.25***	

*p<0.05, **p<0.01, ***p<0.001, ****p<0.0001
SSB = Sugar-sweetened beverage consumption
[a] Math and English language scores obtained annually from the California STAR exam
[b] Intakes of fruits, vegetables, snacks and sugar-sweetened beverages (SSBs) were self-reported by students annually on 3-day food records

One-way ANOVAs were conducted to examine bivariate associations of sociodemographic and behavioral categorical variables with SSB consumption and AP (Tables 4.5-4.7). Relevant associations are briefly described here. There were racial/ethnic differences in SSB consumption (Table 4.5) and in AP (Tables 4.6-4.7) at all three time points. Specifically, African American and Latino children had a higher mean daily SSB consumption and lower mean Math and English z-scores compared to their White and Asian counterparts. Significant differences in mean daily SSB consumption are noted in Year 2 between Latino (11.37 ounces/day), White (3.74 ounces/day) and Asian (0.68 ounces/day) children. At each time point, older children had a higher mean daily intake of SSBs compared to younger children (no statistically significant differences). Across all three time points, children whose mothers had up to some college education had higher SSB consumption and lower AP scores compared to children whose mothers had obtained at least a Bachelor's degree, and children whose mothers were not employed had higher SSB consumption and lower AP scores compared to children whose mothers were employed. Children who attended schools that had implemented a high-level of intervention, had higher mean daily SSB consumption (Year 1 only) and lower mean AP scores (Years 1 and 2 only), compared to children who attended low-level of intervention schools.

Children who watched TV more than 2 hours/day had significantly higher mean daily SSB consumption (Years 1 and 2 only) and significantly lower mean AP scores (Years 1, 2 and 3), compared to children who reported not watching any television. Children who exercised more than three days per week had significantly higher mean AP (Year 3 only) compared to those who exercised no more than 3 days/week. Children who participated in meal preparation several times a week, had significantly higher SSB consumption (Year 1 only) compared to those who only participated less than once a month (6.64 ounces vs 3.33, $p<0.01$). Lastly, children who had dinner with their family no more than once a week had higher SSB consumption and lower AP, compared to children who had dinner with their family several times a week or everyday (significant differences only in Year 2 English z-scores).

Table 4.5. One-way ANOVA for mean SSB consumption for defined categories of sociodemographic and behavioral variables at each of the three time points (continued)

	SSB consumption[a] (ounces/day)					
	Year 1 (N=238)		Year 2 (N=203)		Year 3 (N=177)	
	mean	CI	Mean	CI	mean	CI
Gender[b]						
Female	4.47	3.45, 5.48	5.58	4.25, 6.92	5.08	3.74, 6.42
Male	4.38	3.11, 5.66	5.32	3.58, 7.07	6.02	4.32, 7.71
Race/Ethnicity[b,g]						
White	3.42	2.01, 4.83	**3.74**[1]	1.99, 5.50	4.09	2.33, 5.86
African American	6.36	4.58, 8.15	7.42	5.24, 9.60	8.35	5.61, 11.08
Latino	5.57	3.32, 7.82	**11.37**[1,2,3]	8.54, 14.21	8.65	5.67, 11.64
Asian	3.60	0.82, 6.38	**0.68**[2]	-2.97, 4.34	3.91	0.50, 7.33
Mixed/other	4.00	2.55, 5.45	**4.72**[3]	2.83, 6.61	4.80	2.96, 6.65
Grade[b]						
4th	4.37	3.30, 5.44				
5th	4.51	3.33, 5.69	4.58	3.21, 5.95		
6th			6.77	5.14, 8.40	5.00	3.60, 6.39
7th					6.03	4.42, 7.63
Mother's education[c,g]						
≤ High school	**3.65**[1]	1.69, 5.61	**8.65**	5.96, 11.33	6.66	3.96, 9.36
Some college	**7.21**[1,2]	5.67, 8.75	7.06	5.00, 9.12	7.73	5.43, 10.03
Bachelor's degree	4.08	2.31, 5.85	5.21	2.97, 7.45	3.72	1.51, 5.94
≥ Graduate school	**3.21**[2]	2.01, 4.42	**3.42**	1.77, 5.08	4.79	3.17, 6.41
Mother's employment[c]						
Not employed	5.44	3.08, 7.79	6.52	4.51, 7.42	9.27	5.59, 12.96
Part-time (<40 hrs/wk)	4.27	3.00, 5.53	5.52	3.72, 12.40	4.08	2.49, 5.67
Full-time (≥40 hrs/wk)	4.34	3.21, 5.47	5.26	2.88, 6.15	5.99	4.52, 7.45

Table 4.5 cont.

	SSB consumption[a] (ounces/day)					
	Year 1 (N=238)		**Year 2** (N=203)		**Year 3** (N=177)	
	Mean	**CI**	**mean**	**CI**	**mean**	**CI**
Level of intervention[d,g]						
Low	**3.54**	2.56, 4.51	5.97	4.51, 7.42	6.98	4.78, 9.18
Medium			8.06	3.72, 12.40	6.69	4.87, 8.51
High	**6.02**	4.72, 7.32	4.51	2.87, 6.15	3.82	2.29, 5.35
Physical activity[e,f]						
≤ 3 days/wk	3.26	1.74, 4.79	7.05	4.90, 9.19	6.12	3.86, 8.38
> 3 days/week	4.87	3.94, 5.79	4.99	3.78, 6.20	5.25	4.06, 6.44
TV watching[f,g]						
Do not watch TV	**2.89**	1.54, 4.24	3.33	1.57, 5.08	4.59	2.61, 6.57
≤ 2 hrs/day	4.13	2.85, 5.42	6.49	4.61, 8.37	**4.08**	2.40, 5.75
> 2 hrs/day	**6.42**	5.03, 7.80	6.79	5.02, 8.56	**7.57**	5.83, 9.31
Dinner with the family[c]						
≤ 1 time/week	5.76	3.21, 8.30	8.56	5.36, 11.73	8.37	5.08, 11.65
Several times/week	5.11	3.66, 6.55	6.16	4.28, 8.34	4.69	2.78, 6.61
Everyday	3.91	2.88, 4.94	4.59	3.21, 5.98	5.37	4.19, 6.98
Child assisting in meal preparation[c,g]						
≤ 1 time/month	**3.33**[1]	1.79, 4.87	4.36	2.18, 6.54	3.94	1.90, 5.97
2-3 times/month	4.46	2.88, 6.04	6.89	4.76, 9.03	7.57	5.44, 9.71
1 time/week	**2.84**[2]	1.21, 4.46	4.84	2.56, 7.09	4.23	2.14, 6.31
Several times/week	**6.64**[1,2]	5.17, 8.11	5.66	3.69, 7.63	6.29	4.13, 8.45

SSB = sugar-sweetened beverage
[a] Mean daily SSB consumption calculated from students' 3-day food records, recorded annually
[b] Gender, race/ethnicity and grade were self-reported by students at baseline
[c] Mother's education and employment, frequency of family dinner and assisting with meal preparation were self-reported by parents at baseline
[d] Degree of development of each of the three components of the intervention: hands-on cooking and gardening classes, food and dining services, and integration of nutrition education into the academic curriculum
[e] Defined as frequency of participating in any physical activity (sports, dance, martial arts) that makes one sweat or breathe hard
[f] Physical activity and TV watching were self-reported by the students annually
[g]Significant differences between groups during at least one of the time points; indicated in bold and by identical numeric superscripts when more than one pairwise comparison is significant
Tukey-Kramer adjustment applied for multiple comparisons

Table 4.6. One-way ANOVA for mean Math z-score for defined categories of sociodemographic and behavioral variables at each of the three time points (continued)

	Math z-score[a]					
	Year 1 (N=238)		Year 2 (N=203)		Year 3 (N=177)	
	mean	CI	mean	CI	mean	CI
Gender[b]						
Female	0.35	0.18, 0.53	0.52	0.32, 0.72	0.56	0.36, 0.76
Male	0.54	0.31, 0.76	0.82	0.56, 1.08	0.78	0.53, 1.04
Race/Ethnicity[b,g]						
White	**1.02**[1,2,3]	0.79, 1.24	**1.26**[1,2,3]	1.01, 1.50	**1.18**[1,2,3]	0.94, 1.42
African American	**-0.24**[1,4,5]	-0.52, 0.05	**-0.12**[1,4,5]	-0.43, 0.19	**-0.33**[1,4,5]	-0.70, 0.04
Latino	**-0.16**[2,4]	-0.52, 0.20	**-0.01**[2,4]	-0.41, 0.40	**0.23**[2]	-0.18, 0.63
Asian	**0.76**[4]	0.31, 1.20	**1.09**[4]	0.57, 1.60	**1.01**[4]	0.55, 1.47
Mixed/other	**0.38**[3,5]	0.15, 0.62	**0.63**[3,5]	0.36, 0.90	**0.57**[3,5]	0.32, 0.82
Grade[b]						
4th	0.43	0.24, 0.62				
5th	0.41	0.21, 0.62	0.72	0.51, 0.92		
6th			0.51	0.26, 0.75	0.60	0.39, 0.81
7th					0.71	0.47, 0.95
Mother's education[c,g]						
≤ High school	**-0.23**[1,2]	-0.57, 0.10	**-0.01**[1]	-0.40, 0.39	**0.25**[1]	-0.14, 0.64
Some college	**-0.02**[3,4]	-0.28, 0.24	**0.15**[2]	-0.14, 0.45	**0.21**[2]	-0.12, 0.55
Bachelor's degree	**0.66**[1,3]	0.37, 0.96	**0.89**[1,2]	0.57, 1.21	0.72	0.40, 1.04
≥ Graduate school	**0.84**[2,4]	0.63, 1.04	1.04	0.80, 1.28	**0.96**[1,2]	0.73, 1.19
Mother's employment[c]						
Not employed	0.08	-0.33, 0.48	0.28	-0.23, 0.79	0.10	-0.46, 0.65
Part-time (<40 hrs/wk)	0.68	0.46, 0.90	0.90	0.66, 1.15	0.81	0.57, 1.05
Full-time (≥40 hrs/wk)	0.30	0.10, 0.50	0.48	0.25, 0.70	0.60	-0.38, 0.82
Level of intervention[d,g]						
Low	**0.66**	0.49, 0.83	**0.85**	0.64, 1.07	0.55	0.22, 0.88
Medium			0.47	-0.17, 1.11	0.42	0.15, 0.70
High	**0.00**	-0.22, 0.22	**0.37**	0.12, 0.61	0.85	0.62, 1.08
Physical activity[e,f,g]						
≤ 3 days/wk	0.34	0.07, 0.61	0.42	0.10, 0.74	**0.12**	-0.22, 0.45
> 3 days/week	0.46	0.29, 0.62	0.70	0.52, 0.88	**0.79**	0.62, 0.96
TV watching[f,g]						
Do not watch TV	**0.67**	0.43, 0.91	0.73	0.47, 1.00	**0.82**[1]	0.53, 1.11
≤ 2 hrs/day	0.48	0.25, 0.71	0.82	0.53, 1.10	**0.90**[2]	0.65, 1.14
> 2 hrs/day	**0.11**	-0.14, 0.35	0.36	0.09, 0.63	**0.24**[1,2]	-0.01, 0.50

Table 4.6 cont.

	Math z-score[a]					
	Year 1 (N=238)		Year 2 (N=203)		Year 3 (N=177)	
	mean	CI	mean	CI	mean	CI
Dinner with the family[c]						
≤ 1 time/week	0.40	-0.05, 0.85	0.24	-0.23, 0.72	0.21	-0.28, 0.70
Several times/week	0.32	0.06, 0.57	0.49	0.21, 0.77	0.55	0.26, 0.84
Everyday	0.48	0.30, 0.66	0.77	0.56, 0.98	0.77	0.56, 0.97
Child assisting in meal preparation[c,g]						
≤ 1 time/month	**0.75**	0.48, 1.02	**1.17**	0.86, 1.49	0.97	0.67, 1.27
2-3 times/month	0.36	0.08, 0.64	0.47	0.16, 0.78	0.59	0.27, 0.91
1 time/week	0.41	0.12, 0.70	0.57	0.24, 0.89	0.58	0.26, 0.89
Several times/week	**0.22**	-0.05, 0.47	**0.39**	0.11, 0.68	0.41	0.08, 0.73

[a] Math scores obtained from the California STAR exam
[b] Gender, race/ethnicity and grade were self reported by students at baseline
[c] Mother's education and employment, frequency of family dinner and assisting with meal preparation were self-reported by parents at baseline
[d] Degree of development of each of the three components of the intervention: hands-on cooking and gardening classes, food and dining services, and integration of nutrition education into the academic curriculum
[e] Defined as frequency of participating in any physical activity (sports, dance, martial arts) that makes one sweat or breathe hard
[f] Physical activity and TV watching were self-reported by the students annually
[g] Significant differences between groups during at least one of the time points; indicated in bold and by identical numeric superscripts when more than one pairwise comparison is significant
Tukey-Kramer adjustment applied for multiple comparisons

Table 4.7. One-way ANOVA for mean English z-score for defined categories of sociodemographic and behavioral variables at each of the three time points (continued)

	English z-score[a]					
	Year 1 (N=238)		Year 2 (N=203)		Year 3 (N=177)	
	mean	CI	mean	CI	mean	CI
Gender[b]						
Female	0.64	0.48, 0.80	0.66	0.49, 0.84	0.62	0.44, 0.81
Male	0.49	0.29, 0.69	0.58	0.35, 0.81	0.51	0.28, 0.74
Race/Ethnicity[b,g]						
White	**1.19[1,2,3]**	1.00, 1.39	**1.18[1,2,3]**	0.96, 1.40	**0.99[1,2]**	0.76, 1.21
African American	**-0.08[1,4,5]**	-0.32, 0.17	**-0.03[1,4,5]**	-0.30, 0.24	**-0.27[1,3,4]**	-0.62, 0.07
Latino	**0.07[2,4]**	-0.24, 0.38	**-0.03[2]**	-0.38, 0.32	**0.29[2]**	-0.09, 0.66
Asian	**0.64[4]**	0.26, 1.02	**1.00[4]**	0.55, 1.45	**0.75[4]**	0.32, 1.18
Mixed/other	**0.57[3,5]**	0.37, 0.77	**0.69[3,5]**	0.46, 0.93	**0.58[3]**	0.35, 0.81
Grade[b]						
4th	0.53	0.36, 0.70				
5th	0.65	0.47, 0.83	0.70	0.52, 0.88		
6th			0.54	0.32, 0.75	0.57	0.38, 0.76
7th					0.59	0.37, 0.80
Mother's education[c,g]						
≤ High school	**-0.04[1,2]**	-0.34, 0.25	**-0.01[1,2]**	-0.35, 0.32	**0.12[1]**	-0.23, 0.47
Some college	**0.23[3]**	0.01, 0.46	**0.20[3,4]**	-0.06, 0.45	**0.19[2]**	-0.11, 0.49
Bachelor's degree	**0.65[1]**	0.39, 0.91	**0.76[1,3]**	0.48, 1.03	0.66	0.37, 0.95
≥ Graduate school	**1.00[2,3]**	0.82, 1.18	**1.09[2,4]**	0.89, 1.30	**0.89[1,2]**	0.68, 1.10
Mother's employment[c,g]						
Not employed	**0.15**	-0.21, 0.51	**0.18**	-0.27, 0.62	**-0.10**	-0.59, 0.40
Part-time (<40 hrs/wk)	**0.82**	0.62, 1.00	**0.86**	0.65, 1.08	**0.79**	0.58, 1.00
Full-time (≥40 hrs/wk)	0.49	0.32, 0.67	0.54	0.34, 0.73	0.50	0.31, 0.70
Level of intervention[d,g]						
Low	0.71	0.55, 0.86	0.73	0.53, 0.92	0.58	0.29, 0.88
Medium			0.70	0.09, 1.24	**0.28**	0.04, 0.53
High	0.36	0.16, 0.57	0.51	0.29, 0.73	**0.78**	0.58, 0.99
Physical activity[e,f,g]						
≤ 3 days/wk	0.46	0.22, 0.69	0.46	0.18, 0.74	**0.18**	-0.12, 0.48
> 3 days/week	0.63	0.49, 0.77	0.69	0.53, 0.85	**0.69**	0.53, 0.84
TV watching[f,g]						
Do not watch TV	**0.89**	0.68, 1.10	**0.88[1]**	0.65, 1.10	**0.86**	0.60, 1.13
≤ 2 hrs/day	0.61	0.41, 0.81	**0.77[2]**	0.52, 1.01	0.68	0.45, 0.90
> 2 hrs/day	**0.22**	0.01, 0.44	**0.27[1,2]**	0.04, 0.50	**0.25**	0.02, 0.48

Table 4.7 cont.

	English z-score[a]					
	Year 1 (N=238)		Year 2 (N=203)		Year 3 (N=177)	
	mean	CI	mean	CI	mean	CI
Dinner with the family[c,g]						
≤ 1 time/week	0.25	-0.15, 0.65	**0.15**	-0.26, 0.57	0.07	-0.37, 0.52
Several times/week	0.52	0.30, 0.75	0.54	0.29, 0.79	0.66	0.40, 0.92
Everyday	0.67	0.51, 0.83	**0.77**	0.59, 0.96	0.62	0.44, 0.81
Child assisting in meal preparation[c]						
≤ 1 time/month	0.80	0.55, 1.04	0.96	0.67, 1.24	0.72	0.45, 0.99
2-3 times/month	0.62	0.37, 0.87	0.56	0.28, 0.84	0.56	0.28, 0.87
1 time/week	0.60	0.34, 0.86	0.59	0.30, 0.89	0.59	0.31, 0.88
Several times/week	0.35	0.11, 0.58	0.47	0.21, 0.73	0.42	0.12, 0.71

[a] English language scores obtained from the California STAR exam
[b] Gender, race/ethnicity and grade were self reported by students at baseline
[c] Mother's education and employment, frequency of family dinner and assisting with meal preparation were self-reported by parents at baseline
[d] Degree of development of each of the three components of the intervention: hands-on cooking and gardening classes, food and dining services, and integration of nutrition education into the academic curriculum
[e] Defined as frequency of participating in any physical activity (sports, dance, martial arts) that makes one sweat or breathe hard
[f] Physical activity and TV watching were self-reported by the students annually
[g] Significant differences between groups during at least one of the time points; indicated in bold and by identical numeric superscripts when more than one pairwise comparison is significant
Tukey-Kramer adjustment applied for multiple comparisons

Multivariate analysis

Prior to examining mixed effects models, baseline data (N=238) were assessed using Ordinary Least Squares regression to determine the contribution of selected predictor variables in explaining the variation in AP. Results are presented in Table 4.8 and briefly described here. Sociodemographic variables (race/ethnicity and mother's education) had the greatest effect on AP. Specifically, compared to White children, African American children scored 0.74 standard deviations ($p<0.001$) lower in Math and 0.94 standard deviations ($p<0.0001$) lower in English, and Latino children scored 0.62 standard deviations ($p<0.01$) lower in Math and 0.68 standard deviations ($p<0.001$) lower in English, controlling for all other variables. Further, compared to children whose mothers had no more than a high-school education, children whose mothers had a Bachelor's degree scored 0.64 standard deviations ($p<0.01$) higher in Math and those with a graduate or professional degree scored 0.78 standard deviations ($p<0.001$) higher in Math and 0.67 standard deviation ($p<0.0001$) higher in English, controlling for all other variables. Lastly, SSB consumption was inversely associated with AP (for both Math and English outcome variables) when no other predictors were in the model ($b=-0.03$, $p<0.01$) but after controlling for all other variables, the association remained significant only for English z-score ($b=-0.02$, $p<0.05$). These baseline findings served as a guide in the development of mixed effects models in the next phase of analysis.

Table 4.8. Regression model predicting academic performance in Year 1

	Math z-score[a]			English z-score[a]		
	b	(SE)	CI	b	(SE)	CI
SSB consumption[b] (ounces/day)	-0.01	(0.01)	-0.03, 0.01	**-0.02***	(0.009)	-0.04, 0.00
Level of intervention[c]						
(Low, Ref)						
High	**-0.37****	(0.13)	-0.63, -0.10	-0.02	(0.11)	-0.25, 0.20
Gender[d]						
(Female, Ref)						
Male	0.16	(0.13)	-0.09, 0.41	-0.17	(0.11)	-0.38, 0.05
Race/Ethnicity[d]						
(White, Ref)						
African American	**-0.74*****	(0.20)	-1.14, -0.34	**-0.94*******	(0.17)	-1.28, -0.59
Latino	**-0.62****	(0.23)	-1.09, -0.16	**-0.68*****	(0.20)	-1.08, -0.27
Asian	0.18	(0.25)	-0.32, 0.69	-0.22	(0.22)	-0.66, 0.22
Mixed/Other	**-0.42***	(0.16)	-0.75, -0.10	**-0.45****	(0.14)	-0.73, -0.17
Grade[d]						
(4th, Ref)						
5th	-0.06	(0.13)	-0.28, 0.24	0.01	(0.11)	-0.21, 0.24
Mother's education[b,e]						
(≤ High school diploma, Ref)						
Some college	0.37	(0.20)	-0.06, 0.80	0.37	(0.18)	0.00, 0.74
Bachelor's degree	**0.64****	(0.24)	0.17, 1.11	0.38	(0.21)	-0.03, 0.78
≥ Graduate school	**0.78*****	(0.21)	0.36, 1.21	**0.67*****	(0.19)	0.30, 1.03
Mother's employment[b,e]						
(Not employed, Ref)						
Part-time (<40 hrs/week)	0.16	(0.22)	-0.30, 0.56	0.21	(0.19)	-0.16, 0.58
Full-time (≥40 hrs/week)	-0.21	(0.22)	-0.65, 0.21	-0.09	(0.19)	-0.46, 0.28
Fruit & vegetable intake[b] (cups/day)	0.02	(0.05)	-0.08, 0.12	0.02	(0.04)	-0.07, 0.11
Snack intake[b] (ounces/day)	0.09	(0.07)	-0.04, 0.23	0.10	(0.06)	-0.02, 0.21
Physical activity[b, f]						
(≤ 3 days/week, Ref)						
> 3 days/week	0.06	(0.14)	-0.21, 0.34	0.15	(0.12)	-0.09, 0.39
TV watching[b]						
(Do not watch TV, Ref)						
≤ 2 hours/day	-0.02	(0.15)	-0.31, 0.28	-0.08	(0.13)	-0.33, 0.18
> 2 hours/day	-0.09	(0.17)	-0.42, 0.25	-0.19	(0.15)	-0.48, 0.10

*p<0.05, **p<0.01, ***p<0.001, ****p<0.0001

SSB = Sugar-sweetened beverage

[a] Math and English language scores obtained from the California STAR exams

[b] Physical activity, TV watching and intake of SSBs, fruit, vegetables and snacks were self-reported by students annually

[c] Defined as degree of inclusion of the following nutritional components in school program: hands-on cooking and gardening classes, changes in food and dining services, and integration of nutrition education into the academic curriculum
[d] Gender, race/ethnicity and grade were self reported by students at baseline
[e] Mother's education and employment were self-reported by parents at baseline
[f] Defined as frequency of participating in any physical activity (sports, dance, martial arts) that makes one sweat or breathe hard

To answer the first research question, **"**Is SSB consumption associated with academic performance in elementary and middle school children?" several mixed effects models were developed to test the hypotheses listed on pages 37-38. The first model included sociodemographic variables as covariates to estimate the effects of SSB consumption on AP (Tables 4.9 and 4.10). In the second model, behavioral variables of interest were added, namely, intakes of snacks, fruits and vegetables, and physical activity, to determine if these variables may further confound the effects of SSB on AP. The third, fourth and fifth models tested interactions between those behavioral variables and SSB consumption.

Race/ethnicity and mother's education were consistently significant predictors of AP across all models, for both Math and English z-scores; being African American or Latino, or having a mother with a graduate or professional degree had the greatest effect. Specifically, compared to White children, African American children scored 1.16 standard deviations ($p<0.0001$) lower in Math (Table 4.9, Model 1) and 1.03 standard deviations ($p<0.0001$) lower in English (Table 4.10, Model 1) and Latino children scored 0.89 standard deviations ($p<0.0001$) lower in both Math and English (Tables 4.9 and 4.10, Model 1). Further, compared to children whose mothers had attained no more than a high-school education, children whose mothers had obtained a graduate or professional degree scored 0.77 standard deviations ($p=0.0001$) higher in Math and 0.75 standard deviation ($p<0.0001$) higher in English, controlling for all other variables.

As shown in Table 4.9 (Model 2) none of the behavioral variables was a significant predictor of Math z-score. The interactions between SSB consumption and other behavioral variables (fruit and vegetable intake, snack intake, physical activity) were tested one at a time. There was no evidence that any of these variables modified the effect of SSB consumption on Math z-score.

In Table 4.10, we show associations of the variables examined with English z-score. In comparison to our observations with regard to the association of SSB consumption with Math z-score, we note that SSB consumption is significantly associated with English z-score when the behavioral variables were controlled for. In particular, for each one ounce increase in daily SSB consumption, AP decreases by 0.006 standard deviations ($p<0.05$). This translates into a decrease of 0.084 standard deviations in English z-score for each 12-ounce can of soda, an effect that is about one-fifth that of having a mother with no more than high school education compared to a mother with some college. Snack intake and TV watching were also significant predictors of AP. For each one ounce increase in snack intake, English z-score increases by 0.08 standard deviations ($p<0.01$). Children who watched more than 2 hours of TV per day scored 0.24 standard deviations ($p<0.01$) lower in English compared to those who did not watch any television. In addition, year and level of intervention were control variables in all models that were tested and results show that in the second year of the study, Math z-score was 0.28 standard deviations ($p<0.05$) higher compared to the first year. In addition, children who attended high-level-of-intervention schools scored 0.14 standard deviations ($p<0.05$) lower in Math than those who attended low-level-of-intervention schools.

In summary, the primary hypothesis of this study was partially supported to the extent that SSB consumption was associated with lower AP, but only when English z-score was the outcome variable. The second and third hypotheses of the study were not supported as there was no evidence to suggest that the effect of SSB consumption on AP was modified by the selected dietary variables or by physical activity.

Table 4.9. Mixed effects models predicting Math z-score

	Math z-score[a]				
	Model 1 b (SE)	Model 2 b (SE)	Model 3 b (SE)	Model 4 b (SE)	Model 5 b (SE)
SSB consumption[b] (ounces/day)	-0.003 (0.004)	-0.003 (0.004)	0.002 (0.008)	-0.003 (0.006)	-0.004 (0.007)
Fruit & vegetable intake[b] (cups/day)		-0.026 (0.022)	-0.017 (0.026)	-0.026 (0.022)	-0.026 (0.022)
Snack intake[b] (ounces/day)		0.011 (0.033)	0.010 (0.033)	0.007 (0.039)	0.011 (0.033)
Physical activity[b,c]					
Ref: ≤ 3 days/week					
> 3 days/week		0.026 (0.063)	0.026 (0.063)	0.026 (0.063)	0.017 (0.075)
TV watching[a]					
Ref:Do not watch TV					
≤ 2 hours/day		-0.035 (0.068)	-0.035 (0.069)	-0.036 (0.069)	-0.035 (0.069)
> 2 hours/day		-0.046 (0.099)	-0.045 (0.099)	-0.046 (0.099)	-0.046 (0.099)
SSB*Fruit/Veg Intake			-0.002 (0.003)	---	---
SSB*Snack Intake				0.001 (0.004)	---
SSB*Physical activity					
Ref: ≤ 3 days/week					
> 3 days/week					0.002 (0.008)

*p<0.05, **p<0.01, ***p<0.001, ****p<0.0001
SSB = Sugar-sweetened beverage
[a] Math scores obtained from the California STAR exam
[b] Physical activity, TV watching and intake of SSBs, fruit, vegetables and snacks were self-reported by students annually
[c] Defined as frequency of participating in any physical activity (sports, dance, martial arts) that makes one sweat or breathe hard
All models adjusted for child's gender, race/ethnicity and grade, mother's education and employment, year of measurement, and level of intervention

Table 4.10. Mixed effects models predicting English z-score

	English z-score[a]				
	Model 1 b (SE)	Model 2 b (SE)	Model 3 b (SE)	Model 4 b (SE)	Model 5 b (SE)
SSB consumption[b] (ounces/day)	-0.006 (0.003)	-0.008* (0.003)	-0.017* (0.007)	-0.009 (0.005)	-0.010 (0.006)
Fruit & vegetable intake[b] (cups/day)		-0.009 (0.019)	-0.029 (0.023)	-0.010 (0.019)	-0.010 (0.019)
Snack intake[b] (ounces/day)		0.085** (0.028)	0.085** (0.029)	0.080* (0.034)	0.084** (0.028)
Physical activity[b,c]					
Ref: ≤ 3 days/week					
> 3 days/week		0.065 (0.055)	0.067 (0.055)	0.066 (0.055)	-0.049 (0.066)
TV watching[b]					
Ref: Do not watch TV					
≤ 2 hours/day		-0.101 (0.060)	-0.101 (0.060)	-0.102 (0.060)	-0.101 (0.060)
> 2 hours/day		-0.243** (0.087)	-0.245** (0.087)	-0.242** (0.087)	-0.243** (0.087)
SSB*Fruit/Veg Intake			0.003 (0.002)	---	---
SSB*Snack Intake				0.001 (0.003)	---
SSB*Physical activity					
Ref: ≤ 3 days/week					
> 3 days/week					0.003 (0.007)

*p<0.05, **p<0.01, ***p<0.001, ****p<0.0001
SSB = Sugar-sweetened beverage
[a] English scores obtained from the California STAR exam
[b] Physical activity, TV watching and intake of SSBs, fruit, vegetables and snacks were self-reported by students annually
[c]Defined as frequency of participating in any physical activity (sports, dance, martial arts) that makes one sweat or breathe hard
All models adjusted for child's gender, race/ethnicity and grade, mother's education and employment, year of measurement, and level of intervention

Mediation analysis

To answer the second research question, "Is SSB consumption associated with sociodemographic characteristics, namely race/ethnicity, and maternal education and employment? If it is, do family meal behaviors, specifically frequency of children assisting with meal preparation and having dinner with their family, mediate these associations?" baseline data (N=245) were assessed using Ordinary Least Squares regression to determine the contribution of selected sociodemographic and family meal variables to variation in SSB consumption. Results are presented in Table 4.11 and briefly described here. Mother's education was the only significant predictor of SSB consumption, after controlling for other sociodemographic and family meal variables. Specifically, children whose mothers had some college education (but did not obtain a college degree) consumed 3.9 more ounces ($p<0.01$) of SSBs per day, compared to children whose mothers had no more than a high-school education. These sociodemographic and family meal variables were subsequently tested in mediation models.

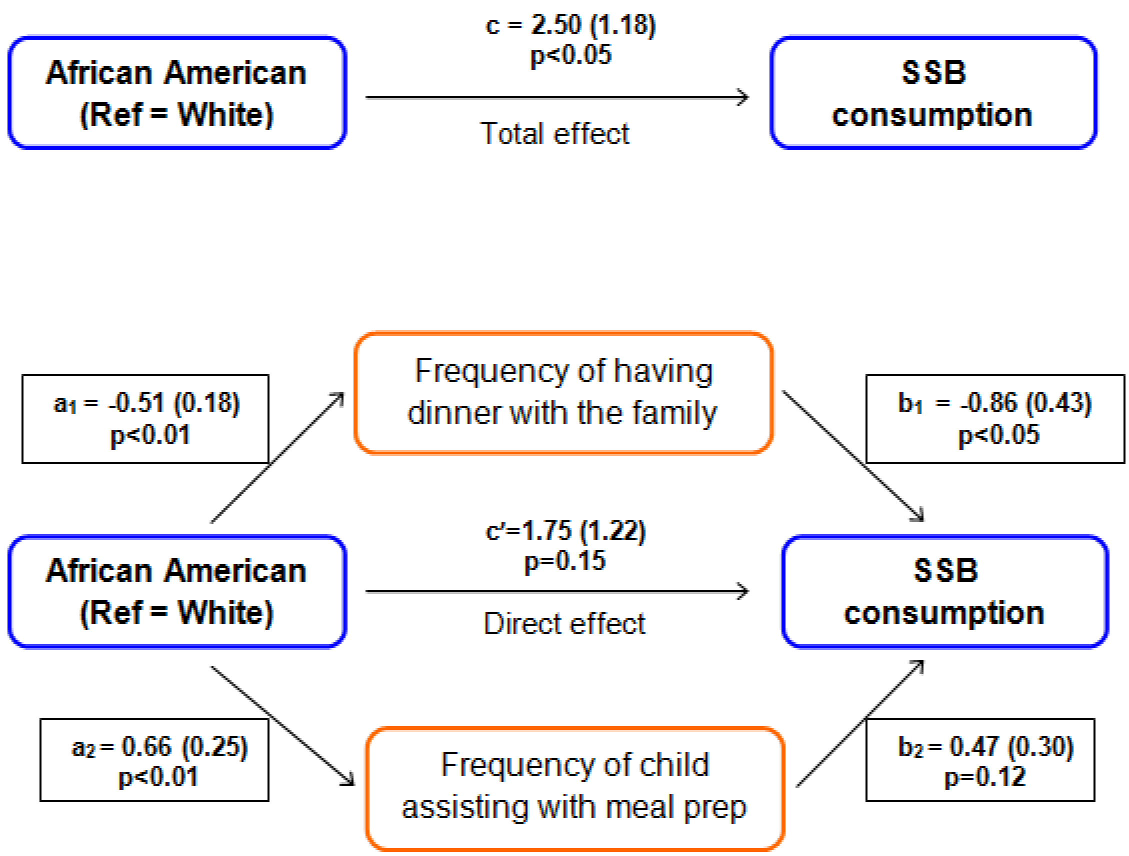
Table 4.11. Regression model predicting baseline sugar-sweetened beverage consumption

	SSB consumption[a] (ounces/day)					
	Model 1			Model 2		
	b	(SE)	CI	b	(SE)	CI
Gender[b]						
(Female, Ref)						
Male	-0.08	(0.81)	-1.68, 1.51	-0.01	(0.81)	-1.59, 1.58
Race/Ethnicity[b]						
(White, Ref)						
African American	1.85	(1.23)	-0.57-4.27	1.09	(1.26)	-1.39, 3.57
Latino	1.71	(1.45)	-1.13, 4.56	1.21	(1.44)	-1.63, 4.05
Asian	-0.14	(1.59)	-3.27, 2.99	0.16	(1.57)	-2.94, 3.25
Mixed/Other	0.63	(1.04)	-1.42, 2.68	0.25	(1.03)	-1.77, 2.28
Mother's education[c]						
(≤ High school diploma, Ref)						
Some college	**3.91****	(1.33)	1.28, 6.54	**3.94****	(1.32)	1.33, 6.55
Bachelor's degree	1.21	(1.51)	-1.78, 4.19	1.10	(1.50)	-1.84, 4.05
≥ Graduate school	0.34	(1.34)	-2.30, 2.98	0.41	(1.33)	-2.21, 3.04
Mother's employment[c]						
(Not employed, Ref)						
Part-time (<40 hrs/week)	-0.61	(1.36)	-3.29, 2.06	-0.49	(1.37)	-3.15, 2.15
Full-time (≥40 hrs/week)	-1.19	(1.34)	-3.83, 1.46	-1.32	(1.35)	-3.95, 1.29
Dinner with the family[d]						
(≤ 1 time/week, Ref)						
Several times/week				-1.10	(1.38)	-3.83, 1.62
Everyday				-2.10	(1.31)	-4.69, 0.49
Child assisting in meal preparation[d]						
(≤ 1 time/month, Ref)						
2-3 times/month				0.02	(1.13)	-2.20, 2.25
1 time/week				-1.34	(1.13)	-3.57, 0.88
Several times/week				2.02	(1.10)	-0.15, 4.19

*p<0.05, **p<0.01, ***p<0.001, ****p<0.0001
SSB = Sugar-sweetened beverage
[a] SSB consumption was self-reported by students annually on 3-day food records
[b] Gender and race/ethnicity were self reported by students at baseline
[c] Mother's education and employment were self-reported by parents at baseline
[d] Frequency of family dinner & assisting with meal preparation were self-reported by parents at baseline

Testing the mediating effects of family meal behaviors in the association between sociodemographic characteristics and SSB consumption

In mediation analysis, the effects of both mediators were examined simultaneously in the association between sociodemographic characteristics and SSB consumption (Figure 4.2). There were statistically significant indirect effects (b=0.75, CI=0.11,1.81) between African American race/ethnicity and SSB consumption suggesting partial mediation. In the unmediated model, the total effect of African American race/ethnicity on SSB consumption was 2.5 ($p<0.05$) and in the mediated model the direct effect, controlling for the mediators, was 1.75 ($p=0.15$) indicating a reduction in the coefficient of 0.75, which is what accounts for the indirect effects attributed to the two mediators. In particular, compared to White children, African-American children consumed 2.5 more ounces (SE=1.18) of SSBs per day and this association was partly explained by the frequency of eating dinner together with the family and assisting with meal preparation. Mediation analyses also indicated that African American children had dinner together with their family less frequently than White children ($p<0.01$) and that as frequency of eating family dinner increased, SSB consumption decreased ($p<0.05$; only significant among African Americans). Furthermore, African-American children assisted with meal preparation significantly more frequently than White children ($p<0.01$) but assisting with meal preparation was not significantly related to SSB consumption. The two mediators alone explained 3% of the variance in SSB consumption, providing some support for the hypothesis that the association between sociodemographic characteristics and SSB consumption is partially mediated by family meal behaviors.



Indirect (mediating) effect = Total effect - Direct effect = c - c' = 2.50 - 1.75 = 0.75 (CI=0.11-1.81)

Figure 4.2. Mediation path model depicting how frequency of having dinner with the family and assisting with meal preparation mediate the relationship between race/ethnicity and sugar-sweetened beverage consumption.
The standard error for each unstandardized coefficient is presented in parentheses.

Summary

In summary, the hypotheses of this study with regard to the associations of sociodemographic characteristics and family meal behaviors with SSB consumption were only partially supported. Gender, race/ethnicity and mother's employment were not associated with SSB consumption. Only mother's education was associated with SSB consumption. In particular, children whose mothers had some college (but did not obtain a college degree) had a higher intake of SSBs than children whose mothers had no more than high school education; statistically significant differences in SSB consumption between children whose mothers held college degrees and children whose mothers had no more than high school education were not observed.

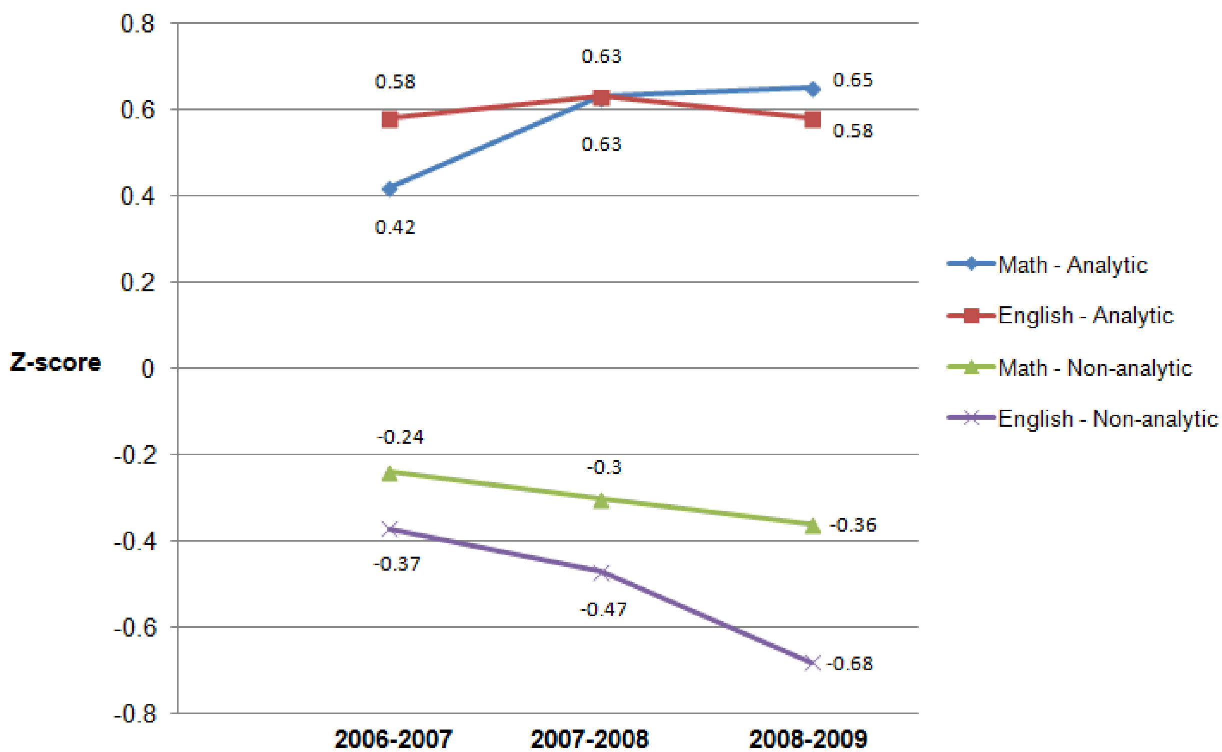
Mediation analysis indicated that family meal behaviors partially mediated the association between African American race/ethnicity and SSB consumption; the higher intake of SSB consumption among African American children, compared to White, is partially explained by the frequency with which they have dinner with their family. There was no evidence to suggest that family behaviors mediated the effects of the other sociodemographic variables (gender, mother's education and mother's employment) on SSB consumption.

Sensitivity analysis and outlier diagnostics

In the mixed model, sensitivity analysis to examine the effect of SSB consumption, including flavored milk and 100% fruit juice, on AP indicated results similar to the original model that did not include flavored milk and 100% juice as SSBs. In the mediation model, results from sensitivity analysis that included flavored milk and 100% fruit juice as SSBs were also similar to the original mediation findings that did not include flavored milk and 100% juice as SSBs. Outliers were examined using Cook's distance, which indicated that no observations were disproportionately influencing regression estimates.

Missing data

Between Year 1 (N=238) and Year 3 (N=177), the sample size was reduced by 25% as a result of incomplete data on variables this study examined and also due to some drop-outs. Consequently, attrition analysis was performed to assess differences in sociodemographic and behavioral characteristics, and in SSB consumption and AP between the analytic (participants) and non-analytic (non-participants) sample, across the three years (results not shown). In brief, compared to participants, non-participants were more likely to be African-American, attend a high level of intervention school, watch more television, have dinner with their family less frequently, and have mothers who had lower levels of education and were not employed. Importantly, compared to study participants, non-participants had lower Math and English z-scores ($p<0.001$) at all three time points and higher SSB consumption in Years 1 and 3 (results not statistically significant). Figures 4.3 and 4.4 illustrate the differences in SSB consumption and AP between the analytic and non-analytic samples.



T-tests indicated that mean differences in academic performance between the analytic and non-analytic samples were statistically significant at $p<0.0001$, at all three time points

Figure 4.3. Mean Math and English z-scores in the analytic and non-analytic samples over time

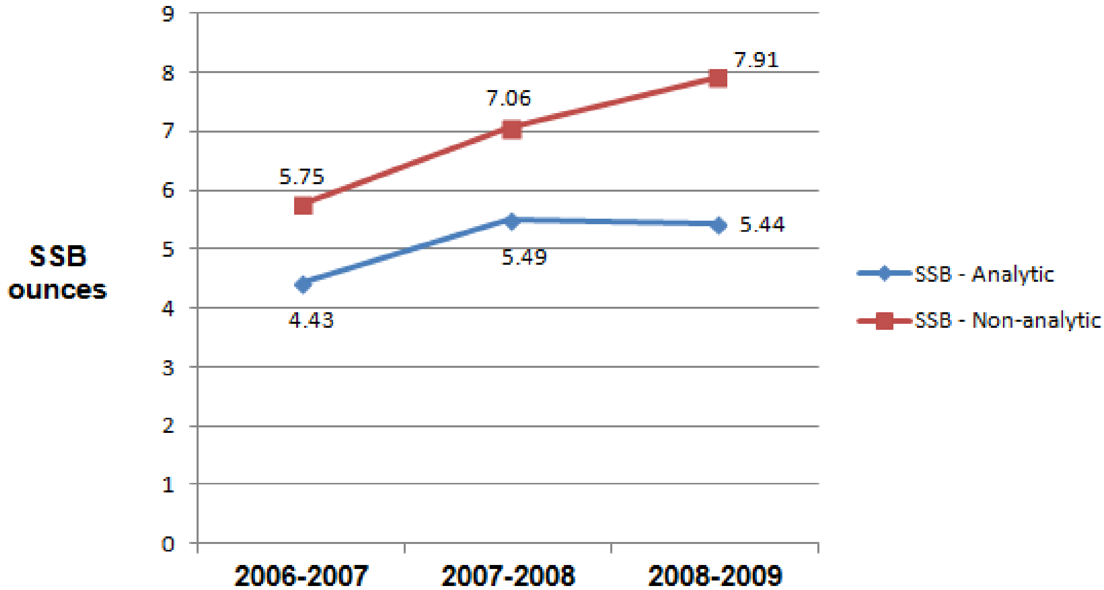


Figure 4.4. Mean daily SSB consumption in the analytic and non-analytic samples over time

Chapter 5. DISCUSSION

This chapter discusses the main findings of this dissertation study, presents the strengths and limitations, and concludes with recommendations for future research.

Association between SSB consumption and AP

In this observational study, there is some, but not clear, evidence for an inverse association between sugar-sweetened beverage (SSB) consumption and academic performance (AP). Using data collected annually over three years from an initial sample of 327 4^{th} and 5^{th} graders at baseline, and applying a mixed effects model that adjusted for sociodemographic and behavioral variables, we found that SSB consumption was inversely associated with English but not Math z-score. The regression coefficient for SSB consumption with English z-score as an outcome was estimated to be -0.008, indicating that for every 24-ounces of soda consumed per day, English z-score decreased by 0.19 standard deviation units or about 3-4% of the mean. While our findings do not definitively support our hypothesis that SSB consumption adversely influences AP in a general way, they are not inconsistent with the limited but growing literature that exists on this topic (Edwards, Mauch et al. 2011; Park, Sherry et al, 2012; Nyaradi, Li et al. 2013; Nyaradi, Foster et al. 2014).

One recent cross-sectional study of nearly 800 sixth graders found that SSB consumption, measured using an adapted version of the Youth Risk Behavior Surveillance Survey instrument, was inversely associated with both Math and Reading standardized test (Edwards, Mauch et al. 2011). Another cross-sectional study of high school students in grades 9 through 12 (N= 6,188 students) found that sugar-sweetened soda intake was inversely associated with AP measured by self-reported academic grades (Park, Sherry et al. 2012). To my knowledge, this is the first study to report a difference in the association between SSB consumption and academic performance for Math and English standardized test scores. With a relatively small sample, it is possible that differences in the spread of academic scores for Math and English may have reduced statistical power to detect significant associations. For example, English scores are slightly closer to the regression line, as indicated by a smaller standard error (b=-0.008, SE=0.003), compared to Math (b=-0.003, SE=0.004). It is also possible that there may be a biological basis for the difference in association between SSB consumption and academic performance that was noted. The hippocampus, which is the learning and memory center of the brain, plays a critical role in the development of both Math (Qin, Cho et al. 2014) and language (Karunanayaka, Holland et al. 2007) abilities. As described earlier, a high intake of fructose from SSBs has been found to reduce cerebral blood flow to the hippocampus (Page, Chan et al. 2013) contributing to neuronal injury, death and memory impairment (Daulatzai 2012; Pappas, de la Torre et al. 1996). However, it is not clear whether SSB consumption can differentially affect areas of the brain that are involved in Math and language learning processes. Recent advancement in neuroimaging techniques, such as functional magnetic resonance imaging (fMRI), have made it possible to detect areas of the brain that become activated during certain cognitive functions (Poldrack 2006), including mathematical calculations and language comprehension (Makuuchi, Bahlmann et al. 2012). Recent studies using fMRIs have reported that areas of the brain that are primarily engaged during math processing differ from those that are primarily, and even exclusively, engaged during language processing (Fedorenko, Behr et al. 2011; Monti, Parsons et al. 2012), raising the question of whether, and to what degree, the normal functioning of those brain regions may be influenced by SSB consumption. This is an area that requires further investigation in order to gain a better understanding of the effects of SSB consumption on different areas of the brain, particularly during sensitive periods of brain development in childhood and adolescence. A recent study by Nyaradi et al. (2013) suggests that diet (including sugar-sweetened beverages) during early childhood may affect cognitive outcomes at ten years of age, suggesting an urgency to confirm the effects of SSB consumption on academic performance over the life-course, and to identify the mechanisms by which SSB consumption affects academic performance.

Do diet and physical activity moderate the association between SSB consumption and AP?

It was hypothesized that the effect of SSB consumption on AP would be stronger at lower intake of fruits and vegetables, at higher intake of unhealthy snacks and at lower physical activity levels, as studies have indicated that poor diet quality and lack of physical activity may have adverse effects on cognitive function (Florence, Asbridge et al. 2008; Davidson, Hargrave et al. 2013; Vassiloudis, Yiannakouris et al. 2014). In this study, we did not observe any moderating effects when we tested the interaction between SSB consumption and each of the other behavioral variables, suggesting that the effects of SSB consumption on AP are not influenced by fruit, vegetable and snack intake or by physical activity. However, it should be noted that our study was not powered to examine interaction effects, and that there are potential biological mechanisms that would justify further investigations of the effects of interactions of SSB with other aspects of diet and physical activity. For example, fruits and vegetables are rich sources of nutrients that are known to affect cognitive function (such as the antioxidant vitamins B9, C and E) and it is feasible that a high intake of fruits and vegetables may diminish the potentially negative effects of SSB consumption on cognitive function (Proteggente, Pannala et al. 2002; Martin, Cherubini et al. 2002; Bourre 2006). Similarly, at higher levels of physical activity, the increased blood flow to the brain (van Praag 2009) and other neuroprotective mechanisms that improve concentration, attention and memory (Rasberry, Lee et al. 2011; Erickson, Voss et al. 2011; Phillips, Baktir et al. 2014) may also reduce the adverse effects of SSB consumption on cognitive function. Hence, the moderating effects of diet and physical activity on the relation between SSB consumption and AP should be further investigated in randomized controlled trials.

Association of sociodemographic and family meal variables with SSB consumption

Sociodemographic characteristics, such as gender and race/ethnicity, and family meal behaviors, such as frequency of having dinner together with the family, have been found to be associated with SSB consumption (Ogden, Kit et al. 2011, Kit, Fakhouri et al. 2013; Miller, McKinnon et al, 2013; Beck, Patel et al. 2013; Larson, Neumark-Sztainer et al. 2007; Larson, Fulkerson et al. 2013). We hypothesized that children whose mothers had lower levels of education would have higher SSB consumption, however, we found that children whose mothers had some college education had higher levels of SSB consumption compared to children whose mothers had no more than a high-school diploma (findings not significant for those with a Bachelor's degree or graduate school education). While the literature suggests that higher levels of maternal education are generally associated with higher diet quality (Cribb, Jones et al. 2011), in particular, with lower levels of SSB consumption (Totland, Lien et al. 2013; Wijtzes, Jansen et al. 2013), it also suggests that maternal employment may influence children's diet quality. Studies have shown that children whose mothers are employed consume more SSBs than children whose mothers are not employed (Hawkins, Cole et al. 2009; Bauer, Hearst et al. 2012; Datar, Nicosia et al. 2014). In our study, 75% of mothers who had some college education were employed (compared to 62% of the least educated group), and their children also had the highest intake of SSBs. Specifically, at baseline, children whose mothers had some college education consumed, on average, 7.21 ounces of SSBs per day, while children whose mothers had no more than a high-school diploma consumed 3.65 ounces per day. It is possible that the higher levels of SSB consumption among children whose mothers had some college education observed in this study may reflect higher levels of maternal employment. Working mothers may not have as much time to spend in meal planning and preparation, compared to non-employed mothers (Cawley and Liu 2007; Devine, Farrell et al. 2009) so they may rely more on meals prepared away from home (such as fast food) which may not be as nutritious (Datar, Necosia et al. 2014). In addition, working mothers may not be around as often to monitor their children's dietary intake so children may be purchasing and consuming SSBs without the knowledge of their parents.

Another unexpected finding was that children who reported assisting in meal preparation several times a week, consumed, on average, two more ounces of SSBs per day compared to children who reported assisting in meal preparation no more than once a month. This finding is not supported by the literature which generally reports that children who are more involved in meal preparation have better diet quality and reduced intake of SSBs, compared to children who are not as involved in assisting with meal preparation (van der Horst, Ferrage et al. 2014; Chu, Storey et al. 2014; Larson, Story et al. 2006). In this sample, children engaged in meal preparation at least several days a week, were more likely to be African American or Latino, and have mothers who had at least some college education or worked full time. It is plausible that when parents are working, they are less likely to be involved in food decisions and their children may be more likely to consume convenience and processed foods. According to the U.S. Census Bureau (2011), mothers are the sole or primary source of income in 40% of U.S. households with children under age 18, and 63% of those households are headed by single mothers who are disproportionately Black or Hispanic. Our findings suggest that the mechanisms by which involvement in food preparation by children improves food choices may depend on the availability of parental supervision and the education of the parent.

Do family meal behaviors mediate the association between sociodemographic characteristics and SSB consumption?

As a next step, family meal behaviors, namely the frequency of children assisting in meal preparation and having dinner with their family, were tested as mediators in order to examine if these modifiable behavioral variables explain part of the association between sociodemographic variables and SSB consumption. The present study is the first to show that the previously observed association between race/ethnicity and SSB consumption may be significantly mediated by family meal behaviors; there were no significant mediating effects in the association between the other sociodemographic variables and SSB consumption.

More specifically, family meal behaviors significantly mediated the association between race/ethnicity and SSB consumption, only among African Americans. Mediation analysis revealed that African-American children consumed, on average, 2.5 more ounces of SSBs per day than their White counterparts and that this association was partially explained by the frequency children had dinner with their family. This means that part of the association is explained by the effect of this one mediator on SSB consumption. Mediation analyses also indicated that African American children had dinner together with their family less frequently than White children and that as frequency of family dinner increased SSB consumption decreased (only significant among African Americans). Both of these findings are further supported by the literature (Neumark-Sztainer, Hannan et al. 2003; Burgess-Champoux, Larson et al. 2009; Gillman, Rifas-Shiman et al. 2000). For example, in a cross-sectional study by Neumark-Sztainer et al. (2003), 4,746 middle and high school students from a Minneapolis school district completed the Project EAT survey and the Youth and Adolescent Food Frequency Questionnaire and provided information on how frequently they had meals together with their family during the previous week. A greater percentage of African-American children (21.2%) reported never having had family meals in the previous week compared to 12% of White, 14.2% of Latino, and 10.3% of Asian children. Similarly, a smaller percentage of African-American children (59%) reported having a meal together with their family $\geq$3 times in the previous week, compared to 66.2% of White, 70.8% of Latino, and 75.4% of Asian children. Since increased frequency of family dinner has been linked to better diet quality among children (Neumark-Sztainer, Hannan et al. 2003; Burgess-Champoux, Larson et al. 2009; Gillman, Rifas-

Shiman et al. 2000), interventions aimed at reducing SSB consumption should target the family meal environment. Research has highlighted the role of Bandura's (1977) Social Learning/Cognitive Theory (i.e., role of observational learning and modeling) in the development of children's dietary patterns (Brown & Ogden, 2004; Gribble, Falciglia et al. 2003; Wardle 1995). For example, the family mealtime can provide an opportunity for parents to act as role models and help their children develop food preferences and eating habits that will facilitate healthy growth by providing healthful food items. As children become older (i.e., in middle school and high school), they participate in family meals less frequently (Fulkerson, Neumark-Sztainer et al. 2006; Neumark-Sztainer, Hannan et al. 2003), mainly as a result of increased independence, so parents can take advantage of teachable moments during mealtimes when the children are still young to help them establish healthy lifelong dietary habits.

The second mediator examined was the frequency of the child assisting with meal preparation and, consistent with the literature, our results showed that African-American children assisted with meal preparation significantly more frequently than White children. In a cross-sectional study by Larson et al. (2006), 3,699 middle and high school students from a Minneapolis school district completed the Project EAT survey and the Youth and Adolescent Food Frequency Questionnaire and provided information on how many times they helped prepare food for dinner in the previous week. They found that a higher percentage of African-American children (12.3%) reported helping to prepare food for dinner $\geq$ 5 times/week, compared to 6.8% of White and 6.3% of Latino children. Future research should explore the circumstances under which children may help with meal preparation in order to help guide appropriate development of interventions. For example, are children preparing meals because a parent or another adult is not at home to prepare the meals or are they preparing the meals along with their parents where they may have the opportunity to learn valuable cooking skills and healthy nutrition. In the same study, Larson et al. (2006), reported that assisting with meal preparation was inversely associated with soft drink consumption among girls ($p<0.01$) but in our study we found no association. Furthermore, the frequency with which children assist with meal preparation may depend on food availability and food insecure families may not always have enough food to provide to their children. In this sample, 14% of families reported having an annual household income of less than $20,000 and of those, about a quarter were African American, a quarter were Latino and just 4% were White. On the contrary, 40% of families reported an annual income of at least $80,000 and of those, 8% were African American, 4% were Latino and 55% were White. This SES disparity between Whites and ethnic minorities is consistent with the literature and, as mentioned earlier, is an indicator of dietary quality and behaviors and also academic performance. Although a large proportion of this sample reported having high household income, future studies should consider evaluating meal preparation behaviors in the context of food insecurity.

In summary, this study has shed light on potential mediating factors that may explain part of the causal pathways linking sociodemographic characteristics to SSB consumption. Family meal behaviors explained part of the association between race/ethnicity (African American) and SSB consumption, after controlling for other sociodemographic covariates. The effect was small as the mediators only explained 3% of the variance in SSB consumption which suggests that other factors not accounted for in the mediation model may contribute to the relation between race/ethnicity and SSB consumption. Unmeasured variables that could possibly explain additional variation in SSB consumption include whether the household is single-parent or dual-parent; individual and family beliefs and perceptions of what foods are considered healthy, cheap and convenient; affordability and accessibility of healthy foods; and SSB marketing exposure (i.e., on children’s TV programs, neighborhood billboards, online websites). To the author's knowledge, the present study is the first to suggest that the already established association between race/ethnicity and SSB consumption, as supported by the literature, may be partially mediated by family meal behaviors.

Strengths and Limitations

The main strengths of this study include the prospective nature of the data, which were collected at three time points so we were able to combine repeated measures of SSB consumption, academic performance, and other variables of interest resulting in increased statistical power; the use of a 3-day food diary to measure food intake, more specifically, the quantity and brand of an SSB and of other dietary variables which provide a richer and more detailed evaluation of SSB dose and quality; assessment of a variety of SSBs, including flavored milk, which provides a more accurate reflection of SSB consumption in our age group and a better understanding of which SSBs children consume most; and being among the few studies that have examined the association between SSB consumption and AP and the first to assess the mediating effects of family meal behaviors between sociodemographic variables and SSB consumption.

This study is also subject to several limitations. First, there may be missing data bias - 25% of the observations were excluded due to attrition or incomplete data on all variables of interest. Analyses comparing participants (analytic sample) and non-participants (those who dropped out or did not have complete data) showed that there were statistically significant differences in sociodemographic, dietary, behavioral, and academic performance variables. This type of missing data bias may potentially threaten external validity because findings from a biased sample might not be generalizable to the intended population. Internal validity might also be compromised because analyses based on biased samples can lead to inaccurate estimates of the variable associations being examined (Cuddeback, Wilson et al. 2004). As mentioned earlier, non-participants had significantly higher SSB consumption and lower AP performance compared to participants, which biased the hypothesis toward the null, thereby possibly contributing to this study's non-robust findings and weak associations, particularly between SSB consumption and AP. Second, this was not a random sample, which means the study findings may not be generalized to other elementary and middle-school children in the U.S. Further, this study sample comes from a Northern California city that is relatively well-off, compared to other cities; for example, according to the US Census Bureau, in 2007-2009, median family income for the Northern California city where the sample originated was $100,000, compared to the city of Los Angeles that had a median family income of $53,000, and the state of California median which was $69,000 during the same time period. This is also partially reflected in the study sample's sociodemographic characteristics where about 85% of the mothers reported having at least some college education and of those, 40% reported having a graduate or professional degree. Corresponding percentages nationally are 30% of adults over age 25 have obtained a college degree and 8% of adults have obtained a graduate degree (U.S. Census). Higher levels of education have been found to be associated with higher paying jobs. Specifically, the US Bureau of Labor Statistics estimated that in 2013 the median weekly earnings for individuals with a graduate or professional degree were more than double of those who only had a high school diploma (http://www.bls.gov/emp/ep_chart_001.htm). Hence, results cannot be generalized to other populations without testing these hypotheses in those populations. Third, this study had limited statistical power. Post-hoc power calculations indicated that this study had a 33% power to detect a small effect size of 0.01 if such a difference in AP was indeed present between SSB consumers and non-consumers. Fourth, there may be social desirability bias. Participants may have under-reported unhealthy behaviors and over-reported healthy behaviors if students felt embarrassed that their parents or study staff would criticize their intake of unhealthy food and drink items. A study among 8–10-year-old African-American girls found a negative association between social desirability and reporting accuracy (Klesges et al, 2004). Fifth, this study did not measure weekend dietary intake. Food diaries assessed weekday dietary intake, and it has been reported that children are more likely to consume unhealthy food/drink items and have a poorer overall diet on the weekend as opposed to weekdays (Rothausen et al. 2012). This could mean that our results are conservative (underestimated) since SSB consumption would have probably been higher, probably among both SSB-consumers and non-consumers, if weekend assessments were also included. We might have expected to obtain a stronger effect between SSB consumption and AP if weekend measurements of SSB consumption had also been included. Further, even though children were appropriately trained on how to correctly record their dietary intake, some level of measurement error may still be introduced as a consequence of forgetting to record, feeling too tired to record, or just over/under-reporting. Sixth, physical activity was measured via self-report to a question about how many days a week children exercised or participated in physical activities that made them sweat. However, details about the type, intensity and duration of the physical activity were not reported which may have resulted in misclassification error. More objective measures of physical fitness/activity by fitness professionals (i.e., at school settings) and more detailed data about the kinds of physical activity children are engaged in could provide more accurate measures of physical activity/fitness. Seventh, caffeine content of SSBs was not measured - the majority of sodas and energy drinks contain caffeine which has psychoactive properties (Keast & Riddell, 2007) that stimulate the reward system in the brain in the ways that resemble the effect on the reward system of consuming refined sugar but in this study we were not able to measure and control for caffeine as a potential confounder. Further, since the effects of caffeine on behavior and physiology have not been extensively studied among children (Temple, 2009; Kristjansson, Sigfusdottir et al. 2014) and there are no maximum intake recommendations, it is difficult to determine whether a certain amount of caffeine in a drink is too much for a child or acceptable to consume. However, in this study, sensitivity analyses revealed that the most commonly reported SSBs were fruit-juice based drinks which do not contain caffeine, therefore, exposure to caffeine may not be an important confounder in this study. Nonetheless, the addictive potential of sodas and sports drinks that contain caffeine should not be underestimated mainly since soda and sports drink consumption increases as children enter adolescence (Temple, 2009), which was also confirmed in this study (sports drinks increased from 4% of all beverages at Year 1 when children were in elementary school to 8% in Year 3 when children were in middle school). Future studies that investigate the effects of SSB consumption on AP should consider taking into account the effects of caffeine in sodas and sports drinks. Eighth, this study used standardized tests to measure AP. No single assessment can completely evaluate a student's academic performance so the results of this study are limited by the degree to which the Math and English standardized tests accurately measure academic performance. Future studies should consider also collecting data on academic grades as studies have shown different results when AP was measured via standardized tests compared to grades (Coe, Pivarnik et al. 2006). Lastly, BMI was not used as a covariate in the association between SSB consumption and AP because Fitnessgram data were measured for 5th and 7th grade students but not for 4th and 6th grade students. In addition, the data that were available were not accurate as they indicate that the same children between grade 5 and 7 grew shorter an average of about 3 centimeters (data not reported), which is implausible. Although findings are mixed, most studies report an inverse association between BMI and AP (Roberts, Freed et al. 2010; Li, Dai et al. 2008). The possible mechanisms that explain this association are not clear, although Roberts et al. (2010) suggest that physical fitness may mediate the relation between BMI and AP. Future studies should control for BMI when examining the association between SSB consumption and AP.

Despite these limitations, the current study findings may have important public health implications and may also serve as preliminary steps for further research that will ultimately help guide effective interventions to promote healthy beverage choices among children.

Public health implications

The findings of this study have a number of potentially important public health implications that may inform theory and policy concerning SSB consumption and AP. Although the evidence is not clear, this study lends some support to the scant but consistent literature that reports an inverse association between SSB consumption and AP. While up until recently educators and researchers encouraged the public to reduce SSB consumption in order to prevent or reduce the risk of developing obesity, diabetes, dental caries and other health ailments, now the potential adverse effects on cognitive function may be another critical factor for parents to consider limiting their children's intake of SSBs. Many schools and parents are concerned about children's AP and what it means for future educational and employment opportunities. More explicitly, the policy implications are that schools that treated SSB consumption as extraneous to the primary mission of schools to improve learning and prepare students for higher education can no longer ignore this issue. As biological mechanisms and neuroimaging techniques elucidate how SSB consumption may affect cognitive function, particularly during the sensitive periods of brain development during early childhood and adolescence, this information should be effectively shared with families in an attempt to reduce SSB consumption. Furthermore, improved understanding about the mechanisms by which various sociodemographic (i.e., race/ethnicity) and behavioral factors (i.e., family meal behaviors, physical activity) may influence SSB consumption can contribute to tailoring interventions to the particular needs of specific populations. Consistent with the literature, this study found that ethnic minority children consume disproportionately larger quantities of SSBs and perform less well academically, compared to White children. As supported by the literature, these ethnic minorities are also exposed to more SSB ads in their physical environment and via various forms of media and may have limited access to establishments that carry or promote healthy food items. Additionally, those same neighborhoods may not have the necessary educational resources, such as safe and free access to libraries and tutoring services, to promote and enhance academic performance. All of these challenges coupled with limited financial resources, makes targeting these vulnerable populations an urgent matter of great public health concern.

In an attempt to reduce SSB consumption among children, school districts across the nation have implemented policies banning the sale of SSBs, primarily sodas, from some elementary, middle- and high-schools. Some studies that have evaluated school nutrition policies that have banned SSBs from school vending machines found that while SSB consumption may decrease in the school setting, overall SSB consumption is not affected (Taber, Chriqui et al. 2012; Blum, Davee et al. 2008). This could be attributed to the fact that once children are outside of the restrictive school environment they may have access to SSBs. Therefore, school policies may not be as effective if the home and neighborhood environments are not also amenable to change in support of healthier food options. There has been a lot of attention lately on reducing the maximum size of SSBs being sold in food establishments, similar to New York City's restriction on SSBs larger than 16 ounces; implementing a soda tax (Rivard, Smith et al. 2012; Andreyeva, Chaloupka et al. 2011); and even reducing access to SSBs for federal nutrition assistance participants (i.e., SNAP and WIC) (Andreyeva, Luedicke et al. 2012) as possible measures to curb SSB consumption but their effectiveness has not been examined. Just this November, Berkeley became the first city in the Nation to pass a soda tax, which adds a penny-per-ounce tax on most SSBs and it is estimated to raise more than $1 million per year to fund health programs. More research is needed on the effectiveness of such changes on SSB consumption before such policies become more widely implemented.

Recommendations for future research

The findings of this study extend current knowledge on the topic of SSB consumption and AP among school-aged children, and may serve as valuable preliminary steps for future research. Future studies should explore how SSB consumption may affect the different areas of the brain throughout the life-course and provide a clearer understanding of the biological mechanisms by which SSB consumption influences AP. In addition, modifiable dietary and physical activity behaviors should be further examined, particularly among ethnic groups with high rates of SSB consumption, to guide interventions aimed at reducing SSB consumption among those populations.

More specifically, future studies are recommended to address the following questions:

1. How are fructose, glucose and sucrose (from cane sugar and HFCS) metabolized by the body after SSB consumption and what are the short- and long-term consequences on the brain and cognitive function?
2. Does SSB consumption differentially affect areas of the brain that are primarily responsible for mathematical calculations compared to English comprehension?
3. How does the effect of SSB consumption on cognitive function vary throughout the lifespan, primarily during the sensitive periods of brain development during early childhood and adolescence?
4. What is the role of diet quality, physical activity and family meal behaviors on SSB consumption and AP among low SES minority populations, particularly African Americans and Latinos, and how can interventions be tailored to more effectively and sustainably reduce SSB consumption among those groups?

Studies attempting to address any of the above questions, should consider the following additional recommendations to strengthen their study design.

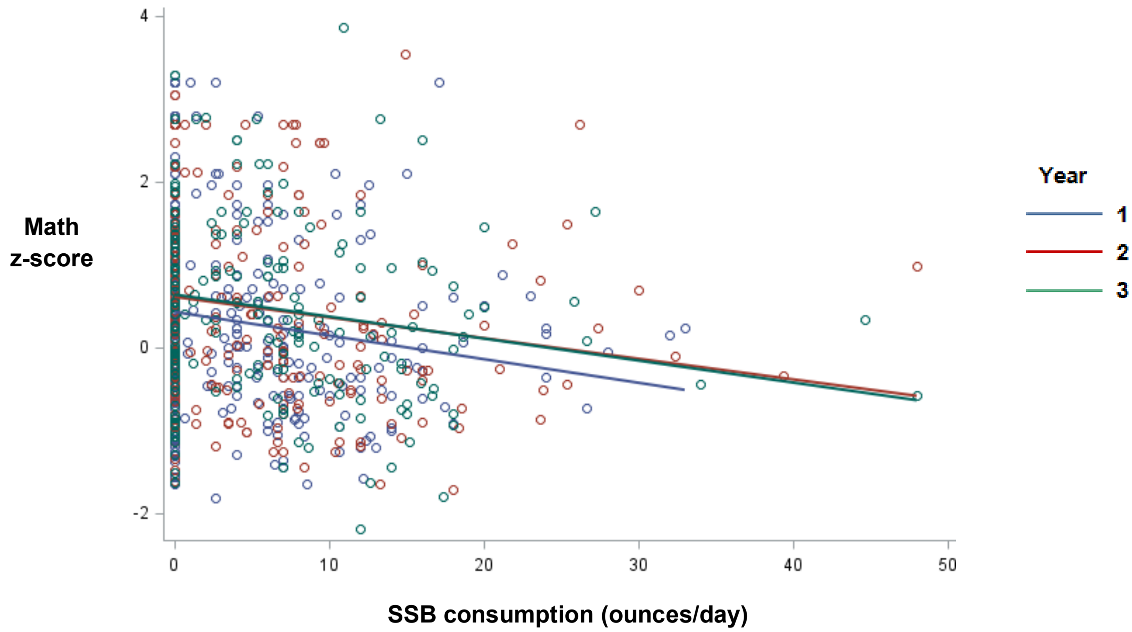
1. Use a longitudinal study design with large representative samples of school-aged children. Randomized controlled studies would be ideal in order to eliminate the possible effect of unmeasured confounders, but such studies may not be ethically feasible, such as randomizing children to consume large amounts of SSBs when there is an indication that they may experience short- and long-term health effects. Therefore, prospective observational study designs may be more appropriate than randomized controlled trials to assess the effect of SSB consumption on AP among children over time. Alternatively, a randomized controlled study would be appropriate if assessing effects of an intervention where children who already consume high amounts of SSBs are randomized to either an intervention to help them reduce SSB consumption or to a control group.
2. Investigate the potential moderating effects of diet and physical activity variables in the relation between SSB consumption and AP and the potential mediating effects of family meal variables in the relation between sociodemographic variables and SSB consumption since we found only modest or no moderating and mediating effects in this study.
3. Use food diaries to assess diet but also include weekend consumption data as it has been demonstrated that children consume more SSBs on weekends.
4. Employ functional Magnetic Resonance Imaging (fMRIs) techniques to examine brain activity (i.e., completing a memory test) after ingesting different types and quantities of SSBs.

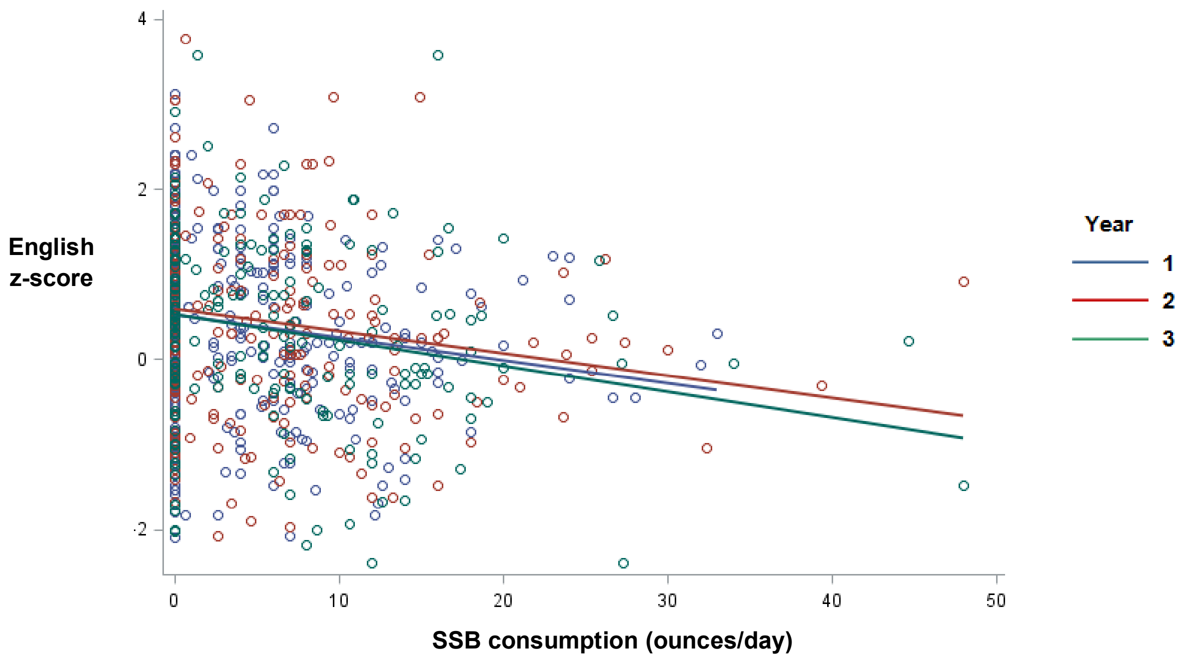
5. Utilize additional assessments to measure academic performance beyond the standardized tests administered by each state. For example, also taking into account school grades and other cognitive performance tests, which may provide a better representation of overall academic achievement and cognitive function, as opposed to a one-time standardized test.
6. More accurate assessments of important covariates (such as physical activity, height and weight). For example, a more comprehensive assessment of physical activity/fitness may include the type, intensity and duration of that activity along with an objective evaluation of a child's physical fitness competencies by a fitness professional.

APPENDIX A. School Lunch Initiative (SLI) components implemented at schools

Level of exposure to SLI intervention	SLI components			
	School food	**School dining**	**Garden & Cooking**	**Lesson integration**
Low (Elementary School #1 and #2)	Healthy food offered	Cafeteria seating available	♦ No paid staff ♦ Gardening exposure less than 9 hours/year ♦ No cooking lessons	Few teachers integrate healthy nutrition into school curriculum
High (Elementary School #3 and #4)	Healthy food offered	Cafeteria seating available	♦ Dedicated classrooms with paid staff ♦ Students attend 22-56 hours/year	Some teachers integrate healthy nutrition into school curriculum
Low (Middle School #1)	Healthy food offered	Cafeteria seating available	♦ Dedicated classrooms with paid staff ♦ Students attend 20-26 hours/year	Few teachers integrate healthy nutrition into school curriculum
Medium (Middle School #2)	Healthy food offered	Cafeteria seating available	♦ Dedicated classrooms with paid staff ♦ Students attend 48 hours/year (in 7th grade it's an elective)	Few teachers integrate healthy nutrition into school curriculum
High (Middle School #3)	Healthy food offered	New dining area opened in Year 3	♦ Dedicated classrooms with paid staff ♦ Students attend 40-45 hours/year	Most teachers integrate healthy nutrition into school curriculum

APPENDIX B. Regression lines showing inverse association between SSB consumption and AP (Math and English) at each of the three time points





REFERENCES

Aeberli, I., M. Hochuli, et al. (2013). "Moderate amounts of fructose consumption impair insulin sensitivity in healthy young men: a randomized controlled trial." Diabetes Care 36:150-156.

Aeberli, I., P.A. Gerber, et al. (2011). "Low to moderate sugar-sweetened beverage consumption impairs glucose and lipid metabolism and promotes inflammation in healthy young men: a randomized controlled trial." American Journal of Clinical Nutrition 94: 479-485.

Agrawal, R. and F. Gomez-Pinilla (2012). "'Metabolic syndrome' in the brain: deficiency in omega-3 fatty acid exacerbates dysfunctions in insulin receptor signaling and cognition." The Journal of Physiology 590: 2485-2499.

Ambrosini, G., L. Oddy, et al. (2013). "Prospective associations between sugar-sweetened beverage intake and cardiometabolic risk factors in adolescents." The American Journal of Clinical Nutrition 98: 327-334.

Andreyeva T., F.J. Chaloupka, et al. (2011). "Estimating the potential of taxes on sugar-sweetened beverages to reduce consumption and generate revenue." Preventive Medicine 52(6):413-416.

Andreyeva T., J. Luedicke, et al. (2012). "Grocery store beverage choices by participants in federal food assistance and nutrition programs." American Journal of Preventive Medicine 43(4):411-418.

Andrieu, E. N. Darmon, et al. (2006). "Low-cost diets: more energy, fewer nutrients." European Journal of Clinical Nutrition 60: 434–436.

Arcan, C., D. Neumark-Sztainer, et al. (2007). "Parental eating behaviours, home food environment and adolescent intakes of fruits, vegetables and dairy foods: longitudinal findings from Project EAT." Public Health Nutrition 10(11): 1257-1265.

Banks, W. (2012). "Role of the blood-brain barrier in the evolution of feeding and cognition." Annals of The New York Academy of Sciences 1264(1): 13-19.

Baron, R. M. and D.A. Kenny (1986). "The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations." Journal of Personality and Social Psychology 51: 1173-1182.

Barr-Anderson, D.J., N.I Larson, et al. (2009). "Does television viewing predict dietary intake five years later in high school students and young adults?" International Journal of Behavioral Nutrition and Physical Activity 7.

Basciano, H., L. Federico, et al. (2005) "Fructose, insulin resistance, and metabolic dyslipidemia." Nutrition & Metabolism 2(1):5.

Bass, R., W. Brown, et al. (2013). “Physical fitness and academic performance in middle school students.” Acta Paediatrica 102(8): 832-837.

Bauer, K., W. Hearst, et al. (2012). “Parental employment and work-family stress: associations with family food environments. “Social Science & Medicine 75(3): 496-504.

Baum, C. L. (2004). “The long-term effects of early and recent maternal employment on a child's academic achievement. “Journal of Family Issues 25(1): 29-60.

Beck, A., L. Patel, et al. (2013). “Trends in sugar-sweetened beverage and 100% fruit juice consumption among California children. “American Academy of Pediatrics 13: 364-370.

Bellisle, F. (2004). “Effects of diet on behavior and cognition in children.” British Journal of Nutrition 92 Suppl 2: S227-232.

Benton, D., A. Maconie, et al. (2007). “The influence of the glycemic load of breakfast on the behavior of children in school.” Physiology & Behavior 92:717-724.

Benton, D. and M.K. Stevens (2008). “The influence of a glucose containing drink on the behavior of children in school.“ Biological Psychology 78(3): 242-245.

Beyer, P., L. Caviar, et al. (2005). “Fructose intake at current levels in the United States may cause gastrointestinal distress in normal adults.“ Journal of The American Dietetic Association 105:1559-1566.

Blakemore, S., J. Burnett, et al. (2010). “The role of puberty in the developing adolescent brain.” Human Brain Mapping 31(6): 926-933.

Blin, J., C.A. Ray, et al. (1991). “Regional cerebral glucose metabolism compared in rodents and humans.“ Brain Research 568: 215-222.

Blum, J.E., A.M. Davee, et al. (2008). “Reduced availability of sugar-sweetened beverages and diet soda has a limited impact on beverage consumption patterns in Maine high school youth.” Journal of Nutrition Education and Behavior 40(6): 341-347.

Bourre, J.M. (2006). “Effects of nutrients (in food) on the structure and function of the nervous system update on dietary requirements for brain. Part 2: macronutrients.” The Journal of Nutrition, Health and Aging 10(5): 386-399.

Boyland, E.J. and J.C. Halford (2013).”Television advertising and branding. Effects on eating behaviour and food preferences in children.” Appetite 62: 236-241.

Bradley, R.H., R.F. Corwyn (2002). “Socioeconomic status and child development.” Annual Review of Psychology 53: 371-399.

Bray, G.A., A. Nielsen, et al. (2004).” Consumption of high-fructose corn syrup in beverages may play a role in the epidemic of obesity.” American Journal of Clinical Nutrition 79: 537–543.

Bray, G.A. (2008). “Fructose: should we worry?” International Journal of Obesity (London) 32 Suppl 7: S127-S131.

Bray, G.A. (2010). “Soft drink consumption and obesity: it is all about fructose.” Current Opinion in Lipidology 21(1): 51-57.

Bray, G.A. (2013). “Energy and fructose from beverages sweetened with sugar or high-fructose corn syrup pose a health risk for some people.” Advanced Nutrition 4(2): 220-225.

Breslau, N., H.D. Chilcoat, et al. (2001). “Stability and change in children's intelligence quotient scores: A comparison of two socioeconomically disparate communities.” American Journal of Epidemiology 154 (8): 711-717.

Briefel, R., R. Wilson, et al. (2009). “Consumption of low-nutrient, energy-dense foods and beverages at school, home, and other locations among school lunch participants and nonparticipants.” Journal of the American Dietetic Association 109: S79-S90.

Buehler, C. and M. O’Brien (2011). “Mothers’ part-time employment: Associations with mother and family well-being.” Journal of Family Psychology 25(6): 895–906.

Burgess-Champoux, T., L. Larson, et al. (2009). “Are family meal patterns associated with overall diet quality during the transition from early to middle adolescence?” Journal of Nutrition Education and Behavior 41(2): 79-86.

Cawley, J. and F. Liu (2012). “Maternal employment and childhood obesity: a search for mechanisms in time use data.” Economics & Human Biology 10(4): 352-364.

Cha, S., H. Wolfgang, et al. (2008). “Differential effects of central fructose and glucose on hypothalamic malonyl-CoA and food intake.” Proceedings of the National Academy of Sciences 105(44): 16871-16875.

Chen, H-J. and Y. Wang (2013). “Influence of school beverage environment on the association of beverage consumption with physical education participation among US adolescents.” American Journal of Public Health 103(11): e63-70.

Childs, G. and M. McKay (2001). “Boys starting school disadvantaged: implications from teachers’ ratings of behaviour and achievement in the first two years.” The British Psychological Society 71(2): 303-314.

Chomitz, V., R. Slining, et al. (2009). “Is there a relationship between physical fitness and academic achievement? Positive results from public school children in the northeastern United States.” Journal of School Health 79: 30-37.

Chu, Y., L. Farmer, et al. (2013). “Involvement in home meal preparation is associated with food preference and self-efficacy among Canadian children.” Public Health Nutrition 16(1): 108-112.

Chu, Y., L. Storey, et al. (2014). “Involvement in meal preparation at home is associated with better diet quality among Canadian children.” Journal of Nutrition Education and Behavior 46(4): 304-308.

Coe, D., P. Pivarnik, et al. (2006). “Effect of physical education and activity levels on academic achievement in children.” Medicine and Science in Sports and Exercise 38(8): 1515-1519.

Coe, D., P. Peterson, et al. (2013). “Physical fitness, academic achievement, and socioeconomic status in school-aged youth.” Journal of School Health 83(7): 500-507.

Collison, K., S. Zaidi, et al. (2010). “Sugar-sweetened carbonated beverage consumption correlates with BMI, waist circumference, and poor dietary choices in school children.” BMC Public Health 10(234): 1-13.

Coltrane, S. (2000). “Research on Household Labor: Modeling and Measuring the Social Embeddedness of Routine Family Work.” Journal of Marriage and Family 62(4): 1208–1233.

Committee on Nutrition and the Council on Sports Medicine and Fitness. (2011). “Sports drinks and energy drinks for children and adolescents: are they appropriate?” Pediatrics 127(6): 1182-1189.

Cordain, L., S. Boyd Eaton, et al. (2005). “Origins and evolution of the Western diet: health implications for the 21st century.” American Journal of Clinical Nutrition 81: 341-354.

Crawford, P., B. Obarzanek, et al. (1994). “Comparative advantage of 3-day food records over 24-hour recall and 5-day food frequency validated by observation of 9 and 10-year old girls.” Journal of the American Dietetic Association 94: 626-630.

Cribb, V., L. Jones, et al. (2011). “Is maternal education level associated with diet in 10-year-old children?” Public Health Nutrition (11): 2037-2048.

Crosnoe, R. and B. Schneider (2010). “Social Capital, Information, and Socioeconomic Disparities in Math Coursework.” American Journal of Education 117(1): 79-107.

Cryan, J.F. and T.G. Dinan (2012). “Mind-altering microorganisms: the impact of the gut microbiota on brain and behaviour.” Nature Reviews Neuroscience 13(10): 701-712.

Cuddeback, G., E. Wilson, et al. (2004). “Detecting and statistically correcting sample selection bias.” Journal of Social Service Research 30(3): 19-33.

Cunningham, I.C. and R.T. Green (1974). “Purchasing roles in the US family, 1955 and 1973.” Journal of Marketing 38: 61–64.

Cunningham, M. (2008). “Changing Attitudes toward the Male Breadwinner, Female Homemaker Family Model: Influences of Women's Employment and Education over the Lifecourse.” Social Forces 87(1): 299-323.

Darmon, N. and A. Drewnowski (2008). "Does social class predict diet quality?" The American Journal of Clinical Nutrition 87(5): 1107-17.

Daulatzai, M.A. (2012). "Quintessential risk factors: their role in promoting cognitive dysfunction and Alzheimer's disease." Neurochemical Research 37(12): 2627-2658.

Datar, A., N. Nicosia, et al. (2014). "Maternal work and children's diet, activity and obesity." Social Science & Medicine 107: 196-204.

Davidson, T., L. Hargrave, et al. (2013). "Inter-relationships among diet, obesity and hippocampal-dependent cognitive function." Neuroscience 253: 110-122.

Davison, K.K. and L. L. Birch (2001). "Childhood overweight: a contextual model and recommendations for future research." Obesity Review 2(3):159–171.

DeBoer, M., D. Scharf, et al. (2013). "Sugar-sweetened beverages and weight gain in 2- to 5-year-old children." Pediatrics 132(3): 413-20.

de Graaf, C. (2011). "Session 1: Balancing intake and output: food v. exercise. Why liquid energy results in overconsumption." Proceedings of the Nutrition Society 70:162-170.

Dekker, M., J. Su, et al. (2010). "Fructose: a highly lipogenic nutrient implicated in insulin resistance, hepatic steatosis, and the metabolic syndrome." American Journal of Physiology - Endocrinology and Metabolism 299(5): E685-E694.

de Koning, L., V.S. Malik, et al. (2012). "Sweetened Beverage Consumption, Incident Coronary Heart Disease and Biomarkers of Risk in Men." Circulation 125(4):1-17.

Demory-Luce, D., M. Morales, et al. (2004). "Changes in food group consumption patterns from childhood to young adulthood: the Bogalusa Heart Study." Journal of the American Dietetic Association 104(11): 1684-1691.

DeVault, M.L. (1994). Feeding the Family: The Social Organization of Caring as Gendered Work. Chicago, IL, University of Chicago Press.

Devine, C., M. Jastran, et al. (2006). "A lot of sacrifices: Work-family spillover and the food choice coping strategies of low wage employed parents." Social Science & Medicine 63(10): 2591–2603.

Devine, C., M. Farrell, et al. (2009). "Work conditions and the food choice coping strategies of employed parents." Journal of Nutrition Education and Behavior 41(5): 365-370.

Dickens, W.T. and J.R. Flynn (2001). "Heritability estimates versus large environmental effects: the IQ paradox resolved." Psychological Review 108(2): 346-369.

Djordjevic, A., B. Bursać, et al. (2013) "The impact of different fructose loads on insulin sensitivity, inflammation, and PSA-NCAM-mediated plasticity in the hippocampus of fructose-fed male rats." Nutritional Neuroscience Accessed at: http://dx.doi.org/10.1179/1476830513Y.0000000098.

Dodd, A., H. Briefel, et al. (2013). “Disparities in consumption of sugar-sweetened and other beverages by race/ethnicity and obesity status among United States schoolchildren.” Journal of Nutrition Education and Behavior 45(3): 240-249.

Donnelly, J.E. and K. Lambourne (2011). “Classroom-based physical activity, cognition, and academic achievement.” Preventive Medicine 52: S36-S42.

Domínguez, S. and C. Watkins (2003). “Creating networks for survival and mobility: social capital among African-American and Latin-American low-income mothers.” Social Problems 50(1): 111-135.

Drewnowski, A. and S.E. Specter (2004). “Poverty and obesity: the role of energy density and energy costs.” American Journal of Clinical Nutrition 79(1): 6-16.

Dwyer, D. (2002). Glucose Metabolism in the Brain. San Diego, CA, Academic Press.

Edwards, J., U. Mauch, et al. (2011). “Relationship of nutrition and physical activity behaviors and fitness measures to academic performance for sixth graders in a midwest city school district.” Journal of School Health 81: 65-73.

Emond, J., A. Patterson, et al. (2014). “Using doubly labeled water to validate associations between sugar-sweetened beverage intake and body mass among White and African-American adults.” International Journal of Obesity 38(4): 603-609.

Erickson, K., I. Voss, et al. (2011). “Exercise training increases size of hippocampus and improves memory.” Proceedings of the National Academy of Sciences of the United States of America 108(7): 3017-3022.

Evans, A.E., A.E. Springer, et al. (2010). ”A descriptive study of beverage consumption among an ethnically diverse sample of public school students in Texas.” The Journal of American College of Nutrition 29(4): 387-396.

Fedorenko, E., M. Behr, et al. (2011). “Functional specificity for high-level linguistic processing in the human brain.” Proceedings of the National Academy of Sciences of the United States of America 108(39): 16428-16433.

Fernandes, M.M. (2012). “Effect of the Supplemental Nutrition Assistance Program (SNAP) on frequency of beverage consumption among youth in the United States.” Journal of the Academy of Nutrition and Dietetics 112(8):1241-6.

Finley, G., E. Mira, et al. (2008). “Perceived paternal and maternal involvement: Factor structures, mean differences, and parental roles.” Fathering 6(1): 62-82.

Florence, M., D. Asbridge, et al. (2008). “Diet quality and academic performance.” Journal of School Health 78(4): 209-215.

Francis, H. and R. Stevenson (2013). “The longer-term impacts of Western diet on human cognition and the brain.” Appetite 63:119-128.

Fulkerson, J.A., P. Hannan, et al. (2013). “Food responsiveness, parental food control and anthropometric outcomes among young American Indian children: cross-sectional and prospective findings.” Ethnicity & Disease 23(2): 136-142.

Fulkerson, J.A, D. Neumark-Sztainer, et al. (2006). “Adolescent and parent views of family Meals.” Journal of the American Dietetic Association 106(4): 526-532.

Fulkerson, J.A., M.Y. Kubik, et al. (2011). “Focus groups with working parents of school-aged children: what's needed to improve family meals?” Journal of Nutrition Education and Behavior 43(3): 189-193.

Fulkerson, J., A. Larson, et al. (2014). “A review of associations between family and shared meal frequency and dietary and weight status outcomes across the lifespan.” Journal of Nutrition Education and Behavior 46(1): 2-19.

Fung, T., T. Malik, et al. (2009). “Sweetened beverage consumption and risk of coronary heart disease in women.” American Journal of Clinical Nutrition 89: 1037–1042.

Gaby, A.R. (2005). “Adverse effects of dietary fructose.” Alternative medicine review: journal of clinical therapeutics 10(4): 294-306.

Galaz, G.A. (2013). “An Overview on the history of sports nutrition beverages.” D. Bagchi, S. Nair and C.K. Sen (Eds.), Nutrition and Enhanced Sports Performance. London, UK, Elsevier.

García Bacete, F.J. and J. Rosel Ramirez (2001). “Family and personal correlates of academic achievement.” Psychological Reports 88(2): 533-547.

Georgieff, M.K. (2007). “Nutrition and the developing brain: nutrient priorities and measurement. American Journal of Clinical Nutrition 85(Suppl): 614S-620S.

Gidding, S., S. Lichtenstein, et al. (2009). “Implementing American Heart Association pediatric and adult nutrition guidelines.” Circulation 119:1161-1175.

Gidding, S., S. Dennison, et al. (2006). “Dietary recommendations for children and adolescents: A guide for practitioners.” Pediatrics 117: 544-559.

Gillman, M., W. Rifas-Shiman, et al. (2000). “Family dinner and diet quality among older children and adolescents.” Archive of Family Medicine 9(3): 235-240.

Glass, C., K. Saijo, et al. (2010). “Mechanisms underlying inflammation in neurodegeneration.” Cell 140(6): 918-934.

Gómez-Pinilla, F. (2008). “Brain foods: the effects of nutrients on brain function.” Nature Reviews Neuroscience 9(7): 568-578.

Goran, M., I. Ulijaszek, et al. (2013). “High fructose corn syrup and diabetes prevalence: a global perspective.” Global Public Health 8: 55–64.

Greenwood, C.E. and G. Winocur (2005). “High-fat diets, insulin resistance and declining cognitive function.” Neurobiology of Aging 26(S1): 42-45.

Gribble, L.S., G. Falciglia, et al. (2003). “A curriculum based on social learning theory emphasizing fruit exposure and positive parent child-feeding strategies: a pilot study.” Journal of the American Dietetic Association 103(1): 100-103.

Gross, L., S. Li et al. (2004). “Increased consumption of refined carbohydrates and the epidemic of type 2 diabetes in the United States: an ecologic assessment.” American Journal of Clinical Nutrition 79: 774–779.

Haerens, L. Craeynest et al. (2008). »The contribution of psychosocial and home environmental factors in explaining eating behaviours in adolescents.” European Journal of Clinical Nutrition 62(1): 51-59.

Hammons, A.J.and B.H. Fiese (2011). “Is frequency of shared family meals related to the nutritional health of children and adolescents?” Pediatrics 127(6): 1565-1574.

Han, E. and L.M. Powell (2013). “Consumption patterns of sugar-sweetened beverages in the United States.” Journal of the Academy of Nutrition and Dietetics 113: 43-53.

Harnack, L. Story, et al. (1998). “Guess who's cooking? The role of men in meal planning, shopping, and preparation in US families.” Journal of the American Dietetic Association 98(9): 995-1000.

Harris, J.L., M.B. Schwartz, et al. (2011) “Food advertising to children and teens score. Evaluating sugary drink nutrition and marketing to youth.” Yale Rudd Center for Food Policy and Obesity Retrieved November 21, 2014, from http://www.sugarydrinkfacts.org/resources/sugarydrinkfacts_report.pdf.

Hawkins, S., S. Cole, et al. (2009). “Examining the relationship between maternal employment and health behaviours in 5-year-old British children.” Journal of Epidemiology and Community Health 63(12): 999-1004.

Hearst, M., O., Pasch, et al. (2012). “Urban v. suburban perceptions of the neighborhood food environment as correlates of adolescent food purchasing.” Public Health Nutrition 15(2): 299-306.

Hiatt, S., R. Sine, et al. (2009). “From Pabst to Pepsi: The deinstitutionalization of social practices and the creation of entrepreneurial opportunities.” Administration Science Quarterly 54: 635–667.

Hillman, C.H., D.M Castelli, et al. (2005). “Aerobic fitness and neurocognitive function in healthy preadolescent children.” Medicine and Science in Sports and Exercise 37(11): 1967-1974.

Hillman, C.H., K.I. Erickson, et al. (2008). “Be smart, exercise your heart: exercise effects on brain and cognition.” Nature Reviews Neuroscience 9(1): 58-65.

Hochuli, M., I. Aeberli, et al. (2014). “Sugar-sweetened beverages with moderate amounts of fructose, but not sucrose, induce fatty acid synthesis in healthy young men: a randomized crossover study.” The Journal of Clinical Endocrinology and Metabolism 99(6): 164-172.

Hoover-Dempsey, K.,V. Bassler, et al. (1995). “Parents' reported involvement in students' homework: Strategies and practices.” The Elementary School Journal 95(5): 435-450.

Hoover-Dempsey, K.V. and H.M. Sandler (1997). “Why do parents become involved in their children’s education?” Review of Education Research 67(1): 3-42.

Hotamisligil, G.S. (2006). “Inflammation and metabolic disorders.” Nature 444(7121): 860-867.

Hover, T.K. (1994). “Some aspects of carbohydrate metabolism in the brain.” Biochimie 76: 111-120.

Jacobson M. (2005). “Liquid candy: how soft drinks are harming Americans’ health 2005.” Retrieved October 16, 2013, from https://www.cspinet.org/new/pdf/liquid_candy_final_w_new_supplement.pdf.

Jin, R. N-A. Le, et al. (2012). “Children with NAFLD are more sensitive to the adverse metabolic effects of fructose beverages than children without NAFLD.” The Journal of Clinical Endocrinology and Metabolism 97(7): 1088-1098.

Johnson, R.,K. Appel, et al. (2009). “Dietary sugars intake and cardiovascular health: a scientific statement from the American Heart Association.” Circulation 120(11): 1011-1020.

Johnson, J.G., P. Cohen, et al. (2007). “Extensive Television Viewing and the Development of Attention and Learning Difficulties During Adolescence.” Archives of Pediatrics & Adolescent Medicine 161(5):480-486.

Jones, H., F. Butler, et al. (2013). “Developmental changes and fructose absorption in children: effect on malabsorption testing and dietary management.” Nutrition Review 71(5): 300-309.

Kanoski, S.E. and T.L. Davidson (2011). “Western diet consumption and cognitive impairment: links to hippocampal dysfunction and obesity.” Physiology & Behavior 103(1): 59-68.

Kanoski, S., E. Zhang, et al. (2010).”The effects of a high-energy diet on hippocampal function and blood-brain barrier integrity in the rat.” Journal of Alzheimer Disease 21(1): 207-219.

Karunanayaka, P., R. Holland, et al. (2007). Age-related connectivity changes in fMRI data from children listening to stories. *NeuroImage* 34(1): 349-360.

Kao, G. and J.S. Thompson (2003). “Racial and ethnic stratification in educational achievement and attainment.” Annual Review of Sociology 29: 417-442.

Keast, R.S. and L.J. Riddell (2007). “Caffeine as a flavor additive in soft-drinks.” Appetite 49(1): 255-259.

Kibbe, K., L. Hackett, et al. (2011). “Ten Years of TAKE 10!®: Integrating physical activity with academic concepts in elementary school classrooms.” Preventive Medicine 52: S43-S50.

Kirkorian, H.L., E.A. Wartella, et al. (2008). “Media and young children’s learning.” Future Child 18(1):39-61.

Kit, B., K. Fakhouri, et al. (2013). “Trends in sugar-sweetened beverage consumption among youth and adults in the United States: 1999-2010.” American Journal of Clinical Nutrition 98:180-188.

Klesges, L.M., T. Baranowski, et al. (2004). "Social desirability bias in self-reported dietary, physical activity and weight concerns measures in 8- to 10-year-old African-American girls: results from the Girls Health Enrichment Multisite Studies (GEMS)." Preventive Medicine 38: S78-87.

Kosova, E.C., P. Auinger, et al. (2013). “The relationships between sugar-sweetened beverage intake and cardiometabolic markers in young children.” Journal of the Academy of Nutrition and Dietetics 113: 219-227.

Kristjansson, A., L., Sigfusdottir, et al. (2014). “Caffeinated sugar-sweetened beverages and common physical complains in Icelandic children aged 10-12 years.” Preventive Medicine 58: 40-44.

Kumanyika, S. and S. Grier (2006).”Targeting interventions for ethnic minority and low-income populations.” Future Child 16(1):187-207.

Kwak, L. Kremers, et al. (2009). “Associations between physical activity, fitness, and academic achievement.” Journal of Pediatrics 155(6): 914-918.

Lakhan, S.E. and A. Kirchgessner (2013). “The emerging role of dietary fructose in obesity and cognitive decline.” Nutrition Journal 12:114.

Lane, M.D. and S.H. Cha (2009). “Effect of glucose and fructose on food intake via malonyl-CoA signaling in the brain.” Biochemical Biophysics Research in Community 382(1):1-5.

Larson, N., I. Story, et al. (2006). “Food preparation and purchasing roles among adolescents: associations with sociodemographic characteristics and diet quality.” Journal of the American Dietetic Association 106(2): 211-218.

Larson, N., I. Neumark-Sztainer, et al. (2007). “Family meals during adolescence are associated with higher diet quality and healthful meal patterns during young adulthood.” Journal of the American Dietetic Association 107(9):1502-1510.

Larson, N., I. Neumark-Sztainer, et al. (2008). “Fruit and vegetable intake correlates during the transition to young adulthood.” American Journal of Preventive Medicine 35(1): 33-37.

Larson, N., J. Fulkerson, et al. (2013). “Shared meals among young adults are associated with better diet quality and predicted by family meal patterns during adolescence.” Public Health Nutrition 16(5): 883-893.

Le Coutre, J. and J.A. Schmitt (2008). “Food ingredients and cognitive performance.” Current Opinion in Clinical Nutrition and Metabolic Care 11(6): 706-710.

Lenroot, R.K. and J.N. Giedd (2006). “Brain development in children and adolescents: insights from anatomical magnetic resonance imaging.” Neuroscience & Biobehavioral Reviews 30(6): 718-729.

Li, Y., Q. Dai, et al. (2008). “Overweight is associated with decreased cognitive functioning among school-age children and adolescents.” Obesity 16(8): 1809-1815.

Liese, A., D. Schulz, et al. (2005). “Dietary glycemic index and glycemic load, carbohydrate and fiber intake, and measures of insulin sensitivity, secretion, and adiposity in the Insulin Resistance Atherosclerosis Study.” *Diabetes Care* 28(12): 2832-2838.

Liu, S., M.J. Rovine, et al. (2012). “Selecting a linear mixed model for longitudinal data: Repeated measures analysis of variance, covariance pattern model, and growth curve approaches.” Psychological Methods 17(1):15-30.

Lloyd-Jones, D., M. Hong, et al. (2010). “Defining and setting national goals for cardiovascular health promotion and disease reduction. The American Heart Association’s strategic impact goal through 2020 and beyond.” Circulation 121(4): 586-613.

London, R.A. and S. Castrechini (2011). “A longitudinal examination of the link between youth physical fitness and academic achievement.” Journal of School Health 81:400-408.

Ludwig, D.S. (2009). “Artificially Sweetened Beverages: Cause for Concern.” Journal of American Medical Association 302(22): 2477-2478.

Lytle, L., A. Seifert, et al. (2000). “How do children's eating patterns and food choices change over time? Results from a cohort study.” American Journal of Health Promotion 14(4): 222-228.

Maersk, M., A. Belza, et al. (2012). “Sucrose-sweetened beverages increase fat storage in the liver, muscle, and visceral fat depot: a 6-mo randomized intervention study.” American Journal of Clinical Nutrition 95: 283-289.

Maillot, M., N. Darmon, et al. (2007). “Low energy density and high nutritional quality are each associated with higher diet costs in French adults.” American Journal of Clinical Nutrition 86: 690–696.

Makuuchi, M., J. Bahlmann, et al. (2012). “An approach to separating the levels of hierarchical structure building in language and mathematics.” Philosophical Transaction of the Royal Society 376, 2033-2045.

Malik, V., S. Pan, et al. (2013). “Sugar-sweetened beverages and weight gain in children and adults: a systematic review and meta-analysis.” American Journal of Clinical Nutrition 98(4):1084-1102.

Malik, V., S. Popkin, et al. (2010). “Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: a meta-analysis.” Diabetes Care 233(11): 2477-2483.

Manios, Y., G. Kourlaba, et al. (2009). “Diet quality of preschoolers in Greece based on the Healthy Eating Index: the GENESIS study.” Journal of the American Dietetic Association 109(4): 616-623.

Marriott, B., P. Cloe, et al. (2009). “National estimates of dietary fructose intake increased from 1977 to 2004 in the United States.” Journal Nutrition 139(Suppl): S1228-S1235.

Marriott, B., P. Olsho, et al. (2010). “Intake of added sugars and selected nutrients in the United States, National Health and Nutrition Examination Survey (NHANES) 2003–2006.” Critical Review of Food & Science Nutrition 50: 228–258.

Mathias, K.C., M.M. Slining, et al. (2013). “Foods and Beverages Associated with Higher Intake of Sugar-Sweetened Beverages.” American Journal of Preventive Medicine 44(4):351-357

Matsumoto, M., R. Kibe, et al. (2013). “Cerebral low-molecular metabolites influenced by intestinal microbiota: a pilot study.” Frontiers in Systems Neuroscience 45:37-45.

Mattes, R.D. (2006). “Fluid energy--Where's the problem?” Journal of the American Dietetic Association 106(12), 1956-1961.

Mayer, E.A. (2011). “Gut feelings: the emerging biology of gut-brain communication.” Nature Reviews Neuroscience 12(8): 453-466.

McCarthy, S. (2014). “Weekly patterns, diet quality and energy balance.” Physiology & Behavior 134: 55-59.

McLeroy, K.R., D. Mibeau, et al. (1988). An ecological perspective on health promotion programs. Health Education Quarterly 15, 351-377.

Mennella, J., A. Finkbeiner, et al. (2014). “Preferences for salty and sweet tastes are elevated and related to each other during childhood.” PLOS One 9(3): e92201.

Mergenthaler, P., U. Lindauer, et al. (2013). “Sugar for the brain: the role of glucose in physiological and pathological brain function.” Trends in Neuroscience 36(10):587-597.

Micha, R., P.J. Rogers, et al. (2010). “The glycaemic potency of breakfast and cognitive function in school children.” European Journal of Clinical Nutrition 64: 948-957.

Miller, P., E. McKinnon, et al. (2013). “Sugar-sweetened beverage consumption in the U.S.: novel assessment methodology.” American Journal of Preventive Medicine 45(4): 416-421.

Milne, A., M. Ginsburg, et al. (1986). “Single parents, working mothers, and the educational achievement of school children.” Sociology of Education 59:125-139.

Molina, M.C.B., P.M. Lopez, et al. (2010). Socioeconomic predictors of child diet quality. Revista de Saude Publica 44(5), 785-732.

Molteni, R., R.J. Barnard, et al. (2002). ”A high-fat, refined sugar diet reduces hippocampal brain-derived neurotrophic factor, neuronal plasticity, and learning.” Neuroscience 112(4): 803-814.

Morin, P., K. Demers, et al. (2013). “Association between perceived self-efficacy related to meal management and food coping strategies among working parents with preschool children”. Appetite 65:43-50.

Monti, M., M. Parsons, et al. (2012). Thought beyond language: neural dissociation of algebra and natural language. Phychological Science 23(8), 914-922.

Muller, C. (1995). “Maternal employment, parent involvement, and mathematics achievement among adolescents.” Journal of Marriage and Family 57(1): 85-100.

Muller, C., C. Riegle-Crumb, et al. (2010). ”Race and academic achievement in racially diverse high schools: opportunity and stratification. “Teachers College Report 112(4): 1038-1063.

Murakami, K., Y. Miyake, et al. (2009). Osaka Maternal and Child Health Study Group. Education, but not occupation or household income, is positively related to favorable dietary intake patterns in pregnant Japanese women: the Osaka Maternal and Child Health Study. Nutrition Research 29(3):164-172.

Myles, I.A. (2014). “Fast food fever: reviewing the impact of the Western diet on immunity.” Nutrition Journal 13: 61.

National Scientific Council on the Developing Child (2006). “*Early Exposure to Toxic Substances Damages Brain Architecture: Working Paper No. 4*.” Retrieved January 5, 2014, from https://www.developingchild.harvard.edu.

Nielson, S.J. and B.M. Popkin (2004). “Changes in beverage intake between 1977 and 2001.” American Journal of Preventive Medicine 27(3): 205-210.

Neumark-Sztainer, D., P.J. Hannan, et al. (2003). “Family meal patterns: associations with sociodemographic characteristics and improved dietary intake among adolescents.” Journal of the American Dietetic Association 103(3): 317-322.

Neumark-Sztainer, D., M. Wall, et al. (2013). “Changes in the frequency of family meals from 1999 to 2010 in the homes of adolescents: trends by sociodemographic characteristics.” Journal of the Adolescent Health 52(2): 201-216.

Neumark-Sztainer, D., R. MacLehose, et al. (2014). “What's for dinner? Types of food served at family dinner differ across parent and family characteristics.” Public Health Nutrition 17(1):145-155.

Nickelson, J., J.C. Lawrence, et al.(2014). "What Proportion of Preschool-Aged Children Consume Sweetened Beverages?" Journal of School Health 84(3): 185-194.

Nyaradi, A., J. Li, et al. (2013). "The role of nutrition in children's neurocognitive development, from pregnancy through childhood." Frontiers in Human Neuroscience, 7(97), 1-16.

Nyaradi, A., J. Li, et al. (2013). "Diet in the early years of life influences cognitive outcomes at 10 years: a prospective cohort study." Acta Paediatrics 102(12):1165-1173.

Nyaradi, A., J.K. Foster, et al. (2014). "Prospective associations between dietary patterns and cognitive performance during adolescence." Journal of Child Psychology and Psychiatry 55(9):1017-1024.

Ogden, J. and R. Brown. (2004). "Children's eating attitudes and behaviour: a study of the modelling and control theories of parental influence." Health Education Research 19(3), 261-271.

Ogden, C.L., B.K. Kit, et al. (2011). Consumption of sugar drinks in the United States, 2005-2008. National Center for Health Statistics Data Brief.

Olafsdottir, S., G. Eiben, et al. (2013). "Young children's screen habits are associated with consumption of sweetened beverages independently of parental norms." International Journal of Public Health 1:67-75.

Page, K.A., O. Chan, et al. (2013). "Effects of fructose vs glucose on regional cerebral blood flow in brain regions involved with appetite and reward pathways." Journal of American Medical Association 309(1): 63-70.

Pappas, B.A., J.C. de la Torre, et al. (1996). Chronic reduction of cerebral blood flow in the adult rat: late-emerging CA1 cell loss and memory dysfunction. Brain Research 708(1-2): 50-58.

Park, S., B. Sherry, et al. (2012). "Self-reported academic grades and other correlates of sugar-sweetened soda intake among US adolescents." Journal of the Academy of Nutrition and Dietetics 112(1): 125-131.

Peters, A. (2011). "The selfish brain: Competition for energy resources." American Journal of Human Biology 23(1): 29-34.

Petraccia, L., G. Liberati, et al. (2006). "Water, mineral waters and health." Clinical Nutrition 25(3): 377–385.

Phillips, C., M.A. Baktir, et al. (2014). "Neuroprotective effects of physical activity on the brain: a closer look at trophic factor signaling." Frontiers in Cellular Neuroscience 8:1-16.

Poldrack, R.A. (2006). "Can cognitive processes be inferred from neuroimaging data?" Trends in Cognitive Science 10(2), 59-63.

Popkin, B.M., L.E. Armstrong, et al. (2006). “A new proposed guidance system for beverage consumption in the United States.” American Journal of Clinical Nutrition 83(3):529-542.

Popkin, B.M. and S.J. Nielsen (2003). “The sweetening of the world's diet.” Obesity Research 11(11):1325-1332.

Powell, L.M., G. Szczypka, et al. (2010). “Trends in exposure to television food advertisements among children and adolescents in the United States.” Archive of Pediatric and Adolescent Medicine 164(9):794-802.

Proteggente, A.R., A.S. Pannala, et al. (2002). “The antioxidant activity of regularly consumed fruit and vegetables reflects their phenolic and vitamin C composition.” Free Radical Biology and Medicine 26(9-10): 1231-1237.

Qin, S., S. Cho, et al. (2014). “Hippocampal-neocortical functional reorganization underlies children’s cognitive development.” Nature Neuroscience. 17(9), 1263-1269.

Ramasamy, R., S.J. Vannucci, et al. (2005). “Advanced glycation end products and RAGE: a common thread in aging, diabetes, neurodegeneration, and inflammation.” Glycobiology 15(7): 16R-28R.

Ranjit, N., M.H. Evans, et al. (2010). “Dietary and activity correlates of sugar-sweetened beverage consumption among adolescents.” Pediatrics 126(4): e754-761.

Rasberry, C.N., S.M. Lee, et al. (2011). ”The association between school-based physical activity, including physical education, and academic performance: a systematic review of the literature.” Preventive Medicine 52, S10-S20.

Rauner, R.R., R.W. Walters, et al. (2013). “Evidence that aerobic fitness is more salient than weight status in predicting standardized math and reading outcomes in fourth- through eighth-grade students.” Journal of Pediatrics 163: 344-348.

Rauzon, S., Wang, M., Studer, N., Crawford, P. (2010). “An evaluation of the School Lunch Initiative: Final report.” Berkeley, CA, University of California at Berkeley Atkins Center for Weight and Health.

Richmond, T.K., J.L. Spadano-Gasparro, et al. (2013). “Middle school food environments and racial/ethnic differences in sugar-sweetened beverage consumption: findings from the Health Choices study.” Preventive Medicine 57(5): 735-738.

Riegle-Crumb, C. (2006). “The Path through Math: Course Sequences and Academic Performance at the Intersection of Race-Ethnicity and Gender.” American Journal of Education (Chic Ill) 113(1): 101-122.

Riley, J.J. (1958). A History of the American Soft Drink Industry; Bottled Carbonated Beverages, 1807–1957. Washington, DC, American Bottlers of Carbonated Beverages.

Rivard, C., D. Smith, et al. (2012). “Taxing sugar-sweetened beverages: a survey of knowledge, attitudes and behaviours.” Public Health Nutrition.15(8): 1355-1361.

Rizkalla, S.W. (2010). “Health implications of fructose consumption: A review of recent data.” Nutrition Metabolism 7:82.

Robert Wood Johnson Foundation (RWJF). 2009. “The negative impact of sugar- sweetened beverages on children’s health: A research synthesis”. Princeton, NJ, Robert Wood Johnson Foundation. Retrieved January 14, 2013, from http://www.rwjf.org/en/research-publications/find-rwjf-research/2009/11/the-negative-impact-of-sugar-sweetened-beverages-on-children-s-h.html.

Roberts, C.K., B. Freed, et al. (2010). “Low aerobic fitness and obesity are associated with lower standardized test scores in children.” Journal of Pediatrics 156, 711-718.

Rosenkranz, R.R. and D.A. Dzewaltowski (2008). “Model of the home food environment pertaining to childhood obesity. Nutrition Review 66(3):123-40.

Ross, A.P., E.C. Bruggeman, et al (2012). “Non-alcoholic fatty liver disease impairs hippocampal-dependent memory in male rats.” Physiology & Behavior 106:133-141.

Rothausen, B.W., J. Matthiessen, et al. (2012). “Differences in Danish children's diet quality on weekdays v. weekend days.” Public Health Nutrition 15(9):1653-1660.

Rouse, C.E. and L. Barrow (2006). “US elementary and secondary schools: equalizing opportunity or replicating the status quo?” Future Child 16(2): 99-123.

Rugg, M.D., P.C. Fletcher, et al. (1996). “Differential activation of the prefrontal cortex in successful and unsuccessful memory retrieval.” Brain 119(6): 2073-2083.

Rushton, J.P. and A.R. Jensen (2005). “Thirty years of research on race differences in cognitive ability.” Psychology, Public Policy and Law 11(2): 235-294.

Schroder, H., J. Marrugat, et al. (2006). ”High monetary costs of dietary patterns associated with lower body mass index: a population-based study.” International Journal of Obesity (Lond) 30: 1574–1579.

Schulze, M.B., J.A.E. Manson, et al. (2004). “Sugar-sweetened beverages, weight gain, and incidence of type 2 diabetes in young and middle-aged women”. Journal of the American Medical Association 292: 927-934.

Seneff, S., G. Wainwright, et al. (2011). “Nutrition and Alzheimer's disease: the detrimental role of a high carbohydrate diet.” European Journal of Internal Medicine 22(2):134-140.

Sevastianova, K., A. Santos, et al. (2012). “Effect of short-term carbohydrate overfeeding and long-term weight loss on liver fat in overweight humans.” American Journal of Clinical Nutrition 96(4): 727-734.

Shin, N. (2004). “Exploring pathways from television viewing to academic achievement in school age children.” The Journal of Genetic Psychology 165(4):367-81.

Short, R.V. (1994). “Human reproduction in an evolutionary context.” Annals of the New York Academy *Sci*ence 709*: 416*–425.

Simopoulos, A. (2013). “Dietary omega-3 fatty acid deficiency and high fructose intake in the development of metabolic syndrome, brain metabolic abnormalities, and non-alcoholic fatty liver disease nutrients.” Nutrients 5(8): 2901-2923.

Smedley, B.D. and S.L. Syme (2001). “Promoting health: intervention strategies from social and behavioral research.” American Journal of Health Promotion 15(3): 149-166.

Sonnenburg, E.D. and J.L. Sonnenburg (2014). “Starving our microbial self: The deleterious consequences of a diet deficient in microbiota-accessible carbohydrates.” Cell Metabolism 20(5): 779-786.

Stanhope, K.L. and P.J. Havel (2008). “Endocrine and metabolic effects of consuming beverages sweetened with fructose, glucose, sucrose, or high-fructose corn syrup. *American* Journal of Clinical Nutrition 88(suppl): 1733S-1737S.

Stanhope, K.L., J.M. Schwarz, et al. (2013). “Adverse metabolic effects of dietary fructose: results from the recent epidemiological, clinical, and mechanistic studies.” Current Opinion in Lipidology 24(3):198-206.

Steinberg, L. (2005). “Cognitive and affective development in adolescence.” Trends in Cognitive Sciences 9(2): 69-74.

Stephan, B., C. Wells, et al. (2010). “Increased fructose intake as a risk factor for dementia.” The Journals of Gerontology. Series A: Biological Sciences and Medical Sciences 65(8): 809-814.

Story, M. and S. French (2004). “Food advertising and marketing directed at children and adolescents in the US.” International Journal of Behavioral Nutrition and Physical Activity 1: 1-3.

Story, M., N. Neumark-Sztainer, et al. (2002). “Individual and Environmental Influences on Adolescent Eating Behaviors” Journal of the American Dietetic Association 102(3): S40-S51

Stranahan, A., M. Norman, et al. (2008). “Diet-induced insulin resistance impairs hippocampal synaptic plasticity and cognition in middle-aged rats.” Hippocampus 18(11): 1085-1088.

Taber, D.R, J.F. Chriqui, et al.(2012). “Banning all sugar-sweetened beverages in middle schools reduction of in-school access and purchasing but not overall consumption.” Archives of Pediatrics & Adolescent Medicine 166(3): 256-262.

Tan, E.T. and W.A. Goldberg (2009). “Parental school involvement in relation to children's grades and adaptation to school.” Journal of Applied Developmental Psychology 30: 442–453.

Tappy, L. and K.A. Lê (2010). “Metabolic effects of fructose and the worldwide increase in Obesity.” Physiololgy Review 90: 23-46.

Tappy, L., K.A. Lê, et al. (2010). ”Fructose and metabolic diseases: new findings, new questions.” Nutrition 26(11-12): 1044-1049.

Taras, H. (2005). “Nutrition and student performance at school.” Journal of School Health 75:199-213.

Teff, K., L. Elliott, et al. (2004). “Dietary fructose reduces circulating insulin and leptin, attenuates postprandial suppression of ghrelin, and increases triglycerides in women.” The Journal of Clinical Endocrinology and Metabolism 89(6): 2963-2972.

Te Morenga, L. Mallard, et al. (2013). “Dietary sugars and body weight: systematic review and meta-analyses of randomized controlled trials and cohort studies.” British Medical Journal 346: e7492.

Temple, J.L. (2009). “Caffeine use in children: what we know, what we have left to learn, and why we should worry.” Neuroscience Biobehavioral Review 33(6), 793-806.

Totland, T., H. Gebremariam, et al. (2012). “Does tracking of dietary behaviours differ by parental education in children during the transition into adolescence?” Public Health Nutrition 9: 1-10.

Totland, T., H. Lien, et al. (2013). “The relationship between parental education and adolescents’ soft drink intake from the age of 11-13 years, and possible mediating effects of availability and accessibility.” The British Journal of Nutrition 110(5): 926-933.

US Census Bureau. (2012) “Labor force, employment and earnings” The 2012 Statistical Abstract of the United States. Retrieved September 16, 2014, from http://www.census.gov/prod/2011pubs/12statab/labor.pdf.

US Department of Agriculture. (2014). “Sugar and Sweeteners Team, Market and Trade Economics, Economic Research Service, US Department of Agriculture. US per capita caloric sweeteners estimated deliveries for domestic food and beverage use, by calendar year.” Retrieved November 28, 2014, from http://www.ers.usda.gov/briefing/Sugar/data/table50.xls.

van Ansem, W.,J. van Lenthe, et al. (2014). “Socio-economic inequalities in children's snack consumption and sugar-sweetened beverage consumption: the contribution of home environmental factors.” British Journal of Nutrition 12(3): 467-476.

van der Borght, K., Köhnke, et al. (2011). “Reduced neurogenesis in the rat hippocampus following high fructose consumption.” Regulatory Peptides. 167(1):26-30.

Van der Horst, K., Ferrage, et al. (2014). “Involving children in meal preparation. Effect on food intake.“ Appetite 79: 18-24.

Van Dusen, D., P. Kelder, et al (2011). “Associations of physical fitness and academic performance among schoolchildren.” Journal of School Health 81: 733-740.

van Praag, H. (2009). “Exercise and the brain: something to chew on.” Trends in Neuroscience 32(5): 283–290.

Vassiloudis, I., N. Yiannakouris, et al. (2014). "Academic performance n relation to adherence to the Mediterranean diet and energy balance behaviors in Greek primary schoolchildren." Journal of Nutrition Education and Behavior 46(3): 164-170.

Venn, B.J.and T.J. Green (2007). "Glycemic index and glycemic load: measurement issues and their effect on diet-disease relationships." European Journal of Clinical Nutrition 61(S1): S122-S131.

Ventura, A.K. and Mennella, J.A. (2011). "Innate and learned preferences for sweet taste during childhood." Current Opinion of Clinical Nutrition and Metabolic Care 14(4): 379-384.

Ventura, E., E. Davis, et al (2011). "Sugar content of popular sweetened beverages based on objective laboratory analysis: focus on fructose content." Obesity 19(4): 868-874.

Vereecken, C., L. Haerens, et al (2010). "The relationship between children's home food environment and dietary patterns in childhood and adolescence." Public Health Nutrition 13(10A): 1729-1735.

Verzeletti,.C., L. Maes, et al. (2010). "Soft drink consumption in adolescence: associations with food-related lifestyles and family rules in Belgium Flanders and the Veneto Region of Italy." European Journal of Public Health 20(3): 312-317.

Volk, B.M. and B.C Creighton (2013). "An overview on caffeine." D. Bagchi, S. Nair and C.K. Sen (Eds.), Nutrition and Enhanced Sports Performance. London, UK: Elsevier.

Vos, M.B. and J.E. Lavine (2013). "Dietary fructose in nonalcoholic fatty liver disease." Hepatology 57(6): 2525-2531.

Wan, W., H. Chen, et al. (2014). "The potential mechanisms of Aβ-receptor for advanced glycation end-products interaction disrupting tight junctions of the blood-brain barrier in Alzheimer's disease." The International Journal of Neuroscience 124(2):75-81.

Wang, M.C., S. Rauzon, et al.(2010). "Exposure to a comprehensive school intervention increases vegetable consumption." Journal of Adolescent Health 47: 74-82.

Wang, W., K. Parker, et al. (2013). "Breadwinner Moms." Retrieved December 1, 2014, from http://www.pewsocialtrends.org/2013/05/29/breadwinner-moms.

Wang,Y.C., S.N. Bleich, et al. (2008). "Increasing caloric contribution from sugar-sweetened beverages and 100% fruit juices among US children and adolescents, 1988-2004." Pediatrics 121(6): e1604-1614.

Wardle, J. (1995). "Parental influences on children's diets." The Proceedings of the Nutrition Society 54: 747-758.

Wärnberg, J., S. Gomez-Martinez, et al.(2009). "Nutrition, inflammation, and cognitive function." Annals of New York Academy of Science 1153: 164-175.

Warner, D. (2011). Sweet stuff: an American history of sweeteners from sugar to sucralose. pg 141. Washington, DC: Smithsonian Institution.

Welk, G.J., A. W. Jackson, et al. (2010). “The association of health-related fitness with indicators of academic performance in Texas schools.” Research Quarterly for Exercise and Sport 81(3 Suppl): S16-23.

Welsh, J.A., E.A. Lundeen, et al. (2013). “The sugar-sweetened beverage wars: public health and the role of the beverage industry.” Current Opinion in Endocrinology, Diabetes and Obesity 20(5):401-6.

Wescott, R.F., B.M. Fitzpatrick, et al. (2012). “Industry self-regulation to improve student health: quantifying changes in beverage shipments to schools.” American Journal of Public Health 102: 1928-1935.

Wijtzes, A.I., W. Jansen, et al. (2013). “Maternal educational level and preschool children’s consumption of high-calorie snacks and sugar-containing beverages: mediation by the family food environment.” Preventive Medicine 57(5): 607-612.

Winkleby, M.A., D.E. Jatulis, et al. (1992). “Socioeconomic status and health: how education, income, and occupation contribute to risk factors for cardiovascular disease.” American Journal of Public Health 82(6), 816-820.

Whitney, E. and S. Rady Rolfes (2011). Understanding Nutrition. Belmont: Wadsworth.

Wiecha, J.L., A. M. Sobol, et al. (2001). “Household television access: Associations with screen time, reading, and homework among youth.” Ambulatory Pediatric 1, 244-251.

Williams, E. and N. Radin (1993). “Paternal involvement, maternal employment, and adolescents' academic achievement: an 11-year follow-up.” The American Journal of Orthopsychiatry 63(2): 306-312.

Wolf, A., G.A. Bray, et al. (2008). “A short history of beverages and how our body treats them.” Obesity Review 9(2): 151-164.

Wolraich, M.L., D.B. Wilson, et al. (1995). “The effect of sugar on behavior or cognition in children: a meta-analysis.” The Journal of American Medical Association 274(20),1617-1621.

Woodruff, S.D. (1992). “Complications of the commonplace: tea, sugar, and imperialism.” Journal of Interdisciplinary History 23(2): 259-278.

Woodruff, S.J. and R. M. Hanning. (2009). “Associations between family dinner frequency and specific food behaviors among grade six, seven, and eight students from Ontario and Nova Scotia.” Journal of Adolescent Health 44(5): 431-436.

Woodward-Lopez, G., W. Gosliner, et al. (2010). “Lessons learned from evaluations of California’s statewide school nutrition standards.” American Journal of Public Health 100(11): 2137-2145.

Wu, T., E. Giovannucci, et al. (2004). “Fructose, glycemic load, and quantity and quality of carbohydrate in relation to plasma C-peptide concentrations in US women.” American Journal of Clinical Nutrition 280(4): 1043-9.

Yamada, M., K. Murakami, et al. (2008). “Soft drink intake is associated with diet quality even among young Japanese women with low soft drink intake.” Journal of the American Dietetic Association 108(12): 1997-2004.

Ye, X., X. Gao, et al.(2011). “Habitual sugar intake and cognitive function among middle-aged and older Puerto Ricans without diabetes.” British Journal of Nutrition: 1-10.

Young, L.R. and M. Nestle. (2003). “Expanding portion sizes in the US marketplace: Implications for nutrition counseling.” Journal of the American Dietetic Association 103: 231-234.

Yurgelun-Todd, D. (2007). “Emotional and cognitive changes during adolescence.” Current Opinion in Neurobiology 17(2): 251-257.

Zhao, X., J.G. Lynch Jr., et al. (2010). “Reconsidering Baron and Kenny: Myths and Truths about Mediation Analysis.” Journal of Consumer Research 37(2): 197-206