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Christina Brumme Date

Sugars in the U.S. Diet: A Description of Consumption Patterns by Type and Purchasing Practices of Adolescent Consumers

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2012

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Abstract

Sugars in the U.S. Diet: A Description of Consumption Patterns by Type and Purchasing Practices of Adolescent Consumers

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Introduction: There are many types of sugars consumed by individuals living in the United States, and the consumption patterns of these different sugars is not known. The purpose of the first study in this thesis is to estimate the amount of each type of sugar consumed among demographic groups: age, gender, income, and race or ethnicity The purpose of the second study is to understand where sugar-containing foods and beverages are purchased and consumed by adolescents.

Data/Methods: For the first study, nationally representative NHANES data from the combined 09-10 and 11-12 cycles were used to describe sugar intake among different demographic groups. For the second study, NHANES data from the 2011-2012 cycle were used to estimate sugar content of foods and beverages consumed by adolescents aged 12 to 19 years (n=1152) based on purchase location. For both studies, food codes were categorized as dairy or non-dairy and as food or beverage according to the Food and Nutrient Database for Dietary Studies (FNDDS) codes. Added sugar values were acquired from the Food Patterns Equivalence Database to determine content of added and natural sugars in each dairy, non-dairy, food, and beverage group were calculated for both studies.

Results: Among all age groups, adolescents aged 12-19 years consumed the most added sugars from all sources at 91.4 (95% CI 87.0, 95.7) grams each day. More than half of this added sugar comes from non-dairy beverages at 47.2 (95% CI 43.1, 51.4) grams. The average amount of added sugar in a non-dairy beverage from a restaurant with a server is 51.4 (95% CI 45.0, 57.8) grams of added sugar, versus the next-highest amount from convenience stores of 42.7 (95% CI 34.6, 50.8).

Discussion/Conclusion: Consumption of sugars peaks in adolescence, particularly of added sugars in non-dairy beverages; as such, efforts to reduce consumption of added sugars should focus on adolescents. Large differences are seen in average sugar content by purchase locations, such as the sugar content of beverages purchased at restaurants compared to other purchase locations. There is a need to determine what causes these differences in sugar intake among adolescents and sugar content from different locations.

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Chapter 1: Introduction

I. Introduction

A. Rationale

Habits formed early in life often continue into adolescence and into adulthood [1, 2]. As such, understanding dietary habits in adolescence requires an understanding of diet in both childhood and adulthood. For example, stating that "the peak of soda consumption is during adolescence when teens aged 13-18 consume about 600 calories per day from sodas, which is more than either children aged 7-12 or adults aged 19-39", gives a different picture that stating that, "teens consume 600 calories per day on average from soda" [3]. The goal of these analyses is to address both of these points: describe the consumption of sugars in the US diet and determine purchase and consumption patterns of sugar among adolescents.

Dietary intake can be evaluated in multiple ways, depending on the factors and outcomes of interest. For example, one can look at measures of the whole diet, such as the Healthy Eating Index (HEI), which compares a person's diet to the Dietary Guidelines for Americans [4], or one can measure the intake of a single food or nutrient to determine the contribution that that food or nutrient makes to the overall diet. Previous studies have determined that there are significant differences in dietary intake between age groups, income levels, genders, and race/ethnicities when diet was measured using the Healthy Eating Index [5]. This finding indicates

that there will likely be similar differences when other dietary measures are used. One such measurable component is sugar intake, which is one aspect of diet quality.

Sugar is an umbrella term used to refer to a category of foods and nutrients that add sweetness and improve the texture and shelf-life of foods and beverages [6]. Sugar can be both a food and a nutrient: there are specific foods, such as table sugar or honey, that are eaten to increase sweetness and there are also measureable components of foods, such as mono- or di-saccharides, called nutrients that also fall under this umbrella term [6]. These mono- and disaccharides can either be natural, meaning they are present in the food while it is grown, as with fructose in fruit or lactose in milk, or added during processing or cooking in the form of cane sugar, high-fructose corn syrup, or other sweeteners [6]. The USDA defines added sugars as, "sugars added to foods during processing, preparation, or at the table" [7].

The health outcomes associated with added and natural sugars appear to be unclear at the individual level, as some studies indicate negative health impacts and some indicate no impact [8, 9]. There has been an increase in diet-related non-communicable diseases such as diabetes, heart disease, and obesity concurrent with an increase in added sugar consumption in the United States since 1970 [8, 10]. Sugar and all foods that fall into this category are carbohydrates. Though carbohydrates are essential for the brain to function properly, the typical American diet often contains more carbohydrate than is necessary to support brain function. However, carbohydrates in food are often consumed as micronutrient and fiber-poor added sugars instead of micronutrient and fiber-rich complex carbohydrate [6].

In addition to types of sugar, differences in sugar content between meals consumed at home and those consumed away from home are examined in this thesis. Some evidence suggests that home-cooked meals are more healthful than those purchased at restaurants, possibly because they contain more fruits and vegetables [11]. Therefore there is a need to document differences in nutritional quality, such as sugar content, between foods and beverages consumed at home or away from home. Efforts to reduce intake of foods high in fat and sugar and improve intake of fruits, vegetables, and water may facilitate decreases in obesity and nutrition related non-communicable diseases [10].

In order to positively impact dietary habits in the United States, it is important to first understand current consumption patterns. The first step in doing so is to determine how much and which types of sugars are consumed by various age groups, including children, adolescents, and adults. Additionally, it is helpful to determine differences in sugar intake between men and women and between individuals with differing economic resources and of different race and ethnic groups.

Research has informed us about some consumption and purchase habits of sugar-containing foods by adolescents in the United States. For example, most added sugars are purchased at stores, including grocery and convenience stores [12]. However, differences in sugar content between foods and beverages consumed at home compared with away from home, along with any differences in sugar consumption patterns between foods purchased in specific locations, is not known. It is important to determine where the majority of foods are being purchased and

consumed and to understand any differences in sugar content of foods and beverages from different locations. Differences in sugar content between locations of purchase may help illuminate what practices at the individual, family, and store level, contribute to increases and decreases in sugar consumption.

B. Objectives

The goals of this thesis was to provide a comprehensive description of sugar consumption patterns in the U.S. by age and to highlight purchasing practices among teenagers, who are the highest consumers of added sugars [12]. More specifically, these studies have the following objectives.

1. Describe the current consumption of added and natural sugars in dairy and non-dairy foods and beverages by adults, adolescents, and children of different demographic groups living in the United States in 2009-2012.
2. Determine the amount of added and natural sugars in dairy and non-dairy foods and beverages consumed in the home versus away from the home by adolescents living in the United States in 2011-2012.
3. Identify differences and similarities in the content of added and natural sugars in dairy and non-dairy foods and beverages consumed by adolescents living in the United States in 2011-2012 based on the place of purchase of the food or beverage.

C. Study Purpose

The primary purpose of this research is to understand consumption patterns of different types of sugar in the United States, including added and natural sugars

in dairy and non-dairy foods and beverages. This research will help determine the contribution of foods and beverages to overall sugar intake as well as identify differences in consumption between different age, income, gender, and race/ethnicity groups.

The second purpose of this research is to comprehensively describe intake of added and natural sugars in dairy and non-dairy foods and beverages in adolescents by purchase and consumption location. Consumption locations included foods and beverages consume either in the home or away from the home. Purchase locations examined are grocery stores, restaurants with servers, fast food restaurants, convenience stores, and school cafeterias. Though this list of purchase locations is not exhaustive, these locations constitute the majority of adolescent food purchases [12].

D. Public Health Relevance

Understanding differences in sugar intake between various groups will help tailor interventions to specific groups according to their needs. This analysis will support public health interventions by showing the sources that contribute most and least to overall sugar intake in different demographic subgroups. Determining whether there are differences in intake will allow for targeted interventions, such as those that reduce consumption of sodas in adolescents or juices in young children.

Additionally, understanding purchase and consumption habits of adolescents will further help focus public health and policy efforts to improve health among this group. This improvement in health may be achieved through interventions tailored to specific purchase locations, such as convenience stores or grocery stores, or

through interventions tailored to specific places of consumption. For example, if it is found that adolescents consume the majority of their meals at home, then efforts to improve food purchasing and preparation habits may be more relevant than efforts to improve restaurant-ordering habits.

Chapter 2: Review of the Literature

II. Background

A. Sources of Foods and Beverages

The number of households who regularly cook and eat meals at home had been consistently decreasing between the 1960's and the 1990s; in the 1990's, the number of meals consumed at home, including meals that required minimal preparation, such as frozen or ready-to-eat meals, began to plateau [13]. This shift toward eating at restaurants more than eating at home has coincided with an increase in the United States of nutrition-related chronic diseases, such as heart disease, diabetes, and obesity [10]. However, in the past decade, the rate of obesity has begun to plateau among adults in the United States [14]. This plateau indicates a need to re-evaluate whether or not there are significant differences between home cooked meals and those purchased at restaurants. There is also a need to determine whether or not the purchase location of these meals impacts the nutritional quality of the food or beverage. For instance, a given meal may be consumed at home and also purchased from a fast food restaurant; there is a need to determine whether or not this meal may differ from a meal purchased elsewhere, such as at a grocery store or in a school cafeteria.

1. Home Cooking

One study, conducted among adults living in Seattle, Washington examined the amount of time spent on cooking and food preparation as it relates to indicators

of a healthful diet such as fruit and vegetable intake [11]. Those who spent over two hours per day on cooking and clean up were more likely to consume more fruits and vegetables than those who spent less time each day on cooking [11]. This finding of higher consumption of fruits and vegetables among those individuals who spend more time cooking food has been supported by other studies [15-17].

It is important to consider the significant barriers that many individuals face to cooking at home, such as time and ability to cook. These barriers are particularly evident among low-income individuals, who either always cook at home, defined as 6-7 dinners per week cooked at home, or never cook at home, defined as 0-1 dinners per week cooked at home [18]. In one study, researchers aimed to evaluate these barriers through semi-structured interviews and found that common barriers included lack of knowledge or self-efficacy with regards to cooking, time constraints, unpredictability of schedules, and the desire for a varied diet of foods they considered "good" or "healthy" [19].

2. Restaurants

There has been an increase in restaurant food consumption in the past three decades in the United States; in 1977, 24.3% of calories were consumed at restaurants and in 2006 33.9% of calories were consumed at restaurants [20]. This increase in calories consumed at restaurants, whether due to frequency of visiting restaurants or increase of calories consumed in one sitting at a restaurant, is not surprising in the context of restaurant policies such as free-refills and increasing serving sizes. For example, in the 1950's, the average soda size sold at fast food

restaurants was 12 ounces; the average medium size soda is now almost double that amount and the average large size soda is triple that amount [21].

This increase in restaurant portion sizes over time raises questions about the quality of restaurant food versus home-prepared foods. The majority of the previously mentioned studies that evaluate diet quality with regards to home cooking do so by comparing the individuals who cook at home with those who consistently eat at restaurants [11, 16, 17]. These studies have found that eating at restaurants more often is associated with an increase in dietary fat and a decrease in fruit and vegetable intake [11, 16, 17]. One study in particular found that young adults who consumed food from a restaurant that primarily served burgers and fries consumed significantly more sugar-sweetened beverages, fat, and overall calories each day; these individuals tended to have higher weight than their peers who did not eat at these restaurants [17].

While these studies show important differences in diet quality and restaurant use, the methods used typically asked survey respondents how often they ate at restaurants and how often they consumed different foods through a Food Frequency Questionnaire (FFQ) [17]. This method of assessment does not allow us to see any differences in the qualities of the foods consumed at home versus at restaurants. More research is needed to determine whether there is a systematic difference in the nutritional quality of these foods that results in differences in dietary intake, obesity, and chronic disease risk or whether there are other more influential factors.

3. Other Sources of Foods and Beverages

Food may be consumed at places other than home or at restaurants, including schools, community kitchens, friend's homes, and others. An analysis using nationally representative data found that about 300 calories each day come from school cafeterias, gifts, and other (such as vending machine, grown/caught, etc.) combined, versus about 1300 calories each day from stores and 500 calories each day from restaurants. This analysis found that adolescents and children consumed 5-10% of their diet from a school cafeteria and that <1% of the diet of all Americans comes from these "other" sources. This analysis will focus both on differences in sugar content of foods consumed in the home and away from the home and on differences in sugar content of foods purchased at stores, restaurants, school cafeterias, and "other" locations.

B. Sugar Consumption

Recent technological developments have led to consumption of sugars other than cane and beet sugar, such as high fructose corn syrup. The term "sugars" is often employed as the umbrella term for these caloric sweeteners [6]. The sweeteners included in the term "sugar" have similar dietary functions, namely sweetening food and helping improve texture and shelf-life, though composition of mono- and disaccharides varies slightly [6]. Sugars can be classified by chemical composition as added or naturally occurring or by the plant source of the sugar, such as beet or cane sugar [6]. Naturally occurring sugars develop in food while it is grown, examples including fructose in fruit or lactose in dairy.

Added sugars were defined by the USDA in the 2005 Dietary Guidelines for Americans as sugars that are added during processing or at the point of consumption, including cane sugar, high-fructose corn syrup, honey, and others. As added sugar has no essential biological function, this term helps consumers identify foods that are higher in calories with no additional nutritional value added to the food or beverage [6, 8, 22, 23]. Added sugars are often associated with negative health outcomes, though little is known about the health impacts of added versus natural sugars [8, 9]. High intake of soda has been associated with higher overall weight, but this association is not seen with sodas and 100% juice combined [24]. This association indicates that there may be difference between added sugars versus natural sugars, because soda contains mostly added sugars while 100% juice contains natural sugars [24].

Additionally, it is important to understand whether there is a difference in nutritional quality of sugars based on the physical form in which it is consumed (i.e. food or beverage). One study found that participants' overall calorie intake increased when participants consumed caloric beverages versus food, possibly because food caused hunger satiation whereas the calories in beverages did not [25, 26]. This difference in satiety is not well understood, but may be due to differences in other nutrients present, such as fat and protein, or may be due to the act of eating versus drinking [26]. Looking at dairy foods and beverages is one way to examine differences in satiety due to other nutrients present because dairy beverages, namely milk, contain both fat and protein in addition to natural sugars and sometimes added sugars [27].

Research has suggested that an increase in food from restaurants and sources outside of the home has driven an increase in energy intake; there is a need to evaluate what it is about food from restaurants that may affect energy intake [20]. Food energy, or calorie content, is determined by three macronutrients, fat, protein, and carbohydrates, which all have essential biological functions [28]. Sugar is one type of carbohydrate that does not contribute nutrients aside from energy to the diet [6]. As a result, the impact of sugar on the body is largely detrimental with little benefit and the calorie contribution of sugar to the diet must be evaluated [8, 25, 29, 30].

C. Nutrition in Adolescence

Adolescence is a formative period in a person's life; habits formed during adolescence often carry over into adulthood [1] and these habits are often formed during adolescence [2]. Additionally, there is some evidence that dietary patterns and dietary quality in childhood and adolescence relate to nutrition later in life [31]. One review article found that studies of multiple designs, including prospective cohort studies, which evaluate long-term health impacts of behaviors, and randomized controlled trials, which evaluate short-term health impacts of behaviors all show a significant association between increased sugar sweetened beverage intake and outcomes including obesity and type 2 diabetes [32].

One characteristic specific to adolescents is growing independence and the ability to make autonomous decisions. One such area is the ability of adolescents to make unsupervised food decisions when they eat out with friends. There is evidence that when children have certain foods restricted in childhood, as adolescents, when

given the freedom to make their own decisions, they tend to consume large amounts of these foods. [33-35] The potential long-term impact of poor nutrition in adolescence makes it important to evaluate sugar consumption patterns in adolescence.

Chapter 3: Sugar Intake in the U.S. Diet: Consumption Patterns of Added and Naturally Occurring Sugars in Liquid and Solid Form

I. Abstract

Introduction: There are many types of sugars consumed by individuals living in the United States, and the consumption patterns of these different sugars is not known. Sugars are present in many foods and beverages, including those made from dairy and non-dairy, and may be naturally occurring or added at the point of consumption. The purpose of this study is to determine the amount of these different types of sugar consumed among different age, income, and racial/ethnic groups.

Data/Methods: NHANES data from the 09-10 and 11-12 cycles were combined and used to describe sugar intake among different age, income, and race/ethnicity groups. Food codes were categorized as dairy or non-dairy and as food or beverage according to the Food and Nutrient Database for Dietary Studies (FNDDS) codes. Added sugar values were acquired from the Food Patterns Equivalence Database to determine content of added and natural sugars in each dairy, non-dairy, food, and beverage group.

Results: Among all age groups, adolescents aged 12-19 years consumed the most added sugars from all sources at 91.4 (95% CI 87.0, 95.7) grams each day. More than half of this added sugar comes from non-dairy beverages, which contributed 47.2 (95% CI 43.1, 51.4) grams each day. Children aged 2-5 years consumed the highest percentage, 28.6% (95% CI 28.0%, 29.2%) of their diet as sugars. The lowest income group had the highest intake of added sugars from beverages, with 41.1 grams (95% CI 38.6, 43.5); the group with the highest income had the highest intake of natural sugars from foods at 28.0 grams (95% CI 26.7, 29.4). There were no differences in intake among racial/ethnic groups.

Discussion/Conclusion: Consumption of sugars peaks in adolescence, particularly added sugars in non-dairy beverages. Young children aged 2-5 years consume the most grams of natural sugars from foods and beverages when compared to all other age groups. Efforts to reduce consumption of added sugars, particularly in non-dairy

beverages, should focus on adolescents, as they consume the most sugar when compared to other age groups. Similarly, those in the lowest income group consumed more added sugars from non-dairy beverages than other income groups, an important finding given that low-income individuals have a higher disease burden, particularly with nutrition related diseases such as diabetes [36].

II. Contribution of the Student

Christina Brumme did all data analyses, figure and table development, and manuscript writing. Co-authors and thesis committee members, Dr. Solveig Cunningham and Dr. Jean Welsh, assisted in editing and advising the development of the manuscript. Dr. Jean Welsh assisted in development of the research question and study objectives.

III. Introduction

Dietary sugars and their food and beverage sources have become a leading contributor of calories in the U.S. diet [29, 30] though the impact of dietary sugars on an individual's health may vary based on the type of sugar [37]. U.S. Dietary Guidelines encourages the consumption of milk and other dairy products, which are high in lactose, a type of sugar, as dairy products are also an important source of calcium and vitamin D, which support bone health [7]. In contrast, current guidelines discourage the consumption of sugar-sweetened beverages and other added sugars given their link to obesity [7]. Variations in chemical structure may explain some of the different effect of sugars on health but other factors, including type (naturally occurring or added) and the physical form (liquid or solid) of the food source may also play a role.

While all sugars are composed of carbon, hydrogen, and oxygen, differences in their chemical structure affect how they are absorbed and metabolized in the body [8]. Commonly consumed sugars include the monosaccharides: fructose, glucose and galactose and the disaccharides: sucrose (fructose + glucose), lactose (glucose + galactose), and maltose (glucose + glucose) [6]. Disaccharides, like all carbohydrates, are quickly broken down during digestion and absorbed as monosaccharides. The monosaccharides glucose and galactose follow the insulin regulated glycolysis pathway in cells throughout the body but fructose undergoes unregulated metabolism almost exclusively in the liver.

Dietary sugars also differ by their type or food or beverage source, specifically whether they are added to or naturally occurring in the foods and beverages consumed. Added sugars include those added during processing, preparation, or at the point of consumption [22, 23]. The most common added sugars in the U.S. food supply are sucrose (cane sugar) and high fructose corn syrup (HFCS) [6, 8], both of which are composed of fructose and glucose in approximately equal parts. As fructose is the sweetest of all of the sugars, it is a frequently used food additive. Naturally occurring sugars are those that form an integral part of a food when it is grown/produced, such as fructose or glucose in fruit or lactose in dairy products.

Research indicates that the physical form in which sugars are consumed affects how they are metabolized. Liquid calories are digested more rapidly than solid calories and are associated with lower satiety, decreased calorie compensation and weight gain [26, 38-40]. Studies of sugar-sweetened beverages have supported these findings, but the health implications of excess sugar-sweetened food intake remain unclear [38]. The U.S. Dietary Guidelines encourage a "reduction in intake of added sugars," though a specific amount is not stated [7]. The World Health Organization (WHO) encourages a reduction of "free sugars" which include both liquid naturally occurring sugars consumed in fruit juices and added sugars [41, 42].

While much research has been done to assess the contribution of some types of sugars (e.g. added sugars, lactose in milk) and some forms (liquids), little is known about total sugar consumption in the U.S. diet and the extent to which the different forms and types contribute to total sugar intake. The purpose of this study

is to describe current intake patterns in the U.S of added sugars compared with naturally occurring sugars and of sugars consumed in liquid compared with solid form. Also included is the intake pattern of free sugars to allow for comparisons with WHO recommendations.

IV. Data & Methods

The National Health and Nutrition Examination Survey (NHANES) is a continuous series of cross-sectional surveys designed to monitor health and nutrition in the United States. NHANES employs a complex, stratified multistage probability sampling method and provides data releases in 2-year cycles. A detailed description of NHANES data collection and sampling procedures can be found elsewhere [43]. The internal review boards of the National Center for Health Statistics approved the data collection protocol. De-identified data was used for this analysis.

Data for this study was collected in the 2009-2010 and 2011-2012 NHANES cycles. NHANES interviewers collect one in-person 24-hour recall for every participant and a second 24-hour recall on select participants collected via telephone. Data from the first 24-hour recall were used in this analysis as the first 24-hour recall was administered to every participant. Dietary recalls are conducted by trained personnel who interview participants about what they ate the previous day. Details about the foods are collected including: the amount consumed, any additions to the food at the point of consumption (such as sugar added to coffee), the brand or specific type (such as milk fat percentage), and many other details.

Twenty-four hour recalls can be used to estimate dietary intake and are particularly effective at estimating the dietary intake at the population level, as individual intake varies day to day but population dietary intake tends to stay consistent. While most participants reported their own intake, there are some instances in which a proxy was used. Situations where a proxy was used include all children younger than 6 years and for disabled individuals. Children 6 to 11 years reported their own intake with the assistance of a proxy and adolescents and adults over the age of 11 reported their own intake. The proxy is typically the person who prepares the interviewee's meals [44]. Estimates of total sugar intake were calculated by the National Center of Health Statistics as the sum of all sugars (grams) and provided as a variable on the NHANES dataset; the researchers calculated estimates of each type and form of sugars consumed.

The authors used NHANES and Food Patterns Equivalent Database (FPED) data to identify the amount (grams) of each type and form of sugars consumed. The added sugar content of each individual food and beverage was first identified using information provided in the 2009-2010 and 2011-2012 FPED database [45]. We then used the NHANES food combination variable to identify sugars that consumers added at the point of consumption (i.e. sugar added to coffee or at the table). Foods and beverages were grouped by liquid and solid sources using the individual food codes and food descriptions provided by the U.S. Department of Agriculture's Food and Nutrient Database for Dietary Studies (FNDDS)[46]. For each item, the amount of naturally occurring sugars was estimated by subtracting the estimated amount of added sugars from the amount of total sugar. The amount of added and natural

sugar was estimated for dairy and non-dairy products and for foods and beverages separately.

We then summed the amount of each type of sugar in individual food and beverage items to determine the total amount of each sugar consumed by each person per day. To ensure the integrity of the analysis, select observations were examined and the sum of all sources of sugar intake was calculated for all observations and compared to the value of total sugar intake provided by NHANES.

Sugar intake, assessed in grams, was multiplied by 4 kcal/gram to get the calories consumed for each type of sugar. This calorie value was then divided by the total energy for the day to get the percent of total energy intake consumed as sugar and the contribution of each sugar type and form. Sample weights were used to estimate intake for the U.S. population by age, income, and race/ethnicity. All analyses were conducted using SAS 9.2 (Cary, NC). Emory University Institutional Review Board approval was not required as the NHANES and FPED data used were de-identified.

V. Results

Mean total sugar intake among American's $\geq$2 years is 118.2 (95% CI 116.3, 120.1) grams per day. Sugars contribute 22.8% (95% CI 22.6, 23.1) of all calories consumed daily. Most sugars, 75.3 (95% CI 73.2, 77.4) grams are consumed in the form of added sugars. Approximately one-third of the sugars consumed daily come from natural sugars, 42.9 (95% CI 41.9, 43.9) grams.

A. Sugar consumption by age group

A description of the US population can be found in Table 1**.** Among children and adolescents under 19 years, which is shown in Table 2, total added sugars from all sources comprised 15.8% (95% CI 15.4%, 16.3%) of total calories, whereas total natural sugars from all sources comprised 10.4% (95% CI 10.0%, 10.8%) of total calories. Those over 5 years consumed significantly more added sugars from all sources, 16.2% (95% CI 15.8%, 16.6%) for 6-11 years and 16.8% (95% CI 16.0, 17.6%) for those 12-19 years, than children aged 5 years and under, who consumed 13.4% (95% CI 13.1%, 13.8%) of their diet as added sugars. Added sugars were commonly found in sodas, sports drinks, flavored milk, and sweet foods such as pancakes with syrup, cookies, cakes, and other desserts.

The opposite relationship was seen for naturally occurring sugars from all sources; those 2-5 years consumed 15.2% (95% CI 14.5%, 15.8%) of their diet as natural sugars, significantly more than those aged 6-11 years, who consumed 10.3% (95% CI 9.8%, 10.7%) of their diet as natural sugars. The amount consumed by those 6-11 years is again significantly more than those aged 12-19 years, who consumed 8.2% (95% CI 7.6%, 8.8%) of their diet as naturally occurring sugars. Naturally occurring sugars were commonly found in whole fruits and fruit juices.

TABLE 1 HERE

More differences were seen among children less than 19 years of age in consumption of sugars from non-dairy foods, such as cakes, cookies, and the like when compared to non-dairy beverages, such as sodas and juices. Overall, this age

group consumed 9.0% (95% CI 8.6%, 9.4%) of total diet as non-dairy sugars from beverages and 11.3% (95% CI 11.0%, 11.5%) as non-dairy food sugars. More specifically, those over age 11 years consumed a significantly higher percentage, 10.5% (95% CI 9.7%, 11.2%) of their diet from non-dairy liquid sugars than those under 11 years; children 2-5 years consumed 8.0% (95% CI 7.3%, 8.6%) as non-dairy liquid sugars and children 6-11 years consumed 7.8% (95% CI 7.4%, 8.3%) of their diet as non-dairy liquid sugars. A different relationship was seen for sugars in non-dairy foods: children aged 2-5 years consumed 12.3% (95% CI 11.9%, 12.8%) of their diet as sugars from non-dairy foods and children 6-11 years consumed 12.2% (95% CI 11.8%, 12.7%). This was significantly more than children 12-19 years, who consumed 10.0% (95% CI 9.7%, 10.4%) of their diet as non-dairy food sugars.

TABLE 2 HERE

This difference of intake between age groups is highlighted in Figure 1, which shows significantly greater intake of sugar with higher age among children; overall intake among children aged 2-5 years in grams is 110.5 (95% CI 106.9, 114.0), among children 6-11 years is 125.7 (95% CI 122.8, 128.5), and among teens 12-19 years overall intake is 134.1 grams (95% CI 129.8, 138.3). However, in terms of percentage of total diet, children aged 2-5 years consumed 28.6% (95% CI 28.6%, 28.0%) of total diet as sugars, children aged 6-11 years consumed 26.4% (95% CI 25.9%, 27.0%) of total diet as sugars, and teens aged 12-19 years consumed 25.0% (95% CI 24.1%, 25.8%) of total diet as sugars.

FIGURE 1 HERE

Differences in sugar intake are seen among adults, with significantly lower consumption of most types of sugar among age groups above 20 years. Adults 20-39 years consume on average 127.5 (95% CI 123.6, 131.4) grams, those aged 40-59 years consume 115.4 (95% CI 110.6, 120.1) grams on average, and those over 60 years consume 98.4 (95% CI 95.3, 101.4) on average. This difference in intake between adult age groups is not significant when looking at percent of total diet from sugar (Table 3). Adults aged 20-39 years consume 22.1% (95% CI 21.6%, 22.6%) of total calories as sugars on average per day, similar to adults aged 40-59 years, who consume on average 21.5% (95% CI 20.7%, 22.2%) per day; and also similar to adults over 60 years, who consume 21.5% (95% CI 21.1, 21.9%) of total diet as sugar per day.

TABLE 3 HERE

B. Sugar consumption and other characteristics

Table 4 shows the mean grams consumed of each type of sugar by poverty to income ratio (PIR), which is the ratio of family income to the poverty line. If a household is at or below the poverty line, they will have a PIR of 1.31 or less; as household income increases so does PIR. There are significant differences in added sugars from non-dairy foods and beverages. First, we see significant differences in intake among PIR groups of added sugars in non-dairy beverages; those with a PIR less than 1.31 consume 41.1 (95% CI 38.6, 43.5) grams on average and those in the 1.31-3.5 PIR group consume significantly less at 36.0 (95% CI 33.7, 38.3) grams on average. Those in the PIR group over 3.5 consume the least on average at 24.8 (95% CI 21.9, 27.7) grams. Those in the lowest PIR group consume significantly fewer

grams of sugar each day from natural sugars in foods than those in the highest PIR group. There are no significant differences in intake of different types of sugars among different racial/ethnic groups including Hispanic, non-Hispanic white, and non-Hispanic black.

TABLE 4 HERE

VI. Discussion

This study analyzed nationally representative data to describe the amount of each type of sugar consumed by each age and demographic group including gender, income, and race/ethnicity. Past studies have calculated intake of added sugars, but this study describes sugar intake more fully looking at added, natural, dairy, non-dairy, food, and beverage sources of sugars.

Children aged 2-5 years and adults over the age of 60 years consumed the fewest grams of sugar, though for children aged 2-5 years, sugar contributed the highest percentage of calories to their overall diet compared to other age groups. This contribution was largely from natural sugars in foods and beverages, including dairy, 100% juice, fruit, and other foods containing natural sugars. This high intake of natural sugar among young children is consistent with findings in other studies, which found that close to 85% of children aged 2-5 years consume beverages including milk and 100% fruit juice [47]. Grams of sugar consumed were highest in adolescents and decreased with increasing age. Percent contribution of all sugars to overall calories stayed somewhat constant in age groups after adolescence.

Sampling for NHANES is done using a multistage cluster design and because the weighted analysis takes this into account these findings can be generalized to the US population. Though this study uses nationally representative data, there are some limitations. Using 24-hour recalls to evaluate dietary intake requires precisely measuring how much of a given food or beverage item was consumed along with a detailed description of the food or beverage item. Difficulty in measuring how much was consumed, along with the possible desire of the interviewee to report more a healthful diet make precise dietary measurements challenging [48]. Specifically, this desire often leads to "flat slope syndrome," which refers to the tendency to report a lower intake of a large portion and report a higher intake of a small portion. Despite these limitations the estimations in this paper are likely accurate due to the large sample size (n=16,973) and well-trained interviewers.

VII. Conclusions

Analysis of NHANES data from two cycles, 2009-2012 indicates that there are some differences in sugar intake in the U.S. population. Adolescents 12-19 years consume the most added sugars in non-dairy beverages; children aged 2-5 years consume the highest percentage of their diet as sugars, the majority of which are natural sugars. Efforts to reduce sugar intake among adolescents and low-income populations are needed [36, 40].

VIII. Tables & Figures

Table 1: Age Group, Race/Ethnicity, Income, Weight Status, and Gender of US population (NHANES 09-12) (n=16,973)	
	% total
Age	
0-5	5.6%
6-11	8.3%
12-19	11.3%
20-39	27.4%
40-59	28.5%
60+	18.9%
Race/Ethnicity	
Mexican American	9.8%
Other Hispanic	6.2%
Non-Hispanic White	64.5%
Non-Hispanic Black	12.2%
Other (including multi-racial)	7.3%
Poverty-to-Income Ratio	
<1	32.0%
1-3.5	32.3%
>3.5	35.6%
Weight Status	
Underweight	2.7%
Normal	38.0%
Overweight	28.4%
Obese	30.9%
Missing	n=73
Gender	
Male	49.0%
Female	51.0%

*Percent total is weighted based on sample weights

Table 2: Percent intake of naturally occurring and added sugars from foods vs. beverages among US children, stratified by age (NHANES 09-12)

	Age (in years)											
	All			2-5			6-11			12-19		
	mean	95% CI		mean	95% CI		mean	95% CI		mean	95% CI	
Added sugars in Beverages												
Milk or Milk-based	1.0%	0.9%	1.1%	1.2%[a]	1.0%	1.4%	1.2%	1.1%	1.4%	0.7%[c]	0.5%	0.9%
Non- dairy	6.7%	6.3%	7.1%	3.9%[c]	3.5%	4.2%	5.8%[b]	5.5%	6.2%	8.7%[a]	8.0%	9.4%
Total	7.7%	7.3%	8.1%	5.1%[c]	4.7%	5.5%	7.1%[b]	6.7%	7.4%	9.4%[a]	8.8%	10.1%
Added sugars in Foods												
Dairy products	1.1%	0.9%	1.3%	1.4%	1.1%	1.6%	1.3%	1.0%	1.5%	0.9%	0.7%	1.1%
Non-dairy	7.0%	6.8%	7.3%	7.0%[c]	6.8%	7.2%	7.9%[a]	7.5%	8.2%	6.5%[c]	6.1%	6.8%
Total	8.2%	7.8%	8.5%	8.4%[c]	8.0%	8.7%	9.1%[a]	8.7%	9.6%	7.4%[c]	7.0%	7.7%
Natural sugars in Beverages												
Milk or Milk-based	3.3%	3.1%	3.5%	5.0%[a]	4.7%	5.3%	3.4%[b]	3.2%	3.6%	2.5%[c]	2.2%	2.7%
Non-dairy	2.3%	2.1%	2.6%	4.1%[a]	3.6%	4.6%	2.0%[c]	1.8%	2.2%	1.7%[c]	1.4%	2.0%
Total	5.7%	5.4%	6.0%	9.1%[a]	8.4%	9.7%	5.4%[b]	5.1%	5.6%	4.2%[c]	3.8%	4.6%
Natural sugars in Foods												
Dairy products	0.5%	0.4%	0.6%	0.7%	0.6%	0.9%	0.5%	0.4%	0.6%	0.4%	0.3%	0.6%
Non-dairy	4.2%	4.0%	4.4%	5.3%[a]	5.0%	5.7%	4.4%[b]	4.1%	4.6%	3.6%[c]	3.3%	3.8%
Total	4.7%	4.5%	5.0%	6.1%[a]	5.7%	6.5%	4.9%[b]	4.6%	5.2%	4.0%[c]	3.7%	4.3%
Total Free Sugars	18.2%	17.8%	18.7%	17.6%	16.9%	18.2%	18.2%	17.8%	18.7%	18.5%	17.8%	19.3%
Total Added Sugars (All Sources)	15.8%	15.4%	16.3%	13.4%[c]	13.1%	13.8%	16.2%[a]	15.8%	16.6%	16.8%[a]	16.0%	17.6%
Total Naturally Occurring Sugars												

Total Non-Dairy Food Sugars	11.3%	11.0%	11.5%	12.3%[a]	11.9%	12.8%	12.2%[a]	11.8%	12.7%	10.0%	9.7%	10.4%
Total All Sugars	26.3%	25.8%	26.7%	28.6%[a]	28.0%	29.2%	26.4%[b]	25.9%	27.0%	25.0%[c]	24.1%	25.8%

[a] Indicates statistical significance and highest value through non-overlapping 95% confidence intervals compared to b and c groups
[b] Indicates statistical significance and mid-value through non-overlapping 95% confidence intervals compared to a and c groups
[c] Indicates statistical significance and lowest value through non-overlapping 95% confidence intervals compared to a and b groups

Figure 1: Contribution of Each Type of Sugar Intake (gm) to Overall Intake by Age Group (NHANES 09-12)

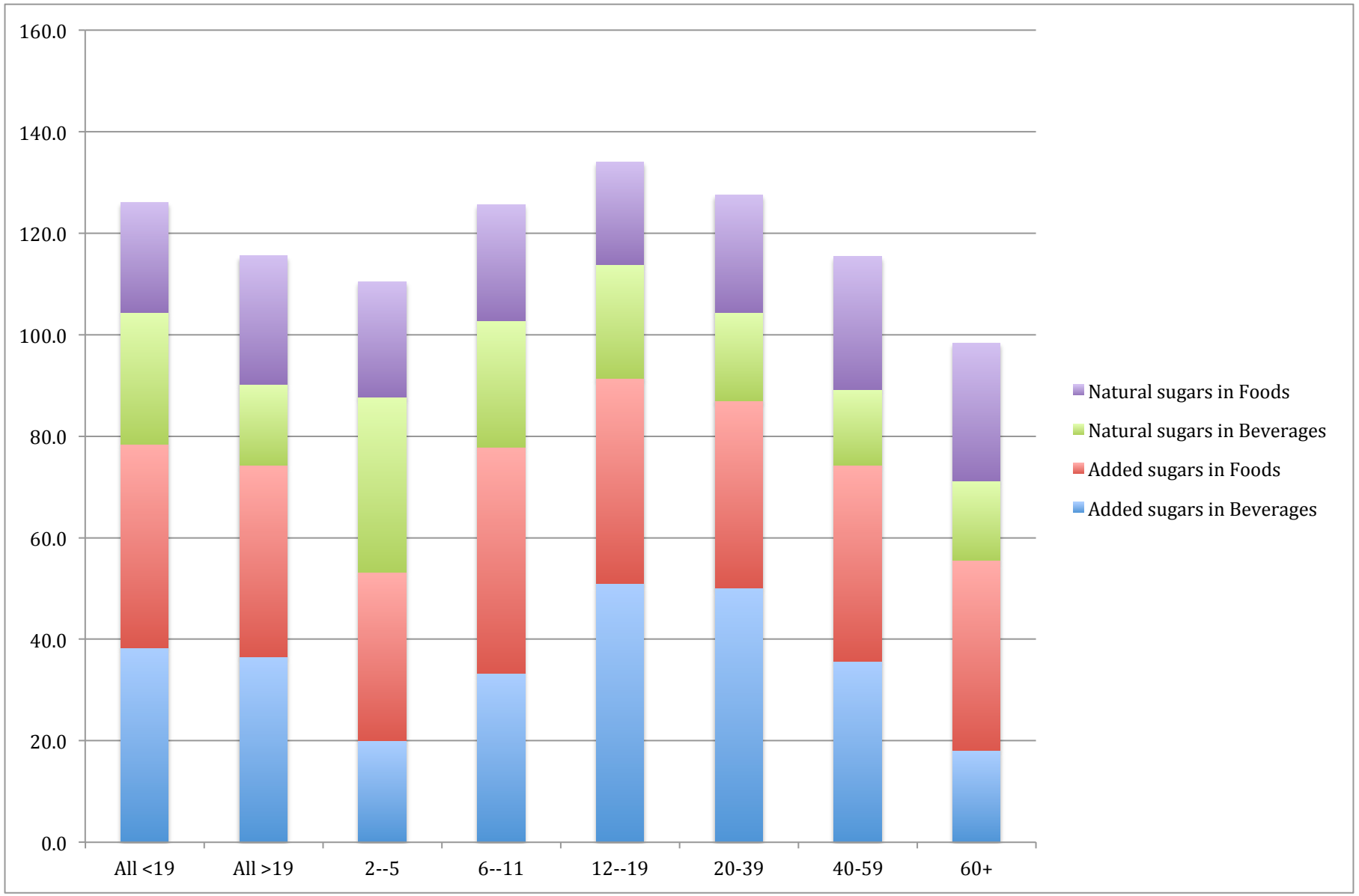

Table 3: Percent intake of naturally occurring and added sugars from foods vs. beverages among US adults stratified by age (NHANES 09-12)

	Age (in years)											
	All			20-39			40-59			60+		
	mean	95% CI		mean	95% CI		mean	95% CI		mean	95% CI	
Added sugars in Beverages												
Milk or Milk-based	0.5%	0.5%	0.6%	0.5%	0.4%	0.5%	0.6%	0.5%	0.7%	0.5%	0.5%	0.6%
Non- dairy	6.0%	5.7%	6.4%	8.1%	7.5%	8.6%	5.8%	5.2%	6.4%	3.4%	3.1%	3.7%
Total	6.6%	6.2%	6.9%	8.5% [a]	7.9%	9.1%	6.5% [b]	5.8%	7.1%	3.9% [c]	3.6%	4.2%
Added sugars in Foods												
Dairy products	0.9%	0.8%	1.0%	0.7%	0.6%	0.8%	0.9%	0.8%	1.0%	1.2%	1.1%	1.3%
Non-dairy	6.0%	5.8%	6.2%	5.4%	5.2%	5.7%	6.0%	5.8%	6.3%	6.7%	6.4%	7.0%
Total	6.9%	6.7%	7.1%	6.1% [c]	5.9%	6.4%	6.9% [b]	6.7%	7.2%	7.9% [a]	7.6%	8.2%
Natural sugars in Beverages												
Milk or Milk-based	1.5%	1.4%	1.6%	1.2%	1.1%	1.4%	1.5%	1.3%	1.6%	1.8%	1.7%	1.9%
Non-dairy	1.6%	1.5%	1.8%	1.9%	1.6%	2.1%	1.5%	1.2%	1.7%	1.6%	1.4%	1.8%
Total	3.1%	3.0%	3.3%	3.1%	2.9%	3.3%	2.9%	2.7%	3.2%	3.4%	3.1%	3.7%
Natural sugars in Foods												
Dairy products	0.5%	0.5%	0.5%	0.4%	0.4%	0.5%	0.5%	0.4%	0.6%	0.6%	0.5%	0.6%
Non-dairy	4.6%	4.5%	4.8%	3.9%	3.7%	4.1%	4.6%	4.4%	4.9%	5.7%	5.4%	5.9%
Total	5.1%	5.0%	5.3%	4.3% [c]	4.1%	4.5%	5.2% [b]	4.9%	5.4%	6.2% [a]	6.0%	6.5%
Total Free Sugars	15.2%	14.8%	15.5%	16.6%	16.0%	17.2%	14.9%	14.2%	15.5%	13.5%	13.1%	13.9%
Total Added Sugars (All Sources)	13.4% [a]	13.0%	13.8%	14.7% [a]	14.0%	15.3%	13.4% [a]	12.7%	14.1%	11.8%	11.4%	12.2%
Total Naturally Occurring Sugars (All Sources)	8.2%	8.0%	8.5%	7.4% [c]	7.1%	7.7%	8.1%	7.7%	8.5%	9.7% [a]	9.3%	10.1%
Total Non-Dairy Liquid Sugars	7.7%	7.4%	8.0%	9.9% [a]	9.4%	10.5%	7.3% [b]	6.8%	7.8%	5.0% [c]	4.7%	5.3%
Total Non-Dairy Food Sugars	10.6%	10.4%	10.8%	9.4% [c]	9.1%	9.7%	10.7% [b]	10.3%	11.0%	12.4% [a]	12.1%	12.6%

Total All Sugars	21.7%	21.4%	22.0%	22.1%	21.6%	22.6%	21.5%	20.7%	22.2%	21.5%	21.1%	21.9%

[a] Indicates statistical significance and highest value through non-overlapping 95% confidence intervals compared to b and c groups
[b] Indicates statistical significance and mid-value through non-overlapping 95% confidence intervals compared to a and c groups
[c] Indicates statistical significance and lowest value through non-overlapping 95% confidence intervals compared to a and b groups

Table 4: Absolute intake (gm) of naturally occurring and added sugars from foods vs. beverages among US racial and ethnic groups (NHANES 09-12)

	Race/Ethnicity				Poverty to Income Ratio		
	All	Hispanic	Non-Hispanic White	Non-Hispanic Black	<1.31	1.31-3.5	>3.5
Added sugars in Beverages							
Milk or Milk-based	3.4	3.8	3.5	2.5	3.4	3.5	3.2
Non- dairy	33.6	38.2	32.4	41.9	41.1	36.0	24.8
Total	37.0	42.0	35.8 [b]	44.4 [a]	44.5	39.5 [b]	28.0 [c]
Added sugars in Foods							
Dairy products	4.9	3.6	5.6	3.7	3.7	5.2	5.6
Non-dairy	33.4	27.4	34.9	35.6	32.5	33.4	34.3
Total	38.3	31.0[b]	40.5 [a]	39.3 [a]	36.2 [b]	38.6 [a]	39.9 [a]
Natural sugars in Beverages							
Milk or Milk-based	9.5	10.6	10.2	5.8	10.0	9.3	9.3
Non-dairy	9.0	10.3	7.7	12.8	10.6	8.9	7.6
Total	18.5	21.0	17.9 [c]	18.7 [b]	20.6 [a]	18.2 [b]	16.8 [b]
Natural sugars in Foods							
Dairy products	2.5	1.7	2.8	1.6	1.9 [c]	2.4 [b]	3.0 [a]
Non-dairy	22.0	22.9	22.5	18.0	19.9 [c]	20.6 [b]	25.0 [a]
Total	24.4	24.6 [b]	25.3 [a]	19.6 [c]	21.8 [c]	23.0 [b]	28.0 [a]
Total Free Sugars	84.3	83.4	84.0	96.6	91.3	87.0	75.5
Total Added Sugars (All Sources)	75.3	73.0	76.3	83.7	80.7 [a]	78.1	67.9 [c]
Total Naturally Occurring Sugars (All Sources)	42.9	45.6	43.2	38.2	42.4 [b]	41.2 [b]	44.9 [a]
Total Non-Dairy Liquid Sugars	42.6	48.6	40.1	54.7	51.7 [a]	44.8 [b]	32.4 [c]
Total Non-Dairy Food Sugars	55.4	50.3	57.4	53.6	52.4 [c]	54.0 [b]	59.3 [a]
Total All Sugars	118.	118.6	119.5	122.0	123.1	119.3	112.8

	2	

[a] Indicates statistical significance and highest value through non-overlapping 95% confidence intervals compared to b and c groups
[b] Indicates statistical significance and mid-value through non-overlapping 95% confidence intervals compared to a and c groups
[c] Indicates statistical significance and lowest value through non-overlapping 95% confidence intervals compared to a and b groups

Chapter 4: The Sweet Life of America's Teens: Where Sugar-containing Foods and Beverages are Purchased by US Adolescents

I. Abstract

Introduction: Adolescents consume the most sugar of any age group; health behaviors and nutrition during adolescence may impact adult health. The goal of this study is to determine where sugar-containing foods and beverages are purchased and consumed by teenagers in order to inform efforts to reduce sugar consumption in this age group.

Data/Methods: Nationally representative NHANES data from the 2011-2012 cycle were used to understand where adolescents aged 12 to 19 years (n=1152) purchase and consume their foods and beverages along with the average sugar content of these foods and beverages. Mean sugar content of foods and beverages consumed in the home and away from the home was calculated, along with mean sugar content of foods and beverages acquired from various purchase locations. Statistical significance was determined using 95% confidence intervals to determine whether the means for each place of consumption (in the home or away from the home) and purchase location were different. The contribution of sugar from each type of food and beverage to overall calorie intake was determined by summing the calorie content of each type of sugar (dairy, non-dairy, added, natural, food, beverage) from each purchase locations for each individual and dividing this sum by the total daily calorie intake.

Results: The majority of meals are eaten at home and purchased from grocery stores, either by the adolescent or by his/her parents. The average amount of sugar in a beverage consumed in the home is 31.4 grams (95% CI 30.0, 32.7), versus away from the home at 35.0 grams (95% CI 33.0, 37.1). Foods consumed in the home average 9.4 grams (95% CI 8.9, 10.0) and those consumed away from the home average 8.1 grams (95% CI 7.5, 8.7). Foods and beverages consumed at school cafeterias are consistently low in sugars. Only about three percent of foods and beverages are purchased at convenience stores, although these foods and beverages tend to be significantly higher in sugar than those purchased elsewhere: foods purchased in convenience stores average 31.9 (95% CI 21.9, 41.9) grams

of added sugar compared to the next-highest amount from other purchase locations, which contain 18.3 grams (95% CI 11.4, 25.2).

Discussion/Conclusions: Large differences are seen in the average sugar content of foods purchased at convenience stores versus other purchase locations. Large differences are also seen in the sugar content of beverages purchased at restaurants, including those with servers and fast food restaurants, compared to other purchase locations. Availability of free-refills and large portion sizes may influence this high sugar content in beverages purchased from these locations. The sugar content of foods and beverages purchased in school cafeterias was consistently and significantly lower than the sugar content of similar items from other locations, likely due to efforts to improve the nutritional content of foods served in schools.

II. Contribution of the Student

Christina Brumme did all data analyses, figure and table development, and manuscript writing. Co-authors and thesis committee members, Dr. Solveig Cunningham and Dr. Jean Welsh, assisted in editing and advising the development of the manuscript.

III. Introduction

Adolescents consume the greatest amount of added sugar of any age group; This age group is particularly vulnerable to long-term effects of dietary choices as habits formed in adolescence can carry into adulthood [49]. Additionally, low diet quality has been associated with low academic achievement, which may also have long-term implications [50]. Adolescent food choices are particularly interesting because of the competing influences of the home environment, peer culture, and desire for autonomy [51-53]. While parents often still have a large amount of control over the diet of the adolescent in the home, most teens begin to explore new-found freedom from parental choices with friends, who may influence dietary choices to a similar extent that the home environment does [51, 52].

The past half-century in the United States has been characterized by a decrease in home cooking and an increase in eating at restaurants [13, 54]. Previous analyses have found that restaurant food consumption is associated with overall energy intake [55]. One analysis found that the number of calories consumed each day by children younger than 18 years of age at restaurants increased from 447 to 702 between 1977 and 2003 ($P<0.1$) [55]. The increasing percentage of calories from restaurant foods, 23.4% of the diet in 1977 versus 33.9% of the diet in 2006, indicates the importance of evaluating nutritional content of commonly consumed restaurant foods [20, 55]. This analysis compares sugar content of foods and beverages from restaurants to foods and beverages from other locations to determine whether there are differences.

Sugar is a non-essential nutrient that provides calories and is becoming increasingly common in the foods we eat. Sugar content is an indicator of diet quality as it is negatively

associated with consumption of important micronutrients in adolescents [56]. A large percentage of added sugar consumed by adolescents comes from sugar-sweetened beverages, as shown in Chapter 3 [12, 57, 58]. Sugar sweetened beverages have been associated with weight gain, risk of chronic diseases such as diabetes and cardiovascular disease, and low diet quality [8, 29, 30, 56]. Additionally, some evidence suggests that when sugars are consumed in beverages the result is lower satiety when compared to sugars in foods, as sugars in beverages may be metabolized differently than food sugars [26]. When large amounts of sugar are present in a food or beverage, the sugar dilutes other nutrients that may be present and decreases the nutritional quality of the food or beverage [6].

A recent study examined the purchase location of added sugars and found that added sugars account for almost 17% of daily energy intake among children and adolescents and that the majority of this added sugar comes from items purchased at stores [12, 57]. The type of stores, such as grocery stores or convenience stores, where these items are purchased and the contribution of different types of foods and beverages to overall sugar intake is still unknown. Added sugar is only one type of sugar, as sugars can be naturally occurring in foods such as fruit and dairy. Lactose, the naturally occurring sugar in dairy, appears to have a more neutral impact on health than added sugars [59]. Additionally, dairy foods and beverages are an important source of calcium and vitamin D and have a different fat, carbohydrate, and protein composition than non-dairy foods and beverages [59]. As such, this analysis examined the average amount of different types of sugars, including added and natural sugars in dairy and non-dairy foods and beverages according to where the food or beverage was purchased and whether or not it was consumed at home. This analysis will help explain differences in the sugar content and

resultant nutritional quality of foods purchased at various places along with any differences in home-cooked meals versus those eaten outside of the home.

IV. Data

The data used are from the National Health and Nutrition Examination Survey (NHANES). These data are collected by the National Center for Health Statistics (NCHS) to evaluate the health status and dietary intake of adults and children living in the United States. In collecting the data, NCHS uses a complex, stratified multistage probably sampling method to choose the participants for each two-year cycle. This complex probability sampling method means that certain groups are sampled at different rates in order to get representative data on sub-groups that may be smaller or more diverse than others.

The NHANES data are collected continuously and datasets are released in a two-year cycle. This paper used data from the 2011-2012 cycle; more specific data on purchase location was collected in this cycle compared with prior years and as such it is the only NHANES dataset that contains this information. Specifically, this data contains information on purchase locations not previously included, such as convenience stores and others. Additionally, this is the first cycle to include "non-Hispanic Asian" as a race/ethnicity category.

NHANES data include laboratory sampling, anthropometric measurements, lifestyle and health history questionnaires, dietary interviews, and others, though dietary and demographic data were the primary data used in this analysis. Dietary interviews collect data through food frequency questionnaires and two days' worth of 24-hour dietary recalls. The first 24- hour dietary recall is done in-person and completed by every participant; the

second day is conducted through a phone call. Participants completed the dietary recall about their own intake when possible, though proxy respondents completed the dietary recall for children younger than 6 years and for disabled individuals. Children aged 6 to 11 completed as much of the dietary interview as they could and had the assistance of a proxy respondent. Proxy respondents were typically the person who prepared the child's meals. Adolescents older than 11 years completed the dietary recall independently unless he or she had a disability that prevented autonomous response [44]. This analysis was restricted to the first dietary recall because this data is available for every person and therefore more rich and reliable. To collect the 24-hour recall, trained interviewers ask participants to list all foods and beverages consumed the previous day. Details about each food and beverage are then collected, including: the amount consumed, any modifications made at the point of consumption such as syrup added to pancakes, where the food was consumed, where the food was purchased, and many other details.

The analytic sample used in this analysis included adolescents aged 12 to 19 years; these adolescents were chosen using the same complex, multi-stage stratified sampling method used for the entire NHANES dataset. More complete information on NHANES data collection and sampling procedures can be found on the Centers for Disease Control and Prevention website [60].

In addition to NHANES data, this analysis used dietary data from the Food Patterns Equivalence Database (FPED), which is published by Agricultural Research Service (ARS), which is part of the United States Department of Agriculture and released in two-year cycles to correspond with each two-year cycle of NHANES data. This database contains the amount of added sugar in each food along with the other information for foods consumed

in the United States that are contained in the Food and Nutrition Data for Dietary Studies (FNDDS), the standard database for dietary information.

V. Methods

The analytical sample used in this analysis consists of adolescents from age 12 to age 19 years; these individuals were classified based on their age at the time of screening for NHANES inclusion. Each individual in the sample completed a Day 1 dietary recall and these data were used to calculate sugar intake for the day. Each food item consumed is coded by a standard food code that is part of the Food and Nutrient Database for Dietary Studies (FNDDS) created by the USDA [61]. Individual food codes were categorized as a dairy beverage, dairy food, or a non-dairy beverage according to the FNDDS coding scheme [46]. Any food not considered a dairy beverage, dairy food, or non-dairy beverage is a non-dairy food and was categorized as such. NHANES provides the total amount of sugar in each individual food or beverage item; this amount was summed with sugar added to the food at the time of consumption. Sugar added by the consumer is determined by the combination food type code, which describes any modifications made to the item by the consumer (i.e. sugar added at the table). The amount of added sugar in each food was determined by summing the value of sugar added by the consumer, from the NHANES file, with the value of added sugar added by the manufacturer, which was provided by the FPED database. This value of both types of added sugar was then subtracted from the amount of total sugar in the item, provided by the NHANES database, to determine the amount of sugar naturally present in each food or beverage. Missing variables were coded as such, as not every

person consumes each type, including dairy, non-dairy, food, beverage, natural, and added sugars in a given day.

During the dietary interview, NHANES personnel record the purchase location of each food along with whether or not it was consumed at home; this information is reported on the 24-hour recall. These variables were used to calculate the mean amount of each type of sugar consumed at the home or outside of the home, as well as the mean amount of each type of sugar from each purchase location. To determine the mean amount of sugar consumed at home versus away from home, the average amount of each type of sugar was calculated and analysis was stratified by whether or not the food or beverage was consumed at home as reported by the participant. Purchase locations of food include grocery store, convenience store, other store, restaurant with a server, fast food restaurant, school cafeteria, and others. Analysis was stratified based on these purchase locations to determine mean sugar content from foods and beverages from each location. Lastly, the amount of each type of sugar in foods and beverages purchased at each location was summed to determine the contribution to overall diet. This calculation was done in grams, which was then multiplied by four (4 kcal/gram of sugar) and divided by the total calorie intake for the day as determined by NHANES in order to get the percent that each type of sugar from each location contributes to overall diet. The grams of each type of sugar were divided by total grams of sugar for the day as provided by NHANES to determine the contribution to overall sugar intake.

Means and confidence intervals were used to calculate statistical significance; this method allows for determination of statistical significance based on whether or not confidence intervals of two or more groups overlap [62]. Mean values were determined in

accordance with the NHANES analytical procedures, which require the use of weights, strata, and cluster identification; the day-1 recall weight was used for this analysis. All analyses were conducted using SAS 9.2, from Cary, NC. Emory Institutional Review Board approval was not required as the data were de-identified.

A. Variables

Analyses were conducted at both the food/beverage level and at the individual level. Food/beverage analysis was done to determine the average amount of sugar in foods and beverages purchased at various locations and consumed in the home and away from the home. Each food or beverage was classified into one of the following categories through the use of the coding scheme from the FNDDS: dairy beverage, non-dairy beverage, dairy food, and non-dairy food. A distinction was made between dairy and non-dairy beverages and foods as dairy products have a different carbohydrate, fat, and protein composition from non-dairy foods and beverages and are an important source of calcium and vitamin D, which support bone health. This different composition of dairy foods and beverages compared to non-dairy foods and beverages may cause the sugars in dairy to have a more neutral impact on health compared to added sugars, which makes examining two separate groups important. Added and natural sugars were assessed from each food/beverage in each sub-group. These results were stratified by purchase location and by whether or not the meal was consumed in the home to estimate the average amount of sugar from each purchase and consumption location. In order to determine where the meal was consumed, interviewers asked participants, “Did you eat this meal at home?” and noted a yes/no response. As such, the definition of “meal” was left up to the interviewee. Due to the nature

of the data collected, meals were categorized based on where they are consumed, so restaurant foods eaten at home are categorized as eaten at home.

The sugar content of each food and beverage were then used to calculate contribution of each sugar type and purchase location to each individual's overall diet. We stratified these analyses by the respondent's gender, race/ethnicity, and poverty-to-income ratio, all self-reported in NHANES. Gender is a dichotomous variable with only male and female options. Race/ethnicity used in this analysis includes: Mexican American, Other Hispanic, Non-Hispanic White, Non-Hispanic Black, Non-Hispanic Asian, and Other Race-Including Multi-Racial. The 2011-2012 NHANES cycle used in this analysis is the first cycle to include Non-Hispanic Asian as a category for the race/ethnicity variable. Poverty-to-income ratio (PIR) is the ratio of family income to the federal poverty line. This variable was used to code individuals into two groups: living in poverty and not living in poverty. Those having a PIR under 1.31 were categorized as living in poverty, as this is the current Federal poverty line.

VI. Results

Table 1 shows the gender, age, and weight status distribution for adolescents in the United States. There are approximately the same proportion of males and females, with 51.7% males and 48.3% females. Each age group between 12 and 19 years contribute approximately 13% to the population; the mean age is 15.4 years. The majority of the population self-reported as "non-Hispanic white" (56.6%) and the fewest self-reported as "Other, including multi-racial" (3.8%) or "Non-Hispanic Asian" (4.4%); 14.2% of the

population was “Mexican American” and 13.9% self-reported as “non-Hispanic black” (Table 1).

Meals are consumed more frequently at home (61.5%) compared to away from home (38.5%). Foods and beverages are most often purchased at the grocery store (58.8%) and least often purchased at convenience stores (2.9%) (Table 1).

TABLE 1 HERE

A. Sugar consumed at home versus away from home

Across sugar-containing foods and beverages and all places of consumption, added sugars contribute more grams of sugar per item than do natural sugars. Beverages tend to have more grams of sugar than foods; on average, beverages contain 32.7 grams, compared to 8.9 grams of sugar on average in foods. The mean amount of added sugar in beverages is 35.8 grams versus 12.4 grams of sugar in a food. The average amount of natural sugars in a beverage is 15.3 grams compared to 2.6 grams in a food item (Table 2).

The average amount of all types of sugar, including added and natural sugars in dairy and non-dairy foods and beverages, consumed in the home is not significantly different from the average amount of sugar consumed away from the home (Table 2).

TABLE 2 HERE

B. Sugars obtained from grocery stores, convenience stores, restaurants, schools, and other sources

There are consistent differences in the amount of sugar from each purchase location (Table 3). The average amount of added sugar in a non-dairy beverage from a restaurant with a server is higher than the average amount of any other type of sugar from any other purchase location by almost 10 grams; non-dairy beverages from restaurants with servers

average 51.4 (95% CI 45.0, 57.8) grams of added sugar, versus the next-highest amount of 42.7 (95% CI 34.6, 50.8) grams of added sugar in non-dairy beverages purchased from a convenience store. This large difference between grams of sugar in non-dairy beverages purchased at restaurants and those purchased elsewhere is similar to the large difference in added sugar content of non-dairy foods purchased from convenience stores compared to other locations. Non-dairy foods purchased at a convenience store average 31.9 (95% CI 21.9, 41.9) grams of added sugar compared to the next-highest average amount of 18.3 (95% CI 11.4, 25.2) grams of added sugar in non-dairy foods from other purchase locations, which include vending machines, food trucks, gifts, and many others. Non-dairy foods purchased from convenience stores have over 13 grams of added sugar more on average than non-dairy foods purchased at different locations.

Food and beverage items purchased in school cafeterias tend to be very low in all types of sugars, particularly added sugars in beverages. When purchased in a school cafeteria, added sugars in dairy beverages contain 11.5 (95% CI 9.8, 13.3) grams on average and added sugars in non-dairy beverages contain 22.2 (95% CI 11.9, 32.5) grams on average. This sugar content is significantly lower than the amount of sugar from almost all other purchase locations for sugar in both dairy and non-dairy beverages.

TABLE 3 HERE

It is also important to consider the contribution of sugars to the diet as a whole, as shown in Tables 4-6. Table 4 shows indicators of the teenage diet, specifically average daily calories, at 2174.7 (95% CI 2080.0, 2269.4), average daily sugar, at 135.0 (95% CI 127.9, 142.1) grams, and average daily carbohydrates (including sugar), at 305.1 (95% CI 290.1, 320.0) grams. Table 4 also shows the contribution to overall diet in grams of sugar from

each category: sugars from beverages, sugars from foods, added sugars, natural sugars, and total sugars. These measures are shown for grocery stores, fast food restaurants, and convenience stores, as these were the top three most common purchase locations. Tables 5 and Appendix 1 show measures similar to those shown in Table 4, however, Table 5 shows contribution to overall diet as a percent of total calories and Appendix 1 shows this contribution as a percent of total sugar intake.

Beverages contribute about 50 grams of sugar per day to the teenage diet, which is about 10% of total calorie intake and represents about 30% of sugar intake for the day. Boys consume more grams of sugar each day than girls; boys consume 152.5 (95% CI 141.1, 163.8) grams each day and girls consume 117.1 (109.7, 124.4) grams each day. Boys consumed more sugars purchased at convenience stores - about 60.7 grams (95% CI 50.2, 71.2) compared with 45.0 (95% CI 40.3, 49.6) in items purchased by girls. Sugars were consumed in similar amounts among white, black, and Hispanic adolescents; Asian adolescents consumed significantly less sugar of all types than other race/ethnic groups. Adolescents living in poverty consumed about 15 grams of sugar less per day from beverages purchased from convenience stores compared to those not living in poverty.

TABLE 4 HERE

Table 5 shows dietary sugar intake represented as a percent of total diet. Percentage of total diet shows a different measure of sugar intake by accounting for differences in overall intake. For example, boys consume 2530.8 (95% CI 2407.0, 2654.6) calories and girls consume 1808.6 (95% CI 1726.8, 1890.5) calories. This difference in overall intake explains differences in grams of sugar intake and shows that boys and girls had the same proportion of total calories from each type of sugar.

Natural sugars from grocery stores contributed 7.1% (95% CI 5.1, 9.1) to overall diet in non-Hispanic black individuals and contributed only 2.4% (95% CI 1.2, 3.6) to the overall diet in Hispanics. The contribution of natural sugars from grocery stores to the overall diet is in non-Hispanic black individuals is similar to the contribution in non-Hispanic white and non-Hispanic Asian individuals. Similarly, a higher proportion of natural sugars from convenience stores appear to contribute to the diet of Asian individuals versus non-Hispanic white or non-Hispanic black individuals. There were no significant differences in sugar intake as a percentage of calories between income groups.

TABLE 5 HERE

VII. Discussion

This analysis examined the purchase location of sugar-containing foods and beverages in the American teenage diet along with where these are consumed and the contribution of these foods and beverages to overall diet. Understanding the sugar content of foods and beverages indicates targets for potential sugar reduction campaigns; understanding the contribution to the diet as a whole gives a more complete picture of the diet and lifestyle habits of US adolescents.

Meals are more frequently consumed at home than outside of the home, and the majority of foods and beverages are purchased at grocery stores. Foods and beverages vary greatly in sugar content based on where they are purchased: beverages purchased at restaurants contain significantly more sugar than beverages purchased elsewhere and foods purchased at convenience stores contain significantly more sugar than foods purchased elsewhere. The sugar content of foods and beverages purchased in school

cafeterias is consistently lower than the sugar content of similar foods and beverages purchased elsewhere. Beverages contain about three times as much sugar as foods and contribute slightly more sugar overall to the diet than foods contribute. There are no significant differences in sugar consumption between demographic subgroups.

A notable finding is that there are differences between the average amounts of sugar in beverages purchased at restaurants and foods purchased at convenience stores when compared to other purchase locations. This pattern is consistent with previous findings, which also showed different nutritional composition of foods from different locations [11, 16, 17, 20]. The high content of added sugar in beverages purchased at restaurants with servers may be due to factors such as free-refill policies, whereas beverages purchased at other locations are typically portion-controlled by the size of the container. The high added sugar content of the non-dairy foods purchased at convenience stores may be the result of the food available at convenience stores, which tend to be desserts and snacks such as cakes, cookies, and doughnuts.

The added sugar in non-dairy beverages contributes about 200 calories per day to the American teenage diet among those who consumed them. While there are differences in the amount of grams of sugar consumed between some groups, for example between boys and girls, these differences are mostly accounted for when looking at sugar intake in relation to total calorie intake. As such, a reduction in sugar intake among all adolescents, regardless of demographic group is necessary given the associations between high sugar intake, poor dietary quality, and adverse health outcomes such as diabetes and obesity [8, 29, 30, 56].

Recipes for foods prepared in the home were not used to determine sugar content, which could result in differences in sugar content at the individual level, though one would expect these differences to be attenuated at the population level. More research is needed to determine the associations between sugar content of foods consumed at and away from home and other markers of food quality, including micronutrient and macronutrient profile, freshness, desirability, and others. As these data are cross-sectional, meaning they represent one point in time, it is important to note that trends of intake cannot be determined. Longitudinal data that represents changes over time would be helpful to evaluate factors that affect dietary intake such as transitioning from childhood to adolescence. More research is needed to understand whether or not interventions policies to regulate or standardize serving sizes or remove free-refill policies would have an impact on sugar consumption and health.

This analysis provides support for interventions in restaurants and stores with the aim of improving nutrition in adolescents. Interventions aimed at reducing the sugar content of beverages served in restaurants, including those with servers and fast food restaurants, and the sugar content of foods from convenience stores may reduce sugar intake especially among adolescents in the United States. Policies to reduce sugar consumption may consist of limiting free refills in restaurants or facilitating healthy food offerings at convenience stores.

VIII. Tables & Figures

Table 1: Gender, Age, and Race/Ethnicity of US teens (NHANES 11-12)

Description of Teenagers (n=1152)	% total
Gender	
Male	51.7
Female	48.3
Age	
12	13.9
13	12.1
14	13.3
15	13.5
16	12.3
17	11.8
18	10.6
19	12.4
Race/Ethnicity	
Mexican American	14.2
Other Hispanic	7.1
Non-Hispanic White	56.6
Non-Hispanic Black	13.9
Non-Hispanic Asian	4.4
Other (including multi-racial)	3.8
Description of Foods and Beverages Consumed (n=14504)	
Place of Consumption	% foods
Meals eaten at home	61.5
Meals eaten away from the home	38.5
Place of Purchase	
Convenience	2.9
Elsewhere	12.8
Fast Food	12.6
Grocery Store	58.8
Restaurant with a Server	6.0
School	7.0

Table 2: Average Sugar Content of Beverage and Food Items Consumed by Teens at Home versus Away from Home in one day (grams) NHANES 11-12

	All			*Home*			*Away*		
	mean	95% CI		mean	95% CI		mean	95% CI	
Dairy Beverages									
Added	17.77	14.77	20.77	21.2	15.1	27.3	16.4	12.9	20.0
Natural	16.67	15.28	18.06	17.9	16.1	19.8	14.3	12.2	16.4
Total	21.75	19.78	23.72	20.5	18.4	22.6	24.1	20.2	28.0
Dairy Foods									
Added	23.64	20.28	27.01	27.4[a]	22.0	32.7	19.2	16.4	22.0
Natural	3.42	2.25	4.60	3.2	2.7	3.8	3.7	1.1	6.3
Total	10.10	7.66	12.54	10.7	8.0	13.4	9.4	5.0	13.8
Non-Dairy Beverages									
Added	38.75	36.37	41.14	38.3	35.3	41.2	39.5	35.4	43.6
Natural	14.18	10.30	18.06	14.1	12.0	16.3	14.3	4.8	23.8
Total	37.53	34.90	40.16	36.4	34.0	38.7	39.4	33.7	45.0
Non-Dairy Foods									
Added	11.90	10.04	13.76	12.5	9.9	15.1	11.0	8.4	13.5
Natural	2.39	2.22	2.56	2.6 [a]	2.4	2.8	2.1	1.8	2.3
Total	8.75	7.72	9.78	9.3	7.9	10.7	7.9	6.5	9.4
Added Sugars									
Beverages	35.84	33.64	38.03	37.1	34.3	39.9	34.3	30.8	37.8
Foods	12.42	10.64	14.21	13.1	10.6	15.6	11.4	9.0	13.8
Total	17.67	16.16	19.18	18.3	16.2	20.3	16.8	14.7	19.0
Natural Sugars									
Beverages	15.34	13.19	17.50	16.0	14.5	17.4	14.3	8.9	19.6
Foods	2.59	2.40	2.79	2.8	2.5	3.0	2.3	2.0	2.7
Total	4.36	3.98	4.74	4.7	4.4	5.0	3.9	3.1	4.7
Sugars in Beverages	32.71	30.71	34.72	31.4	29.5	33.2	35.0 [a]	30.7	39.3
Sugars in Foods	8.86	7.89	9.83	9.4	8.1	10.8	8.1	6.7	9.4
Sugars (All Sources)[b]	13.39	12.47	14.31	13.8	12.6	15.0	12.8	11.3	14.3

[a] Indicates statistical significance through non-overlapping 95% confidence intervals compared to other group

[b] This indicates the average amount of sugar in a food or beverage purchased by US teens and is not the sum total of what was consumed.

Table 3: Average Amount of Sugar in Foods and Beverages Consumed by US teens by Place of Purchase in one day (grams) NHANES 11-12

	Grocery Store			Restaurant with Server			Fast Food Restaurant			Convenience Store			School Cafeteria			Other		
	mean	95% CI		mean	95% CI		mean	95% CI		mean	95% CI		mean	95% CI		mean	95% CI	
Dairy Beverages																		
Added	20.7 [b]	14.5	26.9	17.7 [b]	14.0	21.5	25.6 [b]	16.9	34.3	28.5 [b]	21.4	35.6	11.5 [c]	9.8	13.3	19.0 [b]	13.6	24.4
Natural	18.5 [b]	16.6	20.4	12.7	6.8	18.5	13.4	9.5	17.3	16.6	9.4	23.8	12.4 [c]	11.1	13.7	15.0	9.8	20.1
Total	21.0	18.8	23.1	25.9	15.6	36.2	37.8 [b]	26.6	49.0	19.4	9.7	29.0	19.6 [c]	16.8	22.4	22.1	12.8	31.3
Dairy Foods																		
Added	23.7 [b]	18.7	28.7	27.8	9.6	46.0	30.9 [b]	22.0	39.8	10.2	7.2	13.1	10.9 [c]	7.8	13.9	18.5	14.1	22.9
Natural	2.7	2.2	3.2	1.8	0.8	2.9	7.7	1.7	13.7	3.1	1.6	4.6	1.8	0.9	2.8	2.9	1.9	3.8
Total	9.0	6.6	11.3	5.9	0.8	11.1	19.1	8.8	29.5	8.4	3.9	12.9	3.2 [c]	1.3	5.1	10.2	6.0	14.4
Non-Dairy Beverages																		
Added	37.1 [a]	33.7	40.6	51.4 [b]	45.0	57.8	41.5 [b]	36.7	46.3	42.7 [b]	34.6	50.8	22.2 [c]	11.9	32.5	34.9	28.0	41.8
Natural	17.1 [b]	11.4	22.8	5.6 [c]	0.5	10.7	6.7 [c]	4.1	9.3	9.0	3.0	15.0	13.7	10.7	16.7	8.5	4.0	13.1
Total	36.7 [b]	32.8	40.7	51.3 [a]	45.1	57.5	41.8	37.0	46.6	40.8	33.5	48.2	18.8 [c]	14.5	23.2	33.9 [b]	27.6	40.1
Non-Dairy Foods																		
Added	11.8 [b]	9.2	14.5	6.2 [c]	4.4	8.1	6.0 [c]	4.8	7.2	31.9 [a]	21.9	41.9	6.5 [c]	3.8	9.2	18.3 [b]	11.4	25.2
Natural	2.7 [b]	2.4	2.9	1.6 [c]	1.3	1.9	1.8 [c]	1.5	2.1	1.6 [c]	1.0	2.1	2.8 [b]	2.1	3.5	2.0	1.6	2.5
Total	9.0 [b]	7.6	10.5	4.6 [c]	3.6	5.7	5.0 [c]	4.2	5.7	22.5 [a]	14.6	30.3	6.1	4.5	7.7	12.1 [b]	8.0	16.1
Added Sugars																		
Beverages	35.9 [b]	32.6	39.3	48.4 [a]	42.4	54.3	39.3 [b]	34.9	43.6	42.5 [b]	34.5	50.5	13.2 [c]	10.8	15.5	32.8 [b]	26.5	39.1
Foods	12.3 [b]	9.8	14.9	6.7 [c]	4.8	8.6	7.7 [c]	6.1	9.3	31.5 [a]	21.6	41.4	6.6 [c]	4.0	9.2	18.3 [b]	11.8	24.8
Total	17.3 [b]	15.1	19.4	17.2 [b]	13.0	21.4	15.9 [b]	13.6	18.3	34.9 [a]	27.9	41.9	8.0 [c]	5.9	10.1	21.5 [b]	16.2	26.7
Natural Sugars																		
Beverages	17.8 [b]	14.6	21.0	7.7 [c]	3.5	11.8	8.6 [c]	6.2	11.0	11.5	6.7	16.3	12.8 [c]	11.5	14.1	11.7	7.8	15.5
Foods	2.8 [b]	2.6	3.1	1.6 [c]	1.3	1.9	2.4	1.7	3.1	2.0	1.4	2.7	2.8 [b]	2.1	3.5	2.3	1.8	2.7
Total	5.2 [b]	4.5	5.8	2.0 [c]	1.6	2.4	2.9 [c]	2.2	3.7	3.7	2.5	4.9	4.8 [b]	4.1	5.5	3.2 [c]	2.6	3.9

Foods																	
Sugars (All Sources)[d]	13.6[b]	12.3	14.9	11.0	8.5	13.5	11.9[b]	10.1	13.7	26.5[a]	20.7	32.2	8.5[c]	7.1	9.8	15.0[b]	11.8	18.3

[a] Indicates statistical significance through non-overlapping 95% confidence intervals compared to b and c groups
[b] Indicates statistical significance through non-overlapping 95% confidence intervals compared to a and c groups
[c] Indicates statistical significance through non-overlapping 95% confidence intervals compared to a and b groups
[d] This indicates the average amount of sugar in a food or beverage purchased by US teens and is not the sum total of what was consumed.

Table 4: Contribution of Sugars from Grocery Stores, Convenience Stores, and Fast Food Restaurants to the Overall Diet by Purchase Location, Gender, Race/Ethnicity, and Poverty Status (NHANES 11-12)

	All	*Males*	*Females*	*Hispanic* [b]	*White*	*Black*	*Asian*	*Living in Poverty* [c]	*Not living in Poverty*
Total added sugar (tsp)	23.1	25.7 [a]	20.2	19.9	25.1 [a]	24.2 [a]	15.4	24.1	22.3
Total energy (kcal)	2174.7	2530.8 [a]	1808.6	2314.9	2230.7	2037.4	1967.2	2205.7	2152.1
Total carbohydrate (gm)	305.1	351.9 [a]	254.2	320.1	313.3	287.5	272.3	312.8	299.7
Total sugar (gm)	135.0	152.5 [a]	117.1	130.7	144.1 [a]	129.5	104.6	134.4	135.4
Added Sugars									
Grocery store	41.2	45.5	33.3	34.1	44.1	42.2	39.2	41.6	40.5
Fast Food Restaurant	55.0	55.5	54.4	37.8	60.2	49.0	34.5	52.4	56.6
Convenience Store	53.7	60.7 [a]	45.0	53.1	55.1	52.2	42.7	55.8	52.4
Sugars from Beverages									
Grocery store	35.9	43.9	23.7	28.9	41.9	31.0	20.5	48.3	22.1
Fast Food Restaurant	20.1	19.7	20.6	17.6	19.3	24.3	13.5	17.3	22.0
Convenience Store	48.7	52.8 [a]	44.0	44.6	52.2	45.9	43.9	40.2	54.4 [a]
Sugars from Foods									
Grocery store	52.3	61.2 [a]	37.4	41.4	58.2	49.4	35.4	58.2	42.7
Fast Food Restaurant	35.1	34.1	36.4	27.9	36.4	36.1	18.6	33.2	36.4
Convenience Store	60.8	69.3	51.5	58.2 [a]	63.8 [a]	64.2 [a]	41.2	61.8	60.2
Natural Sugars									
Grocery store	30.6	28.1	33.3	15.1	32.7 [a]	34.0	27.1	27.5	33.9
Fast Food Restaurant	9.9	9.1	11.0	7.7	10.4	9.2	6.7	7.5	11.6
Convenience Store	31.9	36.7	26.4	35.7 [a]	32.4	23.3	32.9	25.6	36.1
Total Sugars									
Grocery store	45.4	55.6	30.4	44.7	48.5	44.1	40.9	58.2	31.1
Fast Food Restaurant	43.6	42.0	45.7	32.9	46.2 [a]	43.4 [a]	23.1	38.5	47.2
Convenience Store	89.2	100.7	76.1	89.0	92.8	83.0	71.8	81.9	94.1

[a] Indicates statistical significance through non-overlapping 95% confidence intervals compared to other groups

[b] Race/ethnicity is self-reported

[c] Living in poverty is determined by a poverty to income ratio below the Federal poverty threshold

Table 5: Contribution of Sugars from Grocery Stores, Convenience Stores, and Fast Food Restaurants to the Overall Diet by Purchase Location, Gender, Race/Ethnicity, and Poverty Status (NHANES 11-12)

	All	*Males*	*Females*	*Hispanic* [b]	*White*	*Black*	*Asian*	*Living in Poverty* [c]	*Not living in Poverty*
Total sugar (% gm sugar)									
Sugars from Beverages									
Grocery store	8.1%	8.0%	8.2%	5.5%	8.8%	8.5%	7.2%	8.3%	7.6%
Fast Food Restaurant	8.9%	7.3%	10.4%	7.6%	9.4%	7.7%	6.5%	8.9%	8.8%
Convenience Store	10.1%	9.8%	10.4%	9.2%	10.1%	10.3%	8.7%	10.7%	9.6%
Sugars from Foods									
Grocery store	5.8%	5.4%	6.3%	2.9%	6.5%	6.1%	4.2%	6.0%	5.5%
Fast Food Restaurant	3.6%	2.8%	4.5%	3.3%	3.6%	4.2%	2.3%	2.8%	4.1%
Convenience Store	9.0%	8.6%	9.5%	7.5%	9.7%	8.7%	9.4%	8.0%	9.8%
Added Sugars									
Grocery store	9.0%	8.5%	9.8%	5.6%	9.6%	9.8% [a]	7.2%	9.0%	9.2%
Fast Food Restaurant	5.7%	4.7%	6.9%	5.1%	5.9%	5.8%	3.5%	5.5%	5.8%
Convenience Store	11.3%	11.1%	11.5%	9.9%	11.8%	11.8%	8.6%	11.9%	10.9%
Natural Sugars									
Grocery store	6.9%	5.0%	8.8%	2.4%	7.5%	7.1% [a]	5.3%	5.4%	8.6%
Fast Food Restaurant	1.8%	1.3%	2.5%	1.5%	2.1%	1.4%	1.1%	1.2%	2.2%
Convenience Store	5.8%	5.8%	5.7%	5.8%	5.8%	4.7%	6.9%	4.8%	6.4%
Total Sugars									
Grocery store	8.0%	7.9%	8.1%	5.9%	8.3%	8.8%	7.6%	8.9%	7.0%
Fast Food Restaurant	7.3%	5.8%	9.0%	6.1%	7.8% [a]	6.9%	4.0%	6.4%	7.9%
Convenience Store	16.4%	16.2%	16.7%	14.9%	17.0%	15.7%	15.0%	15.9%	16.8%

[a] Indicates statistical significance through non-overlapping 95% confidence intervals compared to other groups

[b] Race/ethnicity is self-reported

[c] Living in poverty is determined by a poverty to income ratio below the Federal poverty threshold

Appendix 1: Contribution of Sugars from Grocery Stores, Convenience Stores, and Fast Food Restaurants to the Overall Sugar Intake by Purchase Location, Gender, Race/Ethnicity, and Poverty Status (NHANES 11-12)

	All	*Males*	*Females*	*Hispanic* [b]	*White*	*Black*	*Asian*	*Living in Poverty* [c]	*Not living in Poverty*
Total sugar (% gm sugar)									
Sugars from Beverages									
Grocery store	27.6%	28.6%	26.0%	28.6%	25.2%	31.1%	31.9%	27.1%	28.5%
Fast Food Restaurant	37.6%	33.2%	42.2%	27.5%	41.4%	31.7%	23.1%	35.5%	38.9%
Convenience Store	37.4%	37.2%	37.6%	37.4%	36.0%	37.2%	36.4%	38.4%	36.7%
Sugars from Foods									
Grocery store	20.4%	21.9%	18.6%	13.7%	21.1%	23.6%	16.5%	23.6%	16.8%
Fast Food Restaurant	14.6%	13.3%	16.1%	14.3%	13.3%	17.7%	17.8%	12.6%	15.9%
Convenience Store	37.0%	35.7%	38.3%	32.4%	38.2%	37.4%	45.5% [a]	33.5%	39.5%
Added Sugars									
Grocery store	30.1%	32.0%	27.3%	27.8%	28.0%	36.6%	29.9%	31.8%	27.3%
Fast Food Restaurant	24.2%	21.5%	27.2%	19.9%	25.3%	23.4%	17.7%	22.7%	25.1%
Convenience Store	43.2%	43.1%	43.3%	40.7%	43.9%	45.4%	37.0%	44.0%	42.7%
Natural Sugars									
Grocery store	21.0%	18.9%	23.2%	10.3%	18.2%	26.6% [a]	23.5%	20.2%	22.0%
Fast Food Restaurant	7.3%	6.1%	8.6%	6.4%	7.2%	6.8%	8.7%	5.6%	8.3%
Convenience Store	23.5%	24.0%	23.0%	25.0%	22.4%	20.1%	33.9% [a]	20.7%	25.5%
Total Sugars									
Grocery store	27.8%	30.6%	24.3%	29.3%	25.8%	33.2%	31.9%	32.1%	23.0%
Fast Food Restaurant	30.4%	26.8%	34.4%	24.6%	32.1%	28.9%	23.2%	26.7%	32.8%
Convenience Store	64.4%	64.4%	64.3%	62.3%	64.2%	62.4%	68.9%	61.8%	66.2%

[a] Indicates statistical significance through non-overlapping 95% confidence intervals compared to other groups

[b] Race/ethnicity is self-reported

[c] Living in poverty is determined by a poverty to income ratio below the Federal poverty threshold

Chapter 5: Conclusions and Recommendations

IX. Conclusions

This analysis described intake of added and natural sugars in dairy and non-dairy foods and beverages by age, income, gender, and race/ethnicity in the United States. A second analysis described sugar intake of adolescents to understand where foods with different types of sugars are consumed - in the home or away from the home - as well as where they are purchased, such as in grocery or convenience stores, restaurants, or school cafeterias.

We found that adolescents aged 12 to 19 years consume the most added sugars when compared to all other age groups and a large proportion of added sugars come from non-dairy beverages. While trends cannot be determined as the data are cross-sectional and therefore representative of only one time period, it is reasonable to posit that, as children grow older, natural sugars in the diet are replaced with added sugars, which are consumed in large amounts. Consumption of added sugars is highest among adolescents, as adults over the age of 20 reported consuming fewer grams each day than did adolescents.

A major contributor of added sugars to the diet of adolescents is added sugars in non-dairy beverages, a category that includes beverages such as soft drinks and sports drinks. Further examination of consumption patterns indicate that when adolescents consume these beverages outside of the home they consume beverages with a higher sugar content than similar beverages consumed at home.

Specifically, when these beverages are purchased from restaurants with servers, fast food restaurants, and convenience stores, the sugar content is higher than those purchased at a grocery store or school cafeteria. This difference in sugar intake is likely due to a number of factors that warrant further research. One possible factor is free refill availability at restaurants with servers and fast food restaurants. Policies such as free-refills are especially relevant in adolescents who are experiencing newfound freedom and autonomy in decision-making, which may result in purchasing of foods and beverages, such as sodas, that were restricted during childhood.

Sugar content of foods and beverages purchased in school cafeterias were consistently lower than those purchased elsewhere. This low sugar content is perhaps a result of efforts at the school level to improve the nutritional quality of offerings in schools. While schools are inherently different from restaurants and other purchase locations because many school children do not have an option of purchasing foods from locations other than the school cafeteria, this low sugar content may indicate a positive impact in the nutritional quality of foods offered due to school nutrition standards.

Lastly, one of the few differences seen between demographic groups among the entire US population was a large difference in consumption of sugars between those living in poverty when compared to those not living in poverty. Low-income individuals consumed significantly more added sugars, specifically in non-dairy beverages when compared to higher-income individuals. However, in terms of natural sugars in foods, higher-income individuals consumed more natural sugars

from foods than low-income individuals. This finding may be due to differences in price and neighborhood availability between low and high-income areas.

X. Recommendations

These analyses indicate that the highest consumers of added sugars in the US are those with the lowest income and adolescents aged 12-19 years. Adolescents tend to consume beverages with added sugars in larger amounts when purchased at restaurants with servers, fast food restaurants, and convenience stores. As such, this research a need for interventions among the lowest income groups and adolescents, particularly at the store level.

The main recommendation deals with the high content of added sugars in non-dairy beverages purchased at restaurants with servers, fast food restaurants, and convenience stores. This finding indicates a possible need to address restaurant policies that may promote high consumption of sugar in beverages such as large beverage sizes and free refill policies. As evidenced by the recent failure to implement a restriction on large sized sugary beverages in New York [64], there will not likely be support to similar policies that limit these large sized beverages. Reducing free refill availability may be a simple switch for restaurants to voluntarily adopt. However, it is unlikely that the current political climate will allow for governmental policies that directly regulate beverage offerings at restaurants and it is unknown whether or not this type of regulation would improve health.

However, policy changes are not the only possible course of action. An alternate strategy that may be more acceptable to improve public health would be a

an incentive offered to restaurants that voluntarily adopted measured such as smaller beverage sizes, cessation of a free refill policy, or removal of sugary beverages from the menu. While it's likely that any measure that appears to restrict purchasing decisions will not be accepted easily, the ability of individual restaurants to choose whether or not to adopt these policies may make it more acceptable.

More research is needed to determine what intervention efforts would be successful with adolescent and low-income populations. As indicated in the review of the literature, both populations are vulnerable to long-term and exacerbated impacts of poor nutrition. As such, it is important that both groups benefit from nutrition education, such as Cooking Matters, a program that teaches cooking skills, and improvements in food availability, such as with the Slow Food movement, which aims to make healthful food more widely available, in order to improve health[65, 66].

It is important to focus on efforts that encourage consumption of more healthful foods instead of placing restrictions on less healthful foods. Interventions of this nature could take many forms, but may involve strategies to assist stores and restaurants that traditionally sell calorie dense, high sugar, high fat foods in promoting and selling foods such as fruits, vegetables, and whole grains that are higher in micronutrient and fiber content. Strategies to improve these sales at the store level, particularly at stores in walking distance to high schools and in low-income neighborhoods, will reach a population that may not otherwise be reached by other health improvement methods.

Though sugar content is only one aspect of dietary intake, it is an aspect that is associated with adverse health impacts such as type 2 diabetes and obesity when consumed in large amounts [8, 29, 30]. As such, the findings that indicate high consumption rates of added sugars among adolescents and low-income individuals, along with the higher content of added sugar in non-dairy beverages purchased by adolescents at restaurants with servers, fast food restaurants, and convenience stores when compared to grocery stores and school cafeterias are this research is intended to support efforts to decrease added sugar consumption and improve the health of the United States population.

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