Understanding Consumption of Sugar-Sweetened Beverages by Adolescents with Dental Caries

THESIS

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By

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Abstract

**Purpose:** Sugar consumption habits are difficult to change, and evidence is accumulating that sugar can be addictive. This was a pilot study of adolescents’ sugar-sweetened beverage (SSB) consumption patterns and how underlying behavioral determinants relate to caries status.

**Methods:** A survey was designed by adapting validated instruments from food and addiction research. Questions measured indicators of addiction, perception of caries risk and liking of different beverages. We also measured SSB consumption measures of quantity, frequency, variety, and context of use. The survey included an interview and a written portion. Subjects also completed the Youth Self-Report (YSR), a widely used tool for assessing psychopathology in adolescents. Subjects were grouped by caries severity and also by exposure time to beverages. Groups were compared using chi-square or ANOVA.

**Results:** One hundred and ten subjects (mean age=15yr) completed surveys: 38 caries-free, 40 mild caries, and 32 severe caries. Subjects with caries showed a trend toward liking sweet drinks more than healthy subjects ($P=.09$) and reported greater awareness of caries risk ($P=.04$). They also exhibited more addictive traits such as a greater desire to reduce consumption ($P=.04$). Surprisingly, groups did not differ significantly for self-reported measures of frequency or amount. However, self-reported amounts were inconsistent with contextual data elicited from the interview. Considering their more
negative perception of their beverage consumption, this suggests under-reporting in the caries group. We also discovered that adolescents in the highest exposure group liked SSB (P<0.01) and disliked water (P<0.04). They also had significantly larger means for all except one of the problem scales in the YSR (P<0.02).

Conclusions: These data suggest that adolescents with caries exhibit some signs of addiction to sugar-sweetened beverages, are aware of caries risk, and may be reluctant to admit the extent of their consumption. Additionally, adolescents who consume the most SSB may suffer from behavioral, psychological and social problems.
Dedication

This document is dedicated to my family.
Acknowledgments

I would like to thank my committee for their time, guidance, and support in making this project a success. I would like to thank Kathy Vannatta, Ellen Peters, and Chris Simmons for their contributions. I would also like to thank the following dental students for their time and effort in assisting with the project: Ben Kwok, Rami Mikati, Devin Byard, Rachel Cook, and Ying An.
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Major Field: Pediatric Dentistry
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Chapter 1: Introduction

Consumption of sugar-sweetened beverages (SSB) has increased considerably over the last two decades, especially among adolescents. SSB include but are not limited to soda, fruit drinks, sport and energy drinks, and liquids sweetened with various forms of sugar that provide excess calories and few if any essential nutrients. These drinks are abundant in the United States and are identified as the primary source of added sugars in the diets of children and adolescents.\(^1\)

This increase in consumption of SSB has wide-ranging implications for the overall health of this population. In addition to being linked to an increased risk of dental caries,\(^2\) the association of SSB with many systemic issues such as obesity, diabetes, and cardiovascular disease has recently been substantiated by large epidemiologic studies.\(^3,4\) SSB consumption has also led to a decrease in calcium and nutrient rich dairy products, such as milk among children and adolescents.\(^2\)

Relationships have also been discovered between consumption of SSB and other unhealthy social behaviors, such as smoking and screen media use.\(^5\) High consumption levels of sugar-containing soft drinks were found to be associated with hyperactivity, mental distress and conduct problems in adolescents.\(^6\)

Many studies have investigated the overall consumption distribution and have tried to understand variations in heavy consumption by individual demographic characteristics and socio-economic status. Sugar-sweetened beverage consumption
differs by sex, age, race and ethnicity, and income. Studies consistently find that males, Blacks and Hispanic Americans, and low income/low educated are the most frequent SSB consumers. Data from the National Health and Nutrition Examination Survey, 2005–2008 found that teenagers and young adults consume more sugar drinks than other age groups. Daily consumption of SSB increases with age, peaks at 12–19 years of age, and then steadily decreases with age.

Wang et al reviewed 24-hour diet recalls from NHANES data (1988–2004) and found significant increases in caloric contributions from sugar-sweetened beverages among US youth over time. The percentage of SSB drinkers has changed little over time; however, daily consumption level has increased. This study found that children 2-19 years of age consumed an average 10-16% of their total calories from sugared drinks and fruit juices. On any given day 84% of adolescents 12-19 years of age drank SSBs, and consumed an average of 32.7 oz. throughout the day, which is approximately 356 kcal and 16% of their total energy intake. Additionally, they also consumed 13.4 oz. of fruit juice, which is approximately 184 kcal and 8% of their total energy intake. This is very concerning because it is far above the published recommendations of the American Heart Association and U.S. Department of Agriculture, which agree that sweetened beverages should be limited to 4-6 oz. for children ages 1-6 and 8-12 oz. for children ages 7-18.

Over 50% of SSB are consumed in the home. Most of the SSB are purchased in stores, followed by restaurants or fast-food establishments. Surprisingly, only a small percentage (7-15%) are consumed at school and only 1-5% of SSB are obtained from school vending machines. Carbonated drinks compose two-thirds of all SSB drank by
adolescents, and in the last two decades sports/energy drink consumption has increased threefold.\textsuperscript{9,12}

Sugar and Dental Caries

One of the concerning aspects of SSB consumption among adolescents, especially for the dental community, is the continuous exposure of the teeth to sugar. Studies have confirmed the direct relationship between intake of sugar and dental caries across all ages\textsuperscript{2,13,14} and adolescence remains a period of time in which the risk for dental caries remains especially high.\textsuperscript{15}

High fructose corn syrup (HFCS) is the most common sweetener found in SSBs. HFCS commonly used in beverages is composed of 55\% fructose and 45\% glucose; this monosaccharide composition of HFCS is similar to sucrose or table sugar, which is 50\% fructose and 50\% glucose.\textsuperscript{12} The digestion of these sugars by oral bacteria plays an important role in tooth decay.\textsuperscript{2,13,14} Both naturally-occurring and added sugars are metabolized by bacteria (i.e \textit{Streptococcus mutans}), which produce acid byproducts that demineralize tooth structure, leading to tooth decay. The optimal neutral pH of the oral cavity ranges from 6.5 to 7.5 and a critical pH of 5.5 is considered to be the threshold for caries development.\textsuperscript{13} The longer and more frequently this critical pH is encountered, the more demineralization will occur.\textsuperscript{2,13,14} Additionally, people who regularly consume sugar promote a change in their oral microflora that results in increased colonization by acidurant and cariogenic species.\textsuperscript{13} Compounding the problem, most commercial soft drinks are very acidic; their pH ranges from 2.5 to 3.5. The chronic exposure to these acidic soft drinks contributes to demineralization of enamel and aids in the caries process.\textsuperscript{13}
Although there is very strong evidence linking sugar with caries, its influence on tooth decay varies because there are multiple variables that determine the extent to which sugar consumption causes tooth decay.\(^2\) For instance, since community water fluoridation has become pervasive, the incidence of caries has decreased significantly despite the fact that sugar consumption has continued to increase.\(^1^4\) We must acknowledge that dental caries is a multifactorial chronic disease and is influenced by many factors: bacteria, saliva, diet, sugar intake, oral hygiene, fluoride exposure and genetics.\(^1^3\) Because of all these contributing variables, it has been discovered that caries rates do not necessarily increase proportionally with increasing consumption of sugar.\(^2\)

Nevertheless there is sufficient evidence in the literature to claim that sugar-sweetened beverage consumption contributes to caries, especially in individuals with high rates of consumption. An epidemiological study revealed a significant association between the frequency of soft drink consumption and caries rates in the 12-14, 15-17 and 21-23 age groups, even after accounting for other sugary foods and related variables.\(^1^6\) It has also been suggested that the greatest risk for caries is between-meal consumption of soft drinks, as opposed to consumption during meals.\(^2\) Daily between-meal consumption of soft drinks three or more times a day was found to increase dental caries by 179%.\(^1^6\) Specific behavioral patterns such as constant sipping throughout the day may also increase the cariogenicity of SSBs.\(^1^3\)

**Adolescent Preference for Sweet Taste**

Many factors may contribute to the high consumption of SSB among adolescents. Majewski\(^1^5\) points out several concerns. Marketing and advertising of many high-sugar products is targeted towards a teenage market. Additionally, adolescents gain increasing
independence and ability to make their own choices when it comes to foods and beverages. They also tend to have irregular meal times and increased snacking.\textsuperscript{15} Ultimately, however, SSB consumption is founded on a liking or desire for sweet taste.

It is widely known that humans have an innate preference for sweet taste, but the degree of liking for sweet foods varies individually.\textsuperscript{17} Studies have shown that preference for sweet decreases over the lifespan with young children preferring sweeter concentrations of sucrose in solution than adolescents and adolescents preferring sweeter solutions than adults.\textsuperscript{18}

Sweet liking is influenced by a variety of factors and being able to understand this may help us to modify behaviors, especially when it comes to limiting SSB consumption. Individual differences in sweet taste preferences appear to be partly heritable. A locus on chromosome 16 was found to be associated with liking and consumption of sweet foods.\textsuperscript{17} We also know that repeated exposure to and experience with foods is one of the best predictors of liking. Research has demonstrated that repeated exposure to sweet- and sour-tasting drinks in children led to an increased preference for sweet-tasting drinks but no change in preference for the sour-tasting drinks.\textsuperscript{19}

Additionally, sweet tastes have been found to stimulate pleasure-generating brain circuitry. Clinical studies have found that these pathways are similar to and overlap with those which mediate addictive substances such as drugs and alcohol.\textsuperscript{20} Sugar is also known to have pain-reducing properties. It mediates endogenous opioid and non-opioid systems to block pain afferents.\textsuperscript{21} Sweet-tasting foods have soothing properties and have been reported to reduce symptoms of depression and mediate stress.\textsuperscript{18}
The rewarding and soothing properties of sugar, in addition to repeated exposure to extremely sweet beverages, may make it difficult to change behaviors in teenagers. A recent study on decision-making processes for sugar consumption in adolescents concluded that “the immediate pleasurable taste of sugar outweighed and deferred the recognition of dangers associated with its consumption.”

Sugar Addiction

Due to these hedonic properties of sugar, many researchers have begun comparing foods high in added sugar to addictive drugs like cocaine. Although they are not as behaviorally and psychologically dangerous as many drugs of abuse, the sweet reward and craving are comparable intensity and magnitude to addictive drugs. Addiction or “substance dependence” as it is referred to in the DSM-IV has very specific diagnostic criteria, and three or more of the criteria need to be manifested.

Diagnostic criteria for substance dependence as stated by the DSM-IV-TR

1. Tolerance, as defined by either of the following:
   a. The need for markedly increased amounts of the substance to achieve intoxication or desired effect.
   b. Markedly diminished effect with continued use of the same amount of the substance.
2. Withdrawal, as manifested by either of the following:
   a. The characteristic withdrawal syndrome for the substance.
   b. The same (or closely related) substance is taken to relieve or avoid withdrawal symptoms.
3. Taking the substance often in larger amounts or over a longer period than was intended.
4. There is a persistent desire or unsuccessful effort to cut down or control substance use.
5. Spending a great deal of time in activities necessary to obtain or use the substance or to recover from its effects.
6. Giving up social, occupational, or recreational activities because of substance use.
7. Continuing the substance use with the knowledge that it is causing or exacerbating a persistent or recurrent physical or psychological problem.

Several researchers have found evidence that sugar intake can produce a pattern of symptoms consistent with the DSM-IV descriptions for dependence. Avena et al. found that intermittent sugar access can produce numerous behaviors and corresponding brain changes that are similar to those observed in drug-dependent rats. The behaviors
included bingeing, withdrawal as indicated by signs of anxiety, and craving during sugar abstinence.\textsuperscript{26,28} Additionally, sugar was cross-sensitized to amphetamine and alcohol.\textsuperscript{26}

One of the strongest neurochemical similarities between sugar and drugs of abuse is the increase in extracellular dopamine in the brain’s reward center, the nucleus accumbens.\textsuperscript{29}

Sparked by a concern for the growing obesity epidemic in children, several researchers have provided preliminary support for the concept of food and sugar addiction among children and adolescents.\textsuperscript{30,31} For example, Gearhardt et al\textsuperscript{31} have shown that elements of substance dependence can be applied to relationships with food. They developed and validated a Yale Food Addiction Scale (YFAS) based on the DSM-IV criteria for substance dependence and later adapted it for use in children. The YFAS defines food addiction operationally and applies rating scales to identify addictive-like eating.

Although evidence is growing to support the concept of addictive-like eating among adults and children, little is known about the role addiction may play specifically in the consumption of highly sweetened beverages among adolescents.

Purpose

At Nationwide Children’s Hospital dental clinic we have observed that a vast majority of adolescents drink copious amounts of sugar-sweetened beverages and it is difficult to encourage them to reduce or stop consumption. Likewise, we find that many adolescents in our clinic are afflicted with rampant smooth-surface caries. The purpose of this pilot study was to better understand consumption of sugar-sweetened beverages in this population of adolescents and how underlying behavioral determinants relate to caries status. We also sought to describe what adolescents were drinking and determine
whether there are differences among subjects with regard to likability of beverages. We also wanted to determine whether adolescents with caries and/or those who frequently consume sugar-sweetened beverages exhibit any signs of sugar addiction based on our modified addiction measures. Lastly, we sought to identify any emotional and behavioral differences among groups of adolescents.
Chapter 2: Methods

This was a cross-sectional study that surveyed adolescents presenting to an outpatient dental clinic in a hospital setting. The study was approved by the IRB at Nationwide Children’s Hospital, Columbus, Ohio.

Sample

The sample was drawn from patients presenting to Nationwide Children’s Hospital, in Columbus, Ohio for scheduled dental appointments. The selection criteria were as follows: 13-18 year old healthy patients, English-speaking, who had a minimum 6th grade reading level. Patients who were less than 18 years of age needed to have an English-speaking parent present. Exclusionary criteria included xerostomia, enamel defects such as hypoplasia, or other non-dietary causative factor for caries.

Procedure

Patients were pre-screened by dental providers (dentist or hygienist) upon presentation to the dental clinic in order to assess qualification and interest for the study. The dental providers then alerted trained study personnel to potential participants. After the dental appointment was completed, the subject (and parent if under subject was under 18) was approached by study personnel to assess interest in the study. The subjects who qualified and were interested were given a brief description of the study verbally, and a Study Information Sheet was provided to the family. If the parent and subject agreed to participate, the research team obtained verbal informed consent. Each subject was able to
select a $20 gift card from a choice of superstores as compensation for their participation. Additionally, parking passes were given to their parent or guardian.

Following the informed consent procedures detailed contact information was obtained and sealed in an envelope separate from the other information. Demographic information was obtained on a data collection form. The number of incipient, cavitated, and restored surfaces for each participant were collected from the electronic dental record. Examining dentists who charted the findings used clinical and radiographic criteria to assess caries. Incipient and cavitated smooth surfaces were recorded. Pit and fissure caries/restorations were excluded.

The subject then completed two survey instruments. The first was a survey instrument we designed called the “Sugar Survey.” The second was the Youth Self-Report (YSR) of the Achenbach System of Empirically Based Assessment. Both are described in detail below.

Instrument: Sugar Survey

The Sugar Survey had two parts: a written self-report and an interview portion. The survey was designed by combining several instruments currently in use in food and addiction research and adapting them to focus on sugar-sweetened beverage consumption. It included questions to measure several domains: Likability of beverages, Risk Perception, and Addiction. Questions were modified from the Yale Food Addiction Scale for Children, a survey that adapted diagnostic indicators of substance abuse from the DSM-IV for use in food addiction. Other items were taken from standard quantity-frequency questionnaires used to measure alcohol consumption. Some questions related to risk perception were adapted from those used to study smoking. The survey included
multiple choice questions as well as continuous rating scales. Trained researchers also administered a semi-structured interview to gain more specific insight as to what adolescents are drinking. Subjects were cued to report specific types of beverages that they are drinking, the context of use, and how they obtained their beverages.

Validation of the Sugar Survey

One of the aims of this pilot study was to validate the survey instrument we had designed to assess addiction to sugar-sweetened beverages. Face and content validity were assessed by submitting the survey to a panel of experts in the fields of food science, addiction, and dentistry for critique in their respective domains. We received feedback and altered our survey accordingly.

Instrument: YSR of ASEBA

The Youth Self-Report (YSR) of The Achenbach System of Empirically Based Assessment (ASEBA) is a widely used tool in psychology research for assessing psychopathology in adolescents, specifically behavioral, emotional, and social problems. Reliability and validity of the YSR are well established, and normative T-Scores are based on a nationally representative sample of adolescents 11-18 years of age. Three-point (0-1-2) scales obtain ratings of problems and positive characteristics, which are then summed to yield total scores. The total scores are converted to clinically interpretable T-Scores. When using T-Scores, the mean (average) is always 50, and the standard deviation is 10. The YSR truncates the low end of the syndrome scales, so that a T-Score of 50 is the minimum obtainable on any syndrome scale. The YSR yields scores on eight empirically derived syndrome scales. The syndromes are designated as Anxious/Depressed, Withdrawn/Depressed, Somatic Complaints, Social
Problems, Thought Problems, Attention Problems, Rule-Breaking Behavior, and Aggressive Behavior. Some of these scales group into two higher order factors: Internalizing Problems (Anxious/Depressed, Withdrawn/Depressed, and Somatic Complaints) and Externalizing Problems (Rule-Breaking Behavior and Aggressive Behavior). Cut-off points are provided for the normal-, borderline clinical-, and clinical-range scores for each scale. For the YSR syndrome scales T-Scores of 65-69 (93rd-97th percentiles) are in the borderline clinical range. T-Scores above 69 (>97th percentile) are in the clinical range. For the higher order scales: Total Problems, Internalizing Problems and Externalizing Problems, T-Scores of 60-63 (84th-90th percentiles) are in the borderline range, whereas T-Scores above 63 (>90th percentile) are in the clinical range.34–36 For our purposes, we analyzed groups based on raw total scores to not lose variability, but we used T-scores to clinically interpret the data.

Analysis

The sample population was compared with respect to several independent variables: caries status, caries severity, and sugar exposure. Data was first analyzed according to the presence or absence of caries. Those who had no caries were “Healthy” and those who had ≥1 incipient or cavitated lesions were “Caries.” The caries group was separated further into “Mild” and “Severe.” Comparisons were made using ANOVA and post-hoc student’s t tests. See Table 1 below for description of each variable.

Additionally, we wanted to compare the adolescents by exposure to sugar-sweetened beverages. We computed “total SSB exposure per week in minutes” by multiplying the following variables: “Number of Drinks/day” * “Number of days per week they drink SSB” * “Time in minutes spent drinking each drink”. We called this
variable “Sugar Exposure.” We used a distribution analysis to create 3 groups for “Sugar Exposure.” Subjects in the lowest 25% quartile called “Low.” The middle 50% were called “Moderate” and the highest 25% quartile was called “High.”

<table>
<thead>
<tr>
<th>Variable</th>
<th>Groups</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caries Status</td>
<td>Healthy</td>
<td>No carious or restored smooth surfaces</td>
</tr>
<tr>
<td></td>
<td>Caries</td>
<td>Presence of one or more incipient or cavitated caries.</td>
</tr>
<tr>
<td>Caries Severity</td>
<td>Healthy</td>
<td>No carious or restored smooth surfaces</td>
</tr>
<tr>
<td></td>
<td>Mild</td>
<td>Radiographic “enamel” only” or visible, non-cavitated white spots</td>
</tr>
<tr>
<td></td>
<td>Severe</td>
<td>Radiographic lesions into dentin or visible cavitation of smooth surfaces</td>
</tr>
<tr>
<td>Sugar Exposure</td>
<td>Low</td>
<td>Lowest 25th percentile or &lt;60 minutes/week</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>Middle 50th percentile or 61-240 minutes/week</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Highest 25th percentile or &gt;241 minutes/week</td>
</tr>
</tbody>
</table>

Table 1. Independent variables and associated descriptions

Descriptive statistics were used to describe what adolescents are drinking. T-tests and ANOVA with post hoc student’s t-test were used to examine associations between the independent variables and several outcome variables for each of the domains of: Likability, Risk Perception, and Addiction. Categorical outcome variables were analyzed using chi-square and post hoc pairwise chi square comparisons where needed. ANOVA was also used to analyze the raw scores of the YSR data to normative scores and as well as make several comparisons between groups. P<0.05 was considered as statistically significant.
Chapter 3: Results

One hundred and ten subjects (mean age=15yr) completed surveys. 99% of adolescents drank sugar-sweetened beverages in the last 2 weeks. Only one subject reported no consumption of SSB. This same subject reported drinking sugar-free beverages and did not have any caries. Our sample population of adolescents drank an average 42.1 oz. per day on average, with a standard deviation of 47.2 oz. There was a single outlier that drank 420 oz. per day, thus we found it meaningful to report the median value was 32 oz.

Most of the adolescents were not loyal to one particular drink and drank a large variety of categories of SSB beverages. Even within a particular category such as soda, most adolescents would list that they drank several brands or types of soda in the comments section (ie. Mountain Dew, Pepsi). The categories of SSB identified in this study were: Pop, Juice, Fruit Drinks/Punches, Kool-Aid, Lemonade, Sports Drinks, Energy Drinks, Sweet Tea, Flavored Milk, Sweet Coffee Drinks, and Other. On average the adolescents drank 4.4 different categories of SSB as indicated by Figure 1.
Data were analyzed by grouping adolescents by caries status/caries severity and sugar exposure. These groups did not differ for demographic variables of age, sex, race and ethnicity, except for in the “moderate sugar exposure group” which was slightly older. Table 2 and Table 3 below show the demographic distribution of caries severity and sugar exposure.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Categories</th>
<th>Healthy n=38</th>
<th>Mild n=40</th>
<th>Severe n=32</th>
<th>Total n=110 (Row %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>Female</td>
<td>25</td>
<td>27</td>
<td>18</td>
<td>70 (63.6%)</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>13</td>
<td>13</td>
<td>14</td>
<td>40 (36.3%)</td>
</tr>
<tr>
<td>Race</td>
<td>White</td>
<td>15</td>
<td>11</td>
<td>16</td>
<td>42 (38.5%)</td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>18</td>
<td>20</td>
<td>11</td>
<td>49 (45.0%)</td>
</tr>
<tr>
<td></td>
<td>Asian</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1(0.92%)</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>17(15.6%)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>Hispanic/Latino</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td>12 (11.7%)</td>
</tr>
<tr>
<td></td>
<td>Not Hispanic</td>
<td>30</td>
<td>33</td>
<td>27</td>
<td>90 (88.2%)</td>
</tr>
<tr>
<td>Age</td>
<td>Mean ± SD</td>
<td>14.6 ± 1.5</td>
<td>15.2 ± 1.6</td>
<td>15.1 ± 1.6</td>
<td>15.0 ± 1.6</td>
</tr>
</tbody>
</table>

Table 2. Distribution of caries severity by demographic variables
Table 3. Distribution of sugar exposure by demographic variables

Comparing Subjects Based on Caries Severity

Healthy adolescents and those with caries seem to be drinking similar types of beverages. The most commonly consumed SSB overall, and in healthy and caries groups was Pop. This was followed by Juice and Sports Drinks. The least common SSB overall, and in healthy and caries groups, was Energy Drinks, followed by Other. The largest difference between the healthy and caries groups was seen in Pop and Sweet Tea, with a larger percentage of the caries group having drank both in the last 2 weeks. However, these differences were not statistically significant (P=0.15). Sugar-free beverages were not as pervasive, but Diet Pop was the most commonly drank sugar-free beverage overall and in each group. Table 4 and Table 5 below demonstrate the percentage of adolescents that drank each type of sugared and sugar-free beverage.
### Categories of SSB

<table>
<thead>
<tr>
<th>Categories of SSB</th>
<th>Healthy</th>
<th>Caries</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pop</td>
<td>68.4</td>
<td>80.6</td>
<td>76.4</td>
</tr>
<tr>
<td>Juice</td>
<td>65.8</td>
<td>65.3</td>
<td>65.5</td>
</tr>
<tr>
<td>Sports Drinks</td>
<td>47.4</td>
<td>48.6</td>
<td>48.1</td>
</tr>
<tr>
<td>Energy Drinks</td>
<td>2.6</td>
<td>9.7</td>
<td>7.3</td>
</tr>
<tr>
<td>Fruit Drinks/Punches</td>
<td>39.5</td>
<td>45.8</td>
<td>43.6</td>
</tr>
<tr>
<td>Kool-Aid</td>
<td>34.2</td>
<td>36.1</td>
<td>35.5</td>
</tr>
<tr>
<td>Lemonade</td>
<td>30</td>
<td>38.9</td>
<td>35.5</td>
</tr>
<tr>
<td>Sweet Tea</td>
<td>29</td>
<td>43.1</td>
<td>38.2</td>
</tr>
<tr>
<td>Flavored Milk</td>
<td>47.4</td>
<td>36.1</td>
<td>40</td>
</tr>
<tr>
<td>Sweet Coffee Drinks</td>
<td>28.6</td>
<td>34.7</td>
<td>32.7</td>
</tr>
<tr>
<td>Other Sweet Drinks</td>
<td>7.9</td>
<td>15.3</td>
<td>12.7</td>
</tr>
</tbody>
</table>

Table 4. Percentage of adolescents who drank SSB in the last 2 weeks

### Categories of Sugar-free Beverages

<table>
<thead>
<tr>
<th>Categories of Sugar-free Beverages</th>
<th>Healthy</th>
<th>Caries</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diet Pop</td>
<td>15.8</td>
<td>16.7</td>
<td>16.4</td>
</tr>
<tr>
<td>Crystal Light or Similar</td>
<td>7.9</td>
<td>16.7</td>
<td>13.6</td>
</tr>
<tr>
<td>Sugar-free Kool-Aid</td>
<td>5.3</td>
<td>0</td>
<td>1.8</td>
</tr>
<tr>
<td>Diet Lemonade</td>
<td>0</td>
<td>2.78</td>
<td>1.8</td>
</tr>
<tr>
<td>Sugar-free Sports Drinks</td>
<td>0</td>
<td>4.2</td>
<td>2.7</td>
</tr>
<tr>
<td>Sugar-free Energy Drinks</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Diet Iced Tea</td>
<td>2.6</td>
<td>5.6</td>
<td>4.6</td>
</tr>
<tr>
<td>Sugar-free Coffee Drinks</td>
<td>2.6</td>
<td>2.8</td>
<td>2.7</td>
</tr>
<tr>
<td>Other Sugar-free drinks</td>
<td>0</td>
<td>2.8</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Table 5. Percentage of adolescents who drank sugar-free beverages in the last 2 weeks

Surprisingly, caries severity groups did not differ significantly for self-reported measures of amount, frequency, and time spent drinking. This data is represented in Table 6. However, self-reported drinks per day were inconsistent with contextual data elicited from the interview. When we administered the interview portion of the survey, and verbally walked subjects through a typical day asking at whether or not they drank SSB at defined time points, (ie. as soon as I wake up, at breakfast, between breakfast and lunch, at lunch, between lunch and dinner, etc.) we elicited different numbers. If assume that for each of these time points selected, a subject drank a new SSB, then we begin to
develop a different picture. Reviewing the data from the interview portion, the healthy group drank 1.4 more drinks per day than they reported, the mild caries group drank 1.2 more drinks, and the severe caries group drank 2.6 more drinks. This suggests under-reporting, especially in the severe caries group. Adolescents with caries were also more likely to drink SSB between breakfast and lunch (P=0.01) and at dinner (P=0.02).

<table>
<thead>
<tr>
<th>SSB Consumption Measures</th>
<th>Healthy</th>
<th>Mild caries</th>
<th>Severe caries</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount per beverage (ounces)</td>
<td>17.2</td>
<td>16.4</td>
<td>19.1</td>
<td>P=0.53</td>
</tr>
<tr>
<td>Amount per day (ounces)</td>
<td>38.1</td>
<td>50</td>
<td>37.1</td>
<td>P=0.43</td>
</tr>
<tr>
<td>Time spent drinking each beverage (minutes)</td>
<td>50.8</td>
<td>38.2</td>
<td>51.9</td>
<td>P=0.71</td>
</tr>
<tr>
<td>Days Per Week</td>
<td>3.7</td>
<td>4.8</td>
<td>4.3</td>
<td>P=0.13</td>
</tr>
<tr>
<td>Number of Self-Reported Beverages Per Day</td>
<td>2.2</td>
<td>2.7</td>
<td>2.1</td>
<td>P=0.22</td>
</tr>
<tr>
<td>Number of Drinks Per Day (From Interview)</td>
<td>3.6</td>
<td>3.9</td>
<td>4.7</td>
<td>P=0.18</td>
</tr>
<tr>
<td>Calculated Sugar Exposure Time Per Week (minutes)</td>
<td>406</td>
<td>666</td>
<td>457</td>
<td>P=0.69</td>
</tr>
<tr>
<td>Number of Categories of SSB drank</td>
<td>4.0</td>
<td>4.4</td>
<td>4.7</td>
<td>P=0.17</td>
</tr>
</tbody>
</table>

Table 6. Measures of consumption among caries severity

We found that adolescents with caries exhibited a trend towards liking SSB more than healthy subjects. Figures 2 and 3 below depict likability among caries status and severity. Subjects with caries rated likability of SSB at 68.5% while healthy subjects rated likability at 59.8% (P= 0.09). Taking it a step further, we also found a trend for increasing likability as caries severity increased (P=0.1). However, neither of these trends were statistically significant.
Risk Perception among Caries Severity

Both healthy and caries groups generally agree that SSB cause caries and that they will increase their chance of caries; caries subjects reported greater awareness of caries risk ($P=0.04$). Interestingly, both groups are relatively unafraid of getting caries from sweet drinks. This is depicted in Figure 4 below.
Subjects with severe caries exhibited more addictive traits such as increased attempts to reduce consumption ($P<0.01$). This reflects diagnostic criteria #4 for substance dependence which reads: There is a persistent desire or unsuccessful effort to cut down or control substance use. Figure 5 below depicts the adolescents’ agreement with the statement “I try to cut down or stop drinking it” on a continuous rating scale.
Adolescents with caries did not differ from adolescents without caries on other diagnostic signs of addiction: withdrawal, bingeing, giving up other activities and spending much time and effort to obtain.

Comparing Subjects Based on Sugar Exposure

Although some trends were seen examining adolescents by caries status, these groups were largely similar, especially with respect to SSB consumption patterns and SSB variety. We also examined adolescents by grouping them by how much they were drinking. As aforementioned we called this variable “sugar exposure.” When examining the adolescents in this manner we discovered many more differences among groups with regard to consumption patterns, regardless of caries status. Adolescents in the highest sugar exposure group were more likely than those in the lowest exposure group to drink Kool-Aid (P<0.01) and Energy Drinks (P = 0.02). Those in the moderate exposure group
were more likely than low to drink Kool-Aid (P<0.01) and Sweet Tea (P<0.01). Those in the high exposure were more likely to drink Flavored milk than those in the moderate exposure group (P=0.01)

Adolescents in the high exposure group were more likely than those in the low exposure group to consume SSB at the following times: As soon as they woke up, between breakfast and lunch, at lunch, between lunch and dinner, at dinner, after dinner at bedtime, and during the night (P≤0.01). They were also more likely to drink SSB when watching TV, hanging out with friends, doing homework, and being at school (P≤0.01).

Likability among Sugar Exposure

Higher sugar exposure was associated with liking SSB (P<0.01) and disliking water (P<0.04). Sugar-free beverages were disliked by all groups, but there were no statistically significant differences among the groups (P=0.19). These data are represented in Figure 6.

Figure 6. Likability among sugar exposure
Risk Perception among Sugar Exposure

There were no differences in caries risk perception among sugar exposure groups.

Addiction among Sugar Exposure

Figure 7 and Figure 8 depict measures of addiction among caries severity. Adolescents who were consuming the most SSB reported that it would be relatively harder for them to reduce consumption (P=0.04 vs. low & moderate) and that they do not care to cut down (P=0.02 vs. low and moderate). Figure 8 demonstrates that withdrawal is associated with higher sugar exposure (P=0.01).

![Figure 7. Persistent desire or efforts to reduce consumption among sugar exposure](image-url)
Behavioral, Emotional, and Social Problems among Adolescents

Perhaps the most interesting results of this pilot study lie in the analysis of the YSR data. When we reviewed scores on the eight empirically derived syndrome scales and the 3 higher order scales we found that our population of adolescents was different from the normal population. For almost all scales, our sample population was approximately one-half standard deviation or more from the normal mean. When we compared groups on caries severity, there were no differences among the groups. However, when we analyzed the adolescents based on sugar exposure, virtually all T-score means for the adolescents in the high exposure group were higher in magnitude when compared to both the moderate and low exposure groups. Table 7 demonstrates the T-Score means and standard deviations for all scales by sugar exposure, and also shows our total sample means. Only the “Anxious/Depressed” mean failed to attain traditional standards of statistical significance. The high exposure group T-score means for all of the
scales ranged from 57.8 to 61.9 and were all approximately one standard deviation from the normal population mean of 50.

<table>
<thead>
<tr>
<th>Syndrome Scales</th>
<th>Sugar Exposure Groups</th>
<th>Low x (sd)</th>
<th>Moderate x (sd)</th>
<th>High x (sd)</th>
<th>Total x (sd)</th>
<th>P value for Raw score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anxious/Depressed</td>
<td></td>
<td>55.2 (7.3)</td>
<td>54.8 (7.5)</td>
<td>57.8 (6.2)</td>
<td>55.6 (7.2)</td>
<td>0.1</td>
</tr>
<tr>
<td>Withdrawn/Depressed</td>
<td></td>
<td>55.3 (7.1)</td>
<td>56.4 (9.0)</td>
<td>62.4 (9.6)</td>
<td>57.5 (9.0)</td>
<td>0.002</td>
</tr>
<tr>
<td>Somatic Complaints</td>
<td></td>
<td>54.6 (7.0)</td>
<td>55.5 (6.7)</td>
<td>59.4 (6.6)</td>
<td>56.2 (6.9)</td>
<td>0.02</td>
</tr>
<tr>
<td>Social Problems</td>
<td></td>
<td>55.0 (7.5)</td>
<td>54.3 (5.0)</td>
<td>61.3 (9.0)</td>
<td>56.1 (7.3)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Thought Problems</td>
<td></td>
<td>55.4 (6.5)</td>
<td>55.3 (6.8)</td>
<td>59.7 (7.6)</td>
<td>56.4 (7.1)</td>
<td>0.02</td>
</tr>
<tr>
<td>Attention Problems</td>
<td></td>
<td>54.4 (4.9)</td>
<td>55.6 (7.7)</td>
<td>61.9 (11.0)</td>
<td>56.8 (8.5)</td>
<td>0.002</td>
</tr>
<tr>
<td>Rule-Breaking Behavior</td>
<td></td>
<td>54.0 (5.1)</td>
<td>52.6 (3.9)</td>
<td>58.3 (6.5)</td>
<td>54.4 (5.4)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Aggressive Behavior</td>
<td></td>
<td>53.7 (6.4)</td>
<td>53.3 (5.2)</td>
<td>59.6 (7.8)</td>
<td>54.9 (6.7)</td>
<td>0.0002</td>
</tr>
<tr>
<td>Higher Order Scales</td>
<td>Internalizing Problems</td>
<td>50.8 (11.8)</td>
<td>52.1 (10.5)</td>
<td>59.7 (9.0)</td>
<td>53.5 (11.0)</td>
<td>&lt;0.006</td>
</tr>
<tr>
<td></td>
<td>Externalizing Problems</td>
<td>49.8 (9.1)</td>
<td>48.0 (8.6)</td>
<td>58.0 (10.0)</td>
<td>50.9 (9.8)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Total Problems</td>
<td>50.0 (11.3)</td>
<td>50.8 (9.7)</td>
<td>60.9 (10.1)</td>
<td>52.9 (11.1)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Table 7: T-score means for YSR scales

Figure 9 depicts T-score means for the higher order YSR scales by exposure group. Cut offs are shown in the figure for normal range (T-score: 50-59), borderline range (T-score 60-63) and clinical range (T-score >63). The high exposure group T-scores means including 95% confidence intervals span the borderline and clinical range, and are significantly higher than T-score means for the low and moderate groups.
For all scales, there were a higher percentage of adolescents testing in the borderline and clinical range in the high exposure group, than in the low and moderate groups. Figure 10 shows 61.54% of subjects in the high sugar exposure group had internalizing problems, 50% had externalizing problems, and 65.38% had total problems. This is compared to only 25% in the low and 23.08% in the moderate having internalizing problems, 17.86% in the low and 7.69% in the moderate having externalizing problems, and 17.86% in the low and 21.15% in the moderate having total problems.
Figure 10: Percentage of subjects with borderline or clinical range problems
Chapter 4: Discussion

Our pilot study sought to better understand consumption patterns of adolescents. We did not find any significant differences in consumption among sex and race, which is inconsistent with published studies reporting that Blacks and males are the highest consumers of SSB. This is likely due to our small sample size and the fact that the population we recruited from is typically of low SES, and low SES is associated with high SSB consumption.

Our sample population of adolescents drank an average 42.1 oz. per day with a standard deviation of 47.2 oz. There was a single outlier subject that drank 420 oz. per day, so we found it meaningful to report the median value was 32 oz. Our sample population seems to consume slightly less SSB than that the average 46.1 oz. that was reported from 24-hour diet recalls from NHANES data. We also discovered that adolescents with caries were not all that different from adolescents without caries, in terms of the types of beverages they drank and for measures of frequency, amount, and time spent drinking SSB. As aforementioned the carious process is multifactorial and since fluoride has become pervasive, published studies have found it more difficult to make a linear association between sugar consumption and caries. Nevertheless, we have reason to believe that adolescents were under-reporting the amount they were drinking for several reasons. If we remove the single outlier that drank 420 oz. per day, the average ounces drank per day for our sample population was only 38.6 oz., far below the
average obtained from 24-hour diet recalls in the NHANES study of 46.1 oz.

Furthermore, when we administered the interview portion of the survey, and verbally walked subjects through a typical day asking whether or not they drank SSB at defined time points (ie. as soon as I wake up, at breakfast, between breakfast and lunch, at lunch, between lunch and dinner, etc.), we elicited different numbers. If we assume that for each of these time points selected, a subject drank a new SSB, then we begin to develop a different picture. Adolescents, especially those with the most severe caries, reported higher consumption numbers when asked in this manner. This is not unexpected as self-reports for food and nutrition surveys almost always have some level of under-reporting due to recall bias and self-report bias. Recall bias maintains this it is unlikely that a person would be able to precisely recall how much of a certain beverage they have consumed during a past period of time. Self-report bias refers to the fact that subjects tend to under-report behaviors deemed inappropriate and over-report behaviors viewed as appropriate. Poslusna et al reviewed the nature and determinants of misreporting in dietary assessment and concluded that the percentage of under-reporters was about 30% and energy intake was underestimated by approximately 15%. 37 This is concerning because the self-report is still very much used in nutrition and food science research. In our study adolescents were asked about SSB consumption in an environment that condemns this behavior, likely after they have been informed of having many cavities. For future studies, it may be prudent to use a different method for obtaining diet information and collect the data in a more neutral environment. A newer method used to ensure accurate and valid results for nutrition studies is the USDA Automated Multiple-Pass Method (AMPM). The AMPM is a computerized method for collecting interview-
administered 24-hour dietary recalls. It employs 5 steps to enhance accurate recall. The USDA five-step multiple pass method has been found to be more accurate than the food frequency questionnaires.38

We discovered that adolescents with caries liked sugar-sweetened beverages more than healthy subjects, though this was not statistically significant. Moreover, adolescents in the high sugar exposure group significantly liked SSB more than those in the low and moderate exposure groups (P<0.01). This may be reflective of hereditary differences between subjects and/or repeated exposure to and experience with sweet foods.

We found that adolescents were relatively knowledgeable about the caries-causing potential of SSB, but they seemed to be unaware or in denial of their own susceptibility. This was evidenced by their high agreement with statements that SSB cause cavities and that their chance of cavities may increase by drinking SSB, yet disagreement with the statement that they are afraid of getting cavities. This seems very typical of the adolescent attitude. Previous studies have shown that adolescents with high caries risk are often unaware of their own caries risk, despite being knowledgeable about factors that contribute to caries.39 Subjects with caries were found to be more aware of caries risk and were relatively more afraid of getting caries. From this we deduce that adolescents are well aware of the link between SSB and caries, yet they still engage in the detrimental behaviors (ie. consumption of SSB) that lead to caries. Education and knowledge is not enough to change behaviors. On the other hand, adolescents with caries may superficially be more aware of caries risk of SSB, because they likely have just been told they have caries at their dental appointment.
Subjects with severe caries exhibited more addictive traits such as increased attempts to reduce consumption ($P<0.01$), but they did not demonstrate any other diagnostic signs of addiction tested by our survey such as withdrawal, binging, and spending much time and effort to obtain. Additionally, subjects in the highest consumption group reported that it would be relatively harder for them to reduce consumption ($P=0.04$), and they did not make any attempts to cut down ($P=0.02$). This is the opposite response we expected, but may be due to the fact SSB consumption does not carry with it the same stigma of other substances of abuse, even food. One could argue that eating a box of doughnuts would be perceived less favorably than guzzling a 32 oz Slurpee. In turn, this may represent the honest and problematic attitude of adolescents who are consuming the most SSB: They like the way it tastes; it would be hard to cut down; and they have no intention to stop. Once again, our results with the caries group reporting more attempts to reduce consumption may be biased by the fact that this group has likely been told they have cavities, and has been counseled on dietary habits by dental providers. The high exposure group also reported that drinking SSB relatively helps to relieve anxiety ($P=0.01$), a sign of withdrawal. One limitation of our study is that we did not control for caffeine content, mainly because we found that adolescents were unable to tell us whether the beverages they drank were caffeine-free or not. Thus, it is possible that any addictive-like behaviors may be linked to caffeine content in the SSB.

Perhaps the most interesting and troublesome findings of this study lie in the YSR analysis. Regardless of their caries status, the group of adolescents who consumed the most SSB were also afflicted with the most psychopathology, specifically behavioral, emotional, and social problems. This was reflected by significant higher T scores when
compared to low and moderate exposure groups on almost all of the problem scales. Furthermore, a large percentage of adolescents with T-scores in the borderline clinical- and clinical-ranges were found in the high sugar exposure group. This is not the first time that behavioral problems have been associated with SSB consumption. As already mentioned, high consumption levels of SSB were found to be associated with hyperactivity, mental distress and conduct problems in adolescents. However, the issue maybe more pervasive then we think. It is impossible to distinguish whether excessive consumption of SSB through various pathways is causing the psychopathology, or whether this group of adolescents is using sugar as a means to cope with these problems. We have already explained the euphoric properties of sugar, specifically its ability to reduce pain, mediate depression, and alleviate stress, thus it is not irrational to assume that adolescents maybe self-medicating in this way. Moreover, the adolescents who suffer from these psychosocial problems are probably less equipped to make health-conscious decisions surrounding SSB consumption and are more apt to engage in unhealthy behaviors overall. Counseling adolescents to reduce consumption of SSB may not be as simple as it seems. The cause of this behavior may be rooted or at least connected to more pervasive psychosocial issues. Further psychological and behavioral research is needed in this area.

In order to develop more effective strategies to reduce sugar-sweetened beverage consumption by adolescents and to decrease their caries risk, we need to gain a better understanding of the factors that motivate them to drink SSB and also those that make it difficult to change consumption behaviors. Through this pilot study we came to better understand how adolescents think about SSB. Because few subjects reported drinking
sugar-free beverages, it seems they have minimal experience with them. This may be a potential market that we can explore, encouraging adolescents to make the switch from sugar to sugar-free. Similar to nicotine gum for smokers, we may be able to find a middle ground for excessive consumers of SSB. We need to be able to work with adolescents possibly through motivational interviewing, rather than expecting them to cease a habit just because dentists tell them it is causing caries. We also need to be attentive to the other psychosocial issues that adolescents are struggling with and how they may relate to SSB consumption.
References


