Sugar Sweetened Beverage Consumption and dmft Score in Children Five-years-old and Younger

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Abstract

The purpose of this study was to examine the relationship between sugar sweetened beverage (SSB) consumption and caries in children 0-5 years old. An 11-item questionnaire was developed from Virginia Polytechnic Institute and State University, and administered to the parent or caregiver at the time of the child's dental appointment. Questions included items on the frequency and quantity of SSB and non-SSB beverage consumption over the past week. Two additional questions were added to evaluate the mode of drinking, and supervision of the child. A total of 33 subjects were included in the study. A higher caries rate was observed among two-year-olds compared to the older children, a group that drank more sugary beverages than other cohorts. Children that drank from sippy cups and bottles had higher rates of caries than those that drank from regular cups. In addition, children under the care of a non-parent family member had the highest caries prevalence, while those in daycare had the lowest caries prevalence. Overall, a higher proportion, volume, and frequency in SSB consumption resulted in higher caries presence and dmft score. Children under the care of a family member and used sippy cups also correlated with a higher dmft score.

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1. Introduction

In the United States, dental caries is the most common chronic condition in childhood.[1] Total dental caries among children aged two to 19-year-olds is 45.8 percent.[2] Caries prevalence increases with age, from 21.4 percent among two to five-years-old to 50.5 percent among those ages six to 11 and to 53.8 percent among those ages 12-19.[3] This demonstrates that caries is a chronic, cumulative, and lifelong disease.[4] The costs associated with caries in young children include pain and potential infection.[5] Additionally, there are direct monetary costs - for those who have received dental treatment, the average expense was over 250 dollars for US children aged two to five-years-old and increases to over 440 dollars for US children aged six to 11-years-old.[6]

Caries is often thought of as a multifactorial multilevel disease, with biological, behavioral and social causes including oral hygiene, fluoride exposure, access to dental care, bottle feeding, and intake of food or beverages that are high in sugars and carbohydrates.[7] Additive sugars, especially in SSBs, is one of the primary causes of dental caries in children in the US.[8] However, the specific dietary *causal* factor of caries incidence is sucrose and its individual monosaccharide constituents: glucose and fructose (altogether known as “sugars”).[9] Sugars initiate the caries process and set off a causal chain; the only factor that determines the caries process in practice is sugars.[10] Sugars promote biochemical and physiological changes during biofilm formation which in turn enhance its caries-inducing properties.[11] After sugars are consumed, the pH in biofilms falls rapidly from neutrality to pH 5.0 or below due to acid production by acidogenic and acid-tolerant bacteria. This includes numerous bacteria species such as mutans streptococci, lactobacilli, and bifidobacteria which lead to demineralization of the tooth structure.[12]

To emphasize this point, studies of low-income countries shows that dental caries was uncommon before populations began to consume refined sugars.[13] As a point of comparison, sugar consumption in developed countries is 40-60kg / year:[14]

- *In Nigeria*, where consumption of sugars is limited to 2 g/day, only 2% of the urban and rural population of any age had dental caries
- *In Iraq*, dental caries prevalence *halved* when sanctions reduced sugars from 50kg/year to 12kg/year five years later
- *In Tristan de Cunhans*, only 2% of children 13- to 19-year old children and 7% of those aged 30 to 39 years old were affected by caries. This rate subsequently increased to 17.5% caries incidence rate for children by the 1960s, when sugar intake had risen from 1.8g/day to 50g/day
- *In Japan* during World War II, per capita sugar levels decreased from 15kg/year to 0.2kg/year, then increased again to 15kg/year over a 11 year period. There was a clear relationship between average sugars intake level and dental caries specified which had progress to cavitation

2. Background

2.1 Sugar Sweetened Beverage and Caries

Consumption of sugary beverages is usually the main driver of caries in high-risk populations. One measurement of caries prevalence in children is the Significant Caries Index (SiC index). This sorts each person according to dmft by selecting one-third of children with the highest caries values, and calculating the mean dmft of the group to minimize effects of skewed distributions.[15] In Taiwan, with a SiC index of 6.3 (compared to 3.6 for the United States, 4.1 for Germany, and 4.1 for France), at least one-third of children consumed at least one SSB per day, which was found as a key risk indicator for dental caries among preschool children.[16] This is despite the Taiwanese National Health Insurance offering free fluoride varnish every six

months for children under six years of age.[17] Another high-risk population is American Indian children in the United States - caries is nearly universal by age 36 months, with a prevalence of 80% (and an additional 15% having non cavitated lesions), with a mean dmft of 9.6 and nearly 62% of affected surfaces decayed.[18] Within this population, a study of children aged 4, 8, 12, 16, 22, 28, and 36 months of age found that caries risk factors included higher added-sugar beverage consumption, household size, and some maternal factors.[19]

One longitudinal study of children during infancy and later at six-years-old found that the consumption of SSBs during 10-12 months of age significantly increased the likelihood of having dental caries among six-year-olds.[20] This demonstrates that the frequency of SSB intake during infancy and age of SSB introduction was associated with dental caries.[21] Thus, late infancy may be an important time for parents to establish healthy beverage practices for their children.

SSB consumption among the pediatric population is at an all-time high, and many health effects have been studied related to an increased consumption of SSBs. Several studies related to SSB and adolescents have been examined, but there is limited data on the younger pediatric population especially in children 5 years old and younger.[2223] This study aims to examine the relationship between SSB consumption behaviors and caries in children 0-5 years of age via survey data and clinical exam (dmft). A valid, reliable, and rapid dietary assessment tool will be used to survey caregivers of children 0-5 years old.[24] In addition, data will be collected to evaluate the mode of drinking, and under whose supervision.

3. Methods and Materials

3.1 Subjects, Study Design, Data Collection

This research study was approved by the Institutional Review Board of the University of California, San Francisco (UCSF). The study took place at two pediatric dental clinics at UCSF – one at UCSF Benioff Children's Hospital and the second at the UCSF Dental Center. These

clinics were chosen as they were both accessible by the observer. The subjects included in the study were patients ranging from zero to five years old that presented to the dental clinic for periodic oral evaluations, caries risk assessment, or comprehensive oral evaluations. These patients solely presented for examinations, prophylaxis, and radiographs.

The study surveyed the beverage consumption habits of patients to assess its impact on caries risk. Questionnaire items were drawn from an existing survey instrument that was validated by Virginia Polytechnic Institute and State University and included 21 different types of beverages. 12 beverage items were removed from the questionnaire since they were not related to children consumption (e.g. “beer, ales, and wine coolers”).[25] The instrument included a total of nine beverages (water, fruit juice, sweetened juice, milk, flavored milk, infant formula, regular soft drinks, diet soft drinks, sports and energy drinks) that were most commonly consumed by children.[26] The instrument asked which beverage item subjects consumed in the past seven days. For each beverage, survey respondents were asked to mark how often the beverage was consumed (e.g. 1 time per week, 3+ times per day) to determine the frequency. Respondents were also asked to mark the approximate amount of beverage the child consumed each time (e.g. less than 6 fl oz). Two additional questions were added – the first asked the mode of beverage consumption (bottle, sippy cup, cup, other) and the second asked about child supervision (parent, family member, caretaker, daycare).

Questionnaires were completed by parents or legal guardians of the subjects and were required to be able to speak and read in English. Only subjects who were considered ASA I were included in the study; patients who had a significant medical history and/or were taking medications were not included.

All questionnaires were administered by a single individual – a pediatric dental resident. Parents were approached at the time of the dental appointment at either dental clinic from November 2018 to March 2019. The resident provided a brief overview of the study in order for the parent to accept or decline participation in the study, although none of the parents elected to

decline participation. Informed consent was obtained. Questionnaires were administered on paper. A total of 35 parents agreed to take part in the study, although two were excluded as they did not fill out the survey to completion. No incentives were given to participate in this study.

For purposes of this study, the following were considered SSB: fruit juice, sweetened juice, flavored milk, and soft drinks. The following were *not* considered SSB: water, milk, infant formula, diet soft drinks. In cases where consumption frequency was given as a range, the mid-point of the range was assumed (e.g. “2-3 times per week” was converted to “2.5 times per week”). At the upper end of the range, an additional half-drink was assumed (e.g. “3+ per day” was converted to “3.5 times per day”). Total volume of drinks was computed by multiplying the frequency of consumption by the volume of consumption.

3.2 Data Analysis

Once the patient was treated by clinicians at UCSF, the electronic records were accessed to determine how many teeth were decayed, missing, or filled, as well as total number of teeth. This was combined with the survey data into a database, which was then analyzed using SAS, Python, and Excel software. Caries risk models were developed using probit regressions based on presence or absence of caries. The dmft score was calculated by added the decayed, missing, and filled counts. Counts of dmft were modeled using negative binomial regressions. A 5% significance level was used for all analyses.

Subject ID: _____

Date: _____

Beverage Questionnaire

Instructions: In the past week, please indicate your response for each beverage type by marking an "X" in the box for "how often" and "how much each time"

1) Indicate how often your child drank the following beverages, for example, you drank 5 glasses of water per week, therefore mark 4-6 time per week.
2) Indicate the approximate amount of beverage your child drank each time, for example, you drank 1 cup of water 2 times per day, therefore mark 1 cup under "how much each time"

	HOW OFTEN (MARK ONE)							HOW MUCH EACH TIME (MARK ONE)			
Type of Beverage	Never or less than 1 time per week	1 time per week	2-3 times per week	4-6 times per week	1 time per day	2+ times per day	3+ times per day	Less than 6 fl oz (3/4 cup)	8 fl oz (1 cup)	12 fl oz (1 ½ cups)	More than 20 fl oz (2 ½ cups)
Water											
100% Fruit Juice (ex: *apple, orange*)											
Sweetened Juice (ex: *lemonade, punch, Sunny Delight*)											
Milk											
Flavored Milk (ex: *chocolate, strawberry*)											
Infant Formula											
Soft Drinks, Regular (ex: Coke, Sprite)											
Diet Soft Drinks, Artificially Sweetened (ex: *Diet Coke, Crystal Light)*											
Sports and Energy Drinks (ex: *Gatorade, Powerade, Vitamin water*)											

1. How does your child usually consume these beverages? Please circle one answer.
    a. Bottle
    b. Sippy cup
    c. Cup
    d. None of the above
2. Under who's supervision does your child spend the majority of their time during the week?
    a. Parent and/or Guardian (primary caretaker)
    b. Family member (grandparents, aunt)
    c. Caretaker (not a family member, nanny, babysitter)
    d. Daycare, Pre-school

Figure 3.1 – Beverage Questionnaire used in this study

4. Results

4.1 Characteristics

Of the total 35 subjects enrolled in the study, 33 with completed surveys were included in the analysis. Figure 2 presents the dental exam and survey results characteristics of these 33 subjects. For the exam portion, the caries prevalence among children was 52% overall, The 2-year-old age group included 8 subjects with a caries prevalence of 62% – the highest compared to all other age groups. 3-year-olds had a total of 14 subjects in the study, and a caries prevalence of 42%. 4-years-olds and older had 9 subjects with a caries prevalence of 27%. For the survey results, the patients that drank from sippy cups (70%) and bottles (50%) had higher rates of caries than those that drank from cups (42%). This aligned with rates at which sugary beverages were consumed. Notably, all patients under the care of a non-parent family member had an incidence of caries (100% - compared to 56% under the care of a parent), while those in daycare had the lowest caries prevalence (31%).

Table 4.1 - Summary Statistics from Exam and Survey Results

	Total		Exam results			Survey results		
Characteristics	**N**	**%**	**% caries**	**dmft**	**# teeth**	**SSB (oz/wk)**	**non-SSB (oz/wk)**	**% SSB**
Age	**33**	**100%**	**52%**	**3.5**	**18.4**	**56.7**	**210.7**	**16%**
<2 yrs	2	6%	-	-	5.5	68.3	122.5	27%
2 years old	8	24%	63%	3.9	17.6	155.7	207.3	33%
3 years old	14	42%	50%	3.8	19.6	25.6	187.9	11%
4+ years old	9	27%	56%	3.7	20.0	14.7	268.6	6%
Gender	**33**	**100%**	**52%**	**3.5**	**18.4**	**56.7**	**210.7**	**16%**
Male	15	45%	47%	4.0	18.1	59.5	248.3	14%
Female	18	55%	56%	3.2	18.7	54.4	179.3	18%
Consumption Vehicle	**33**	**100%**	**52%**	**3.5**	**18.4**	**56.7**	**210.7**	**16%**
Bottle	4	12%	50%	4.5	18.5	0.8	343.0	0%
Sippy cup	10	30%	70%	5.7	17.9	117.2	161.3	24%
Cup	19	58%	42%	2.2	18.6	36.7	208.8	15%
Supervision	**33**	**100%**	**52%**	**3.5**	**18.4**	**56.7**	**210.7**	**16%**
Family member	4	12%	100%	8.5	18.5	124.1	306.5	27%
Parent	16	48%	56%	4.0	19.6	28.7	201.5	12%
Daycare	13	39%	31%	1.5	16.8	70.5	192.4	17%

Table 4.1 presents the rates of caries prevalence and dmft scores by beverage consumption type, including SSB portion of total beverages, total volume of SSB, and total volume of SSB as a proportion of total beverage consumption. In almost all cases, increased consumption in SSB resulted in higher caries prevalence and generally higher dmft scores.

Table 4.2 demonstrates the percentage of caries and dmft increased as the percentage of SSB drinks consumed increased to 60-80%. Caries and dmft increased from 43% to 100% and 3.7 to 4.0, respectively.

Table 4.2 - Summary Statistics from Exam by SSB consumption

	Total		Exam results	
Behavior	**N**	**%**	**% caries**	**dmft**
SSB as % of drinks	**33**	**100%**	**52%**	**3.5**
No SSB	7	21%	43%	3.7
0-20%	17	52%	47%	3.2
20-40%	4	12%	50%	2.5
40-60%	3	9%	67%	6.3
60-80%	2	6%	100%	4.0
SSB as % of volume	**33**	100%	**52%**	**3.5**
No SSB	7	21%	43%	3.7
0-20%	18	55%	44%	3.0
20-40%	3	9%	67%	3.3
40-60%	3	9%	67%	3.7
60-80%	2	6%	100%	8.0
SSB by volume	**33**	100%	**52%**	**3.5**
No SSB	7	21%	43%	3.7
0-10 oz/wk	4	12%	50%	4.3
10-20 oz/wk	10	30%	50%	2.7
20-50 oz/wk	5	15%	40%	2.4
50-100 oz/wk	3	9%	67%	3.3
100+ oz/wk	4	12%	75%	6.3

Table 4.3 presents caries prevalence by demographic factors (age, number of teeth) as well as select survey results (including sugar beverage frequency and volume). While none of the factors are significant under a univariate regression, the group with caries drank more sugary beverages in both frequency and volume.

Table 4.3 - Caries Prevalence for Selected Demographic and Survey Risk Factors

Variable	n	mean	SD	p-value
Age (months)				
No caries	16	40.0	14.8	0.7504
Has caries	17	42.3	11.9	
Gender (% female)				
No caries	16	50%	52%	0.638
Has caries	17	59%	51%	
Number of teeth				
No caries	16	17.5	5.1	0.663
Has caries	17	19.2	1.4	
Frequency of SSB (times per week)				
No caries	16	5.9	7.6	0.3699
Has caries	17	9.7	13.3	
Frequency of SSB as % of total times beverage consumed				
No caries	16	13%	13%	0.2603
Has caries	17	22%	22%	
Volume of SSB (oz per week)				
No caries	16	27.9	37.4	0.2373
Has caries	17	83.9	149.3	
Volume of SSB as % of total beverages consumed				
No caries	16	12%	13%	0.3356
Has caries	17	20%	22%	

Table 4.4 presents results of a univariate dmft model for each independent demographic factor (age, number of teeth) as well as selected behavioral variables (including sugar beverage frequency and volume). It shows that children with more total number of teeth had significantly higher dmft, and those who attended day care had significantly lower dmft at the 5% significance level

Table 4.4 - Univariate Negative Binomial Regression of the Factors Associated with dmft

Parameter	Coef	95% CI		p-value
Age (months)	1.0005	0.9714	1.0305	0.973
Total teeth	1.1696	1.0050	1.3607	0.042**
Female versus male	0.7917	0.3646	1.7194	0.555
Consumption type				
Bottle	1.3182	0.4131	4.2038	0.641
Sippy cup	2.1850	0.9560	4.9928	0.064
Cup	0.4126	0.1879	0.9066	0.027
Supervision				
Family member	2.9698	0.9704	9.0884	0.057
Parent	1.2830	0.5921	2.7815	0.528
Daycare	0.2983	0.1269	0.7005	0.005**
Sugary beverages				
Frequency	1.0143	0.9792	1.0502	0.425
% of incidences	1.8904	0.2334	15.3176	0.551
Volume	1.0020	0.9990	1.0050	0.237
% of volumes	1.9190	0.2355	15.6426	0.543

* coefficients are exponentiated allowing for direct interpretation based on dmfs
** denotes statistically significant result at the 5% level of significance

A multivariable negative model was fitted to assess the effects of demographics and behavioral variables on dmft score. Table 4.5 shows that after controlling for other variables, children who attended daycare had significantly lower dmft score (p=0.006) and children who used sippy cup had marginally significantly higher dmft score (p=0.052).

Table 4.5 - Multivariate Negative Binomial Regression of the Factors Associated with dmft

Parameter	Coef	95% CI		p-value
Age (months)	1.0269	0.9695	1.0876	0.366
Total teeth	1.1441	0.8504	1.5388	0.373
Female versus male	1.4670	0.5769	3.7322	0.421
Consumption type				
Bottle	0.4225	0.0934	1.9117	0.77
Sippy cup	1.0334	0.3000	3.5573	0.052
Cup	0.4024	0.1214	1.3351	0.612
Supervision				
Family member	1.9035	0.5412	6.6993	0.316
Parent	0.6216	0.1705	2.2660	0.471
Daycare	0.1485	0.0382	0.5769	0.006
Sugary beverages				
Volume	1.0037	0.9990	1.0080	0.137

* coefficients are exponentiated allowing for direct interpretation based on dmft
** denotes statistically significant result at the 5% level of significance

5. Discussion

This study found that 52% of children had cavitated (dmft) caries, which is more than double the national average of 21.4% of youths aged two to five.[27] This finding of high prevalence of caries in young U.S. children is interesting, but not very surprising given that the sample was selected from children receiving care from a clinic serving low-income families, with care being provided by students in a teaching environment, and a small sample size.

In almost all cases, higher SSB consumption rates were correlated with higher caries risk and dmft scores. While there appeared to be higher rates of caries and dmft for children who primarily used sippy cups, (even after controlling for age), this also corresponded to an increase in SSB consumption. Similarly, in a self-report study, parents reported that diluted fruit juice was the most frequently used liquid in the sippy cup in children aged one to four-years-old.[28] This supports our finding that use of sippy cups correlates with an increase in SSB consumption. It is beneficial to educate parents on effects of prolonged exposure to sugary and acidic drinks with a sippy cup.

Children under the care of family members or parents also exhibited higher rates of caries prevalence; it is not clear what the causal factor here may be. Children in daycare exhibited the lowest dmft score (dmft=1.5), followed by parent's supervision (dmft=4.0), and family members with the highest dmft (dmft=8.5). It may be that children in families with higher socioeconomic status are more likely to place their children in daycare and also to be more cognizant of oral hygiene. The finding that family member supervision has the highest caries prevalence seems consistent from interactions with parents in clinic. From personal interactions with parents after discussing that their young child has caries, most parents name family members (e.g. grandparents, uncle, aunt) as the responsible person(s) for high sugar consumption.

However, few of these factors were deemed statistically significant, which was potentially due to limitations in sample size. Age was not a significant factor for this population as 93% were between the ages of 2 and 4 and experienced comparable caries prevalence. None of the SSB factors were statistically significant at the 5% level in the models. The use of a daycare as the primary child caretaker was shown to reduce the likelihood of caries risk. This may be due to improved education within the daycare system, but also may be due to other factors not captured in this study including socioeconomic status.

One of the main limitations of this study is convenience sampling along with reporting and response bias. This study was regional, self-selected, and exclusive to English-speaking population which is not representative of the general population as a whole. Parents and caregivers may have experienced reporting bias, due to social desirability. Especially in a dental setting, where a high intake of sugars is generally disapproved, parents may have felt uncomfortable or reluctant selecting SSBs in the survey. After taking the survey, some parents felt like they had to justify why their child consumed an SSB (e.g. special event, birthday party, dinner outing) which emphasizes that parents may have felt regretful in their answers.

Overall, while there are mixed results for some of the ancillary drivers, there does seem to be support - although in some cases non conclusive - that sugary beverages result in caries. The population with caries had 3x the sugary beverage exposure as the group that did not, and in some cases over half of beverage consumption was from SSB. This highlights the importance of proper education of patients – not only of the risk incurred with SSB but also as a reminder that this extends to all potential caretakers, including family members. This is particularly important in this group of children with caries risk double the national average.

Due to the fact that higher consumption of SSBs is associated with higher caries prevalence, it is crucial that health care providers educate parents and patients on the importance of limiting SSBs. Initiatives in restricting the intake of SSBs have been taking place, including policies in schools, alongside with the state, and national levels.[29] Educating parents

on the associated health risks of type 2 diabetes, hypertension, obesity, and coronary heart disease as a result of high SSB consumption is of high importance. Not only will a reduction in SSB consumption benefit health outcomes, but it can also result in a projected medical cost savings of up to $320-620 million in one year alone.[30] In addition, taxes on SSB have effectively reduced SSB consumption.[31] In Berkeley, California, a one penny per ounce SSB excise tax was put into effect on January 2015. As the nation's first large SSB tax, it has shown to be effective with results including an overall decline in SSB sales and an increase in untaxed beverages (especially water).[32] Advocating for policy change, such as taxes on SSBs, along with dental and health professionals helping to identify problematic sugar-related behaviors can ultimately reduce sugar intake, dental caries, and improve overall health in the pediatric population.[33]

6. Conclusion

Based upon the study's results, the following conclusions can be made:

1. Children with increased consumption in SSB resulted in higher caries prevalence and generally higher dmft scores.
2. Children under the supervision of a family member had the highest dmft score, followed by parent and daycare.
3. Children drinking with a sippy cup resulted in a higher dmft score, followed by cup and bottle.

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