



Association of Sugar-Sweetened Beverage Intake during Infancy with Dental Caries in 6-year-olds

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To examine whether sugar-sweetened beverage (SSB) intake during infancy is associated with dental caries by age 6, a longitudinal analysis of 1,274 U.S. children was conducted using data from the 2005–2007 Infant Feeding Practices Study II and the 2012 Follow-up Study at 6 years of age. The exposure variables were maternal-reported SSB intakes during infancy (i.e., any SSB intake during infancy, age at SSB introduction during infancy, and average frequency of SSB intake during 10–12 months of age). The outcome variable was maternal-reported dental caries of their 6-year-old in his/her lifetime. Multivariable logistic regression analyses were used to calculate adjusted odds ratios (aOR) for associations of SSB intake during infancy with having dental caries among 6-year-olds after controlling for baseline characteristics of children and mothers and child's tooth brushing habits and sweet food intake at follow-up. Based on maternal recall, almost 40% of 6-year-olds had dental caries in their lifetime. Adjusted odds of having dental caries was significantly associated with higher frequency of SSB intake during 10–12 months (aOR=1.83 for ≥ 3 times/week, vs. none). Any SSB intake during infancy and age at SSB introduction during infancy were not associated with dental caries. In conclusion, frequent SSB intake during 10–12 months of age significantly increased the likelihood of having dental caries among 6-year-olds. Late infancy may be an important time for mothers to establish healthy beverage practices for their children. These findings can be used to inform efforts to reduce dental caries among children.

Key Words: Sugar-sweetened beverages, Dental caries, Child, Infancy, Public health, Longitudinal studies

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Introduction

Having good oral health is vital to the overall health of all children [1]. Dental caries is one of the most common chronic diseases in childhood [1], and the prevalence of dental caries is high among U.S. children [2,3]. In 2005–2008, among U.S. children aged 5–11 years 20.4% had untreated dental caries and 38.7% had treated dental caries (i.e., dental restoration) [3]. According to the 2009 Medical Expenditure Panel Survey, the annual mean dental expense among individuals with any dental expense was \$257.93 for U.S. children aged 2–5 years and \$443.63 for children aged 6–11 years [4]. Furthermore, poor oral health is significantly associated with poor school performance [5]. Additionally, reducing “the proportion of children and adolescents who have dental caries experience in their primary or permanent teeth” is one of the Healthy People 2020 Objectives [6].

Dental caries is multifactorial disease and several factors have been associated with dental caries, including oral hygiene [7], fluoride exposure [8], access to dental care [9,10], bottle feeding [7,11,12], and intake of foods or beverages that are high in sugars and carbohydrates [13,14]. Sugar-sweetened beverages (SSBs) are defined as "liquids that are sweetened with various forms of sugars that add calories. These beverages include, but are not limited to, soda, fruit ades and fruit drinks, and sports and energy drinks" based on the 2010 Dietary Guidelines for Americans [15]. Although the consumption of SSBs among U.S. children and adolescents has decreased recently, SSB intake remains high among U.S. youth [16]. Infants are sometimes fed SSBs during the first year of their life. For example, according to the Feeding Infants and Toddlers Study (FITS) in 2008, 10.7% of U.S. infants aged 9–11.9 months and 14.3% of children aged 12–14.9 months consumed SSBs on a given day [17]. Based on the 2009–2010 National Health and Nutrition Examination Survey (NHANES) data, 4.5% of daily energy intake (or 69 kcal/day) came from SSBs among U.S. children aged 2–5 years and 6.3% of daily energy intake (or 118 kcal/day) came from SSBs among children aged 6–11 years [18]. In addition to dental caries [19–25], youth SSB intake has been linked to obesity [26–28], asthma [29], poor dietary quality [30, 31], and low academic performance [32].

Previous studies examined the associations between SSB intake and dental caries in children using cross-sectional data [19–21] or longitudinal data [22–25]. However, these longitudinal studies had relatively short follow-up periods [22,24], small sample sizes [24,25], included low-income children only [22, 24], and/or were limited in one specific geographic area [22–25]. The present study examined whether SSB intake during infancy predicts dental caries in child' lifetime among 6-year-olds by linking the data from the largest longitudinal study of infant feeding practices across the United States to its follow-up study conducted when children were 6 years old.

Materials and Methods

Study design and survey administration

The Food and Drug Administration (FDA) and Centers for Disease Control and Prevention conducted the Infant Feeding Practice Study (IFPS) II in 2005–2007 and a Year 6 Follow-Up (Y6FU) survey in 2012. IFPS II was a nationwide longitudinal study that tracked the mothers of infants from late pregnancy throughout the first year of life. IFPS II was conducted among

a sample of pregnant women from a consumer opinion mail panel of about half a million households. Sequences of 11 survey questionnaires were sent to pregnant women during the last trimester of pregnancy and at about months 1, 2, 3, 4, 5, 6, 7, 9, 10 and 12 after the child's birth. In depth information on this survey administration and data collection can be found elsewhere [33]. For Y6FU survey conducted in 2012, 48% of children who participated in IFPS II were lost to follow-up at 6 years old [34]. The Y6FU survey collected data on dietary intake, physical activity, behavioral outcomes, and health conditions of children. Both the IFPS II and Y6FU survey were approved by the FDA Institutional Review Board. Because we used de-identified data for this secondary analysis, it was deemed exempt by the CDC Institutional Review Board.

Outcome variable

The main outcome variable was dental caries in a child's lifetime from Y6FU survey. Parents/caregivers (mainly mothers) were asked "How many dental cavities (teeth with decay) has your 6-year-old had in his or her lifetime?" Response options ranged from zero to ≥ 6 dental caries, and we dichotomized into no (0 dental caries) or yes (≥ 1 dental caries) based on data distribution.

Exposure variables

The exposure variables were obtained from 10 postpartum surveys throughout infancy on intake of SSBs. In each survey of IFPS II administered almost monthly, mothers were asked "In the past 7 days, how often was your baby fed sweet drinks: juice drinks, soft drinks, soda, sweet tea, Kool-Aid, etc.?" Mothers described either the number of times per day or per week their infant was fed the item or responded zero when their baby was not fed SSBs. Weekly intake was converted to daily intake by dividing weekly intake by 7. Because some mothers completed the questionnaire after several days or weeks of receiving it, SSB data were analyzed based on the age of infants when the questionnaire was finished. Even though covariates had fairly small proportion of missing data (ranges 0%–4.6%), there was a relatively large proportion of SSB intake data missing throughout the infancy (ranges 10%–27% for each postpartum survey). We imputed values for the exposure variables and covariates based on their non-missing values and other relevant non-missing variables for children with at least one SSB data point available during the 1st and 2nd half year of infancy. Detailed information on this multiple

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imputation methodology is available in a previous study [35]. In brief, we used the Amelia II package in R to perform 25 imputations [36, 37]. Because of the longitudinal nature of the survey data during infancy, with SSB consumption assessed 10 times, these survey data were treated as a time series for each child.

For SSB consumption during infancy, we estimated any SSB intake during infancy (no or yes), age at SSB introduction during infancy (never, ≥ 6 months, or < 6 months), and average frequency of SSB intake during 10–12 months after birth (no SSB, < 1 , 1 to < 3 , or ≥ 3 times/week). SSB consumption during infancy was classified as 'yes' if the mother reported any intake of SSBs by the child during the 1–7, 9, 10 and 12-month surveys, and classified as 'no' if no SSB consumption was reported in all 10 surveys. Given that the age of introduction to SSBs was not specifically reported, we appraised the age at introduction to SSBs by computing the midpoint between the age of the infant when SSBs were first reported and the age of the infant on the prior questionnaire in which the mother did not specify that her infant was fed any SSBs. Afterwards, we generated a categorical variable using 6 months as a cutoff for age at SSB introduction during infancy. For average frequency of SSB consumption during 10–12 months, we calculated a mean of the SSB consumption at 10 and at 12 months. The average frequency of SSB intake during 10–12 months of age was 2.4 times as frequent as that during 1–9 months of age (2.74 times/week vs 1.14 times/week) among children who drank SSBs. Therefore, the dose-response relationship focused on SSB intake during 10–12 months of age. Response categories were mutually exclusive.

Covariates

Both child and maternal characteristics at the baseline study (IFPS II) were included as covariates. Child characteristics included sex, birth weight (≤ 4000 or > 4000 grams), and breastfeeding duration (< 6 or ≥ 6 months). Maternal characteristics included age (18–24, 25–29, 30–34, or ≥ 35 years), prepregnancy weight status (underweight and normal weight, body mass index (BMI) < 25 kg/m²; overweight, BMI 25– < 30 kg/m²; and obese, BMI ≥ 30 kg/m²) based on self-reported weight and height data collected during the last trimester, race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, or other), education level (\leq high school, some college, or college graduate), marital status (married or not married), income-to-poverty level (< 185 , 185–349, or $\geq 350\%$) [33] and parity (pri-

miparous or multiparous) collected during prenatal period. Not married was defined as widowed, divorced, separated, or never married. Additional covariates included child's tooth brushing status (never/a few times a week, 1 time/day, or ≥ 2 times/day) and sweet food intake (e.g., candy, cookies, cake, doughnuts, muffins, and pop-tarts) during the past month (0 or > 0 times/day) at the follow-up study at age 6 years (Y6FU). Sweet food intake was assessed using a single question.

Statistical analysis

We used chi-square tests to explore the unadjusted bivariable association between dental caries and child and parental characteristics, and a p value of < 0.05 was considered statistically significant. We used logistic regression models to estimate unadjusted odds ratio (OR) and 95% confidence interval (CI) for examining the associations of having dental caries and any SSB intake during infancy. We used multivariable logistic regression models to estimate adjusted OR and 95% CI after controlling for all covariates described beforehand. Any SSB intake during infancy, age at SSB introduction, and average frequency of SSB intake during 10–12 months of age were modeled independently.

Of those 1,542 children who participated in both IFPS II and Y6FU survey, we excluded 16 children because they were greater than 13 months of age when they participated in the last survey of IFPS II, 78 children with missing data on the outcome variable (i.e., dental caries in child's lifetime), and 174 children who did not have any SSB intake information throughout all the postpartum surveys, resulting in a final analytic sample of 1,274 children. All statistical analyses were performed using R and SAS callable SUDAAN software version 9.3 (SAS Institute, Cary, NC, USA) and accounted for multiple imputation.

Results

Table 1 illustrates characteristics of the study sample for all respondents and by dental caries. About 38% of 6-year-olds had at least one dental caries in their lifetime. Characteristics significantly associated with dental caries were maternal education, maternal income-to-poverty level at baseline and the child's tooth brushing status at the follow-up ($p < 0.05$ based on χ^2 tests). Explicitly, the proportion of 6-year-olds having dental caries was the highest among children whose mothers were less educated or had lower incomes and children who

Table 1. Respondents' characteristics at baseline and follow-up and the prevalence of dental caries in child's lifetime among 6-year-old children by characteristics, Infant Feeding Practices Study II, 2005–2007 and Year 6 Follow-Up Study, 2012 (n = 1,274)

Characteristic	Total	Dental caries in child's lifetime among 6-year-old children		p value*
	n (%) [†]	No % [†]	Yes % [†]	
Total	1274 (100)	61.7	38.3	
<i>Characteristic at Baseline</i>				
Child's sex				0.76
Boys	638 (50.1)	62.1	37.9	
Girls	636 (50.0)	61.3	38.7	
Child's birth weight				0.92
≤ 4,000 grams	1111 (87.2)	61.7	38.3	
> 4,000 grams	163 (12.8)	61.4	38.7	
Breastfeeding duration				0.94
< 6 mons	623 (48.9)	61.6	38.4	
≥ 6 mons	651 (51.1)	61.8	38.2	
Maternal age				0.44
18–24 yrs	176 (13.8)	59.6	40.4	
25–29 yrs	408 (32.1)	64.9	35.1	
30–34 yrs	416 (32.7)	60.3	39.7	
≥ 35 yrs	273 (21.4)	60.4	39.6	
Maternal race/ethnicity				0.60
White, non-Hispanic	1114 (87.4)	61.7	38.3	
Black, non-Hispanic	44 (3.5)	65.0	35.0	
Hispanic	63 (5.0)	65.6	34.4	
Other, non-Hispanic	53 (4.2)	53.8	46.2	
Maternal education				0.002
≤ High school	209 (16.4)	55.0	45.0	
Some college	445 (35.0)	58.0	42.0	
College graduate	620 (48.7)	66.6	33.4	
Marital status				0.20
Married	1080 (84.8)	62.5	37.5	
Not married	194 (15.2)	57.4	42.6	
Income-to-poverty level				0.02
< 185%	422 (33.1)	57.8	42.2	
185–349%	486 (38.2)	60.9	39.1	
≥ 350%	366 (28.7)	67.2	32.8	
Prepregnancy weight status				0.10
Underweight or normal weight (< 25.0 kg/m ²)	621 (48.8)	59.7	40.3	
Overweight (25–< 30 kg/m ²)	329 (25.8)	66.6	33.4	
Obese (≥ 30 kg/m ²)	324 (25.4)	60.5	39.5	

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Table 1. Continued

Characteristic	Total	Dental caries in child's lifetime among 6-year-old children		p value*
	n (%) [†]	No % [†]	Yes % [†]	
Parity				0.19
Primiparous	373 (29.3)	64.5	35.5	
Multiparous	901 (70.7)	60.5	39.5	
<i>Characteristic at Follow-Up</i>				
Tooth brushing at 6 years old				0.02
Never/a few times a week	83 (6.5)	48.2	51.8	
1 time/day	427 (33.5)	60.4	39.6	
≥ 2 times/day	764 (60.0)	63.9	36.1	
Sweet food intake during the past month [‡] (n = 1269)				0.76
0 times/day	782 (61.6)	62.5	37.5	
> 0 times/day	487 (38.4)	61.6	38.4	

* χ^2 test was used for each variable to examine differences across categories, $p < 0.05$; [†]Sample distribution, percentages may not add up to 100% because of rounding; [‡]Sweet foods included candy, cookies, cake, doughnuts, muffins, and pop-tarts.

Table 2. Associations between sugar-sweetened beverage (SSB) intake during infancy and dental caries in child's lifetime among 6-year-old children, Infant Feeding Practices Study II, 2005–2007 and Year 6 Follow-Up Study, 2012 (n = 1,274)

SSB Intake during infancy [†]	Total	Dental caries in child's lifetime among 6-year-old children		p value*
	n (%) [†]	No % [†]	Yes % [†]	
SSB intake during infancy				0.14
No SSBs	932 (73.1)	63.1	36.9	
Any SSBs	342 (26.9)	57.8	42.2	
Age at SSB introduction during infancy				0.28
Never consumed SSBs during infancy	932 (73.1)	63.1	36.9	
SSB introduction at or after 6 months	231 (18.2)	59.4	40.6	
SSB introduction before 6 months	111 (8.7)	54.4	45.6	
Average frequency of SSB intake during 10–12 months of age				0.04
No SSBs	1,046 (82.1)	63.0	37.0	
< 1 time/week	60 (4.7)	58.7	41.4	
1–< 3 times/week	81 (6.3)	63.7	36.3	
≥ 3 times/week	87 (6.8)	45.9	54.1	

* χ^2 test was used for each variable to examine differences across categories, $p < 0.05$; [†]SSBs during infancy includes juice drinks, soft drinks, soda, sweet tea, Kool-Aid, and others; [‡]Sample distribution, percentages may not add up to 100% because of rounding.

never or seldom brushed their teeth.

Unadjusted associations between SSB intake during infancy

and dental caries are shown in Table 2. Having dental caries

was significantly associated with average frequency of SSB

Table 3. The associations of sugar-sweetened beverage (SSB) intake during infancy with dental caries in child's lifetime among 6-year-old children, Infant Feeding Practices Study II, 2005–2007 and Year 6 Follow-Up Study, 2012

SSB Intake during infancy [†]	Having dental caries in child's lifetime among 6-year-old children	
	n = 1,274	n = 1,269*
	Unadjusted OR (95% CI)	Adjusted OR (95% CI) [‡]
SSB intake during infancy		
No SSBs	Reference	Reference
Any SSBs	1.25 (0.93, 1.68)	1.14 (0.82, 1.57)
Age at SSB introduction during infancy		
Never consumed SSBs during infancy	Reference	Reference
SSB introduction at or after 6 months	1.17 (0.84, 1.63)	1.07 (0.76, 1.52)
SSB introduction before 6 months	1.43 (0.89, 2.31)	1.29 (0.77, 2.17)
Average frequency of SSB intake during 10–12 months of age		
No SSBs	Reference	Reference
< 1 time/week	1.20 (0.65, 2.21)	1.15 (0.61, 2.18)
1–< 3 times/week	0.97 (0.57, 1.65)	0.85 (0.48, 1.49)
≥ 3 times/week	2.01[§] (1.27, 3.18)	1.83[§] (1.14, 2.92)

*Sample size was reduced because of missing data on sweet food intake at follow-up (n = 5); †SSBs during infancy includes juice drinks, soft drinks, soda, sweet tea, Kool-Aid, and others; ‡Three variables on SSB intake during infancy were modeled independently and models adjusted for child's sex, child's birth weight, breastfeeding duration, maternal age, maternal race/ethnicity, maternal education, marital status, income-to-poverty ratio, prepregnancy BMI, and parity at baseline and tooth brushing and sweet food intake at follow-up; §Significant findings are bolded and based on the 95% CI (i.e. the CI does not include 1).

intake during at 10–12 months of age ($p = 0.04$ for χ^2 tests), but not with any SSB intake during infancy or age at SSB introduction during infancy. The proportion of children with at least one dental caries by 6 years of age was highest among children who were fed SSBs ≥ 3 times/week at 10–12 months of age (54.1%) (Table 2).

According to the logistic regression models, both the unadjusted odds ratio and adjusted odds ratio of having dental caries in child's lifetime were greater among children with average frequency intake of SSBs ≥ 3 times/week at 10–12 months of age compared to children with no SSB intake during this time [unadjusted OR=2.01 (95% CI = 1.27, 3.18) and adjusted OR=1.83 (95% CI = 1.14, 2.92)]. Additionally, odds of having dental caries in child's lifetime did not differ by SSBs during infancy and age at SSB introduction during infancy (Table 3).

Discussion

Our findings showed that 38.3% of children had dental caries by age 6 based on maternal reports. A previous study reported that the prevalence of dental caries in primary teeth was 27.9% in children aged 2–5 years based on NHANES 1999–2004 [2], which is the most recent published data available

in this age group. Similar to previous studies [2,3,19], we also found higher prevalence of dental caries among children who had mothers with lower education, those living in low-income household, and those with infrequent tooth brushing than their counterparts.

Furthermore, our findings showed that higher average frequency of SSB intake during 10–12 months of age was a predictor for dental caries in a child's lifetime among 6-year-olds. Compared to children who were never fed SSBs during 10–12 months of age, children with average frequency intake of SSBs ≥ 3 times/week during 10–12 months of age had 83% higher odds for having dental caries by age 6 after adjusting for covariates included in this study. Infants who consumed SSBs more frequently during 10–12 months of age may increase their odds for having dental caries by age 6. SSB is a vehicle for sugars. Current evidence does not show a simple causal relationship between exposure to sugars, including SSB and dental caries [13,38]. However, when sugars are metabolized by certain cariogenic oral bacteria in dental plaque, acid is produced which can begin to dissolve the enamel of the tooth surface [13,38,39]. It is possible that children who were fed SSBs more frequently during 10–12 months of age may be more likely to consume SSB later in their life. Longer dura-

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tion and higher frequency of SSB consumption could increase the availability of sugars for cariogenic oral bacteria [22]. Park and colleagues reported that the odds for daily SSB intake at 6 years increased with higher average frequency of SSB intake during 10–12 months of age [40]. Based on a sensitivity analysis, findings remained the same after further controlling for SSB intake at age 6 in the present study. In other words, SSB intake during infancy was independently associated with dental caries regardless of SSB intake at year 6.

Somewhat similar to our findings, a previous study reported that the odds of having dental caries at the 18-month follow-up was higher among SSB consumers at baseline among 212 low-income children aged 6–24 months of age [24]. Another longitudinal study reported that the incidence rate for dental caries was 75% higher among 369 African-American children aged 3–5 years who had low soft drink intake at baseline but high SSB intake at 2 years follow-up compared to those who had low SSB intake at both baseline and follow-up periods [41].

Of note, in our study, any consumption of SSBs during infancy or timing of SSB introduction during infancy did not play a significant role in terms of increasing risk for dental caries among 6-year-olds. Potential reasons why we did not observe the association with early infancy is that very few mothers fed SSBs during this time and most infants do not have teeth during early infancy. However, this null finding does not mean that early infancy is not an important time to limit SSB intake among infants.

When making decisions about feeding their children SSBs, parents should consider numerous adverse health consequences related to SSB intake including obesity [26–28] and dental caries among children [19–25]. Parents play an essential role in developing a child's dietary behaviors and infancy is an important time to start healthy dietary habits [42]. Given that only 37.3% of children aged 2–5 years and 55.0% of children aged 6–11 years had at least one dental visit in 2009, improving dental visits for children may offer an opportunity to increase counseling and education about adverse consequences associated with consuming SSBs and to motivate parents to remove or reduce SSB from child's diet [4]. However, a previous study reported that only 23% of parents reported ever receiving counseling from a child's physician to limit their child's SSB consumption in 2009 [43]. A previous study suggested that dentists and other health care providers could provide counseling to parents to limit their child's SSB [44]. Additionally, dentists and health care providers can counsel to encourage oral hygiene (e.g., brushing teeth) [7] and appropriate use

of fluoride toothpaste [45]. Our finding that brushing teeth ≥ 1 time per day was associated with lower caries prevalence may reflect the use of fluoride toothpaste. Brushing with fluoride toothpaste is an effective intervention for caries prevention [45]. Strategies to assure that young children receive the benefits of fluoride toothpaste while decreasing risk of fluorosis have been recommended [45–47].

IFPS II is the largest longitudinal study of infant feeding practices in the United States that collected SSB intake almost monthly throughout infancy. Nevertheless, there are several limitations in our study. First, the survey was conducted in a convenience sample with a higher proportion of non-Hispanic white mothers and mothers with higher education level, so it may limit generalizability of our findings. Compared to those who participated in the Y6FU survey, those who did not participate in the follow-up survey had significantly higher proportion of mothers aged 18–24 years, mothers who were not married, those who had high school or less education, those with income-to-poverty level $<185\%$ [34]. Because other reports have documented a higher prevalence of SSB intake and dental caries among non-whites and those with lower education level [3,18,19,48], it is possible that SSB intake and dental caries may be even more serious problem in certain subpopulations than reported in the present study. Second, in the absence of objective measures, the validity of maternal responses to survey questions on SSB and dental caries is unknown. Third, we were not able to quantify the association by the volume of SSB intake, because SSB intake was measured in frequency rather than volume. Fourth, we could not fully adjust for other potential risk factors for dental caries, such as fluoride exposure and use of other preventive dental care. Finally, although we imputed missing data by using multiple imputation methodology to reduce possible biases, the residual bias may still remain.

Conclusion

Almost 2 in 5 children in our study sample had dental caries by 6 years of age. Frequent consumption of SSB during 10–12 months of age increased the odds of having dental caries in their lifetime 83%. Our results suggest that infancy may be an important time for mothers to begin healthy beverage habits for their children.

Disclaimer

The findings and conclusions in this report are those of the

authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Conflict of Interests

No conflict interests were declared by any of the authors.

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