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Dietary intake and severe early childhood caries in low-income, young children

E. Whitney Evans, MS, RD¹, Catherine Hayes, DMD, Dr.Med.Sc.², Carole A. Palmer, EdD, RD^{1,3}, Odilia I. Bermudez, PhD⁴, Steven A. Cohen, DrPH^{4,5}, and Aviva Must, PhD⁴

¹Tufts University Friedman School of Nutrition Science and Policy, 150 Harrison Ave, Boston, MA 02111

²Health Resources in Action 95 Berkeley Street, Boston, MA 02116

³Tufts University School of Dental Medicine, 1 Kneeland Street Boston, MA 02111

⁴Tufts University School of Medicine, 136 Harrison Ave, Boston, MA 02111

⁵Virginia Commonwealth University School of Medicine 830 E. Main St Richmond, VA 23298

Abstract

Evidence suggests that risk for early childhood caries (ECC), the most common chronic infectious disease in childhood, is increased by specific eating behaviors. To identify if consumption of added sugars, sugar-sweetened beverages (SSB), and 100% fruit juice, as well as eating frequency, are associated with severe-ECC (S-ECC), cross-sectional data collected from a sample of low-income, racially diverse children, ages two to six years old, were used. Four-hundred and fifty-four children with S-ECC and 429 caries-free children were recruited in 2004-2008 from three pediatric dental clinics in Columbus, OH, Cincinnati, OH and Washington, D.C. Dietary data were obtained from one parent-completed 24-hour recall and an interviewer-administered food frequency questionnaire (FFQ). Multivariate logistic regression analyses were conducted to assess associations between S-ECC and dietary variables. On average, children with S-ECC consumed 3.2-4.8 fluid ounces more SSB (24HR: 1.80 versus 1.17; $p < .001$; FFQ: 0.82 versus 0.39; $p < .001$) and reported significantly more daily eating occasions (5.26 versus 4.72; $p < .0001$) than caries-free children. After controlling for age, sex, race/ethnicity, maternal education, recruitment site and family size, children with the highest SSB intake were 2.0 to 4.6 times more likely to have S-ECC as compared with those with the lowest intake, depending on dietary assessment method (24HR: OR 2.02; 95% CI: 1.33, 3.06; FFQ: OR 4.63; 95% CI: 2.86, 7.49). The relationship between eating frequency and S-ECC status was no longer significant in multivariate analyses. Specific dietary guidance for parents of young children, particularly regarding SSB consumption, could help reduce S-ECC prevalence.

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Corresponding Author: E. Whitney Evans MS, RD, Tufts University Friedman School of Nutrition Science and Policy, 136 Harrison Avenue, Boston, MA 02111, (t) 617-636-3852 (f) 617-636-4017, whitney.evans@tufts.edu.

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Keywords

Diet; Sugar-sweetened Beverages; Early Childhood Caries; Eating Frequency; Cariogenicity

Introduction

Early Childhood Caries (ECC), defined by the Academy of American Pediatric Dentists as the presence of one or more decayed, missing (due to caries), or filled tooth surfaces in any primary tooth in a child under the age of six years, is the most common chronic infectious disease in childhood^{1, 2}. Approximately 33% of children ages two to five years old in the United States have ECC, and recent estimates show that prevalence has increased, particularly in low socioeconomic status families where prevention and treatment services are often deficient³⁻⁶. Estimates suggest that 30% of children below the poverty line have untreated decay as compared to only 6% of children at or greater than 300% of the poverty line⁷. Untreated caries are associated with pain and can lead to problems with speech, sleeping, and eating in children⁸. Severe-ECC (S-ECC) is defined as having one or more Decayed (non-cavitated or cavitated lesions), Missing (due to caries), or Filled smooth surfaces (DMF) in the primary teeth for children younger than three years of age or having four, five or six or more DMF in the primary teeth of children three, four and five years of age, respectively². Children with S-ECC are more likely to suffer from malnourishment, specifically low weight-for-height and iron deficiency anemia⁹.

Both ECC and S-ECC are entirely preventable diseases, which result from the interaction of susceptible, newly erupted dentition, bacterial plaque, and dietary components¹⁰. Considerable evidence suggests that dietary sugars are needed to initiate caries development; however, this relationship is complicated by food-related factors, eating frequency, variations in oral microflora and fluoride use¹¹⁻¹³. Evidence from the 2005-2008 National Health and Nutrition Examination Survey (NHANES) suggests that children ages two to five years old consume approximately 50 grams of added sugars per day¹⁴. Given the large amount of added sugar in the diets of young children, as well as evidence that added sugars may be more cariogenic than natural sugars^{15, 16}, both added sugar in foods and sugar-sweetened beverages (SSB) have been implicated in caries development¹⁷⁻¹⁹.

One-hundred percent fruit juice has also been associated with caries, but the relationship is less clear. Data from children ages two to ten years old who participated in NHANES III suggest that children who consume 17 or more ounces of 100% juice are more likely to have caries than those who are high water or milk consumers²⁰. Conversely, in a cohort of low-income African American children, 100% fruit juice was found to be protective of caries¹⁸. Given that 100% fruit juice contains about the same amount of sugar as the average SSB¹⁷, it is important to understand its role in caries. Finally, eating frequency, particularly constant grazing or sipping of foods and beverages, is also caries promoting^{11, 12, 21}. In a recent study in a diverse sample of children ages two to six years old, eating frequency was associated with S-ECC²¹.

Although many studies have examined how dietary intake behaviors affect caries risk in older preschool-age children (ages 3.5 and older), studies in young children from low-

income, racially diverse families are few¹³. The Effect of Severe Early Childhood Caries (S-ECC) and Comprehensive Dental Intervention on Weight of Children Study, was a multi-center, cohort study designed to examine the impact of S-ECC on weight in low-income children ages two to six years old²². The availability of standardized dental examinations and dietary assessments in this large sample of young children with and without S-ECC provided the opportunity for this cross-sectional, secondary data analysis. The aim of this study was to examine the association between specific dietary intake behaviors, namely consumption of added sugars, SSB, and 100% fruit juice, as well as eating frequency, and the presence of S-ECC in a diverse sample of low-income, young children. It was hypothesized that intake of added sugar, sugar-sweetened beverages, and fruit juice would be positively associated with S-ECC, and that children with S-ECC would have a higher eating frequency compared to caries-free children.

Methods

Selection of Participants

From 2004-2008, children with and without S-ECC were recruited from pediatric dental clinics at Children's National Medical Center (Washington, D.C.), Columbus Children's Hospital (Columbus, OH), and Cincinnati Children's Hospital (Cincinnati, OH). This study was undertaken prior to the use of a widely accepted definition of ECC. Therefore, investigators established criteria for S-ECC as the presence of three or more smooth surface carious lesions, including at least one pulpally-involved tooth, in which the carious lesion has spread into the pulp or nerve-center of the tooth. A total of 454 children, age two to six years old, who met the definition of S-ECC and had full primary dentition, no previous invasive dental procedures, and non-contributory medical history (disease diagnosis with known oral impact) were enrolled in the study. As a comparison group, 429 children without caries or white-spot lesions (a precursor of caries) were also enrolled. Given that this was a secondary data analysis and data were fully de-identified, this study was deemed exempt by the Tufts University Health Sciences Campus Institutional Review under federal regulation 45 CFR §46.101(b)²³.

Oral Health Assessment

Prior to enrollment, all potential participants received a comprehensive oral evaluation conducted by a licensed dentist as part of routine care. Clinical data obtained from this standard exam allowed for identification of children for the S-ECC and caries-free groups. The dentists were not calibrated across study sites; however, caries were diagnosed using standard criteria, equipment (light, air, explorer) and radiographs. After enrollment into the study, primary caregivers of participants completed a brief socio-demographic questionnaire, which included questions on their child's race/ethnicity, age, family income, family size, maternal education, and insurance type.

Dietary Assessment

Dietary intake was assessed using two standard dietary assessment methods: one 24-hour diet recall and the Block 2004 Kids' Food Frequency Questionnaire (FFQ) (NutritionQuest, Berkeley, CA)²⁴. Trained and certified interviewers collected a 24-hour diet recall from each

participant's primary caregiver using the multiple-pass method of the University of Minnesota Nutrition Data System for Research (NDSR) (Versions 2005-2007, Nutrition Coordinating Center, Minneapolis, MN). To determine the consumption of added sugars from all foods and beverages, added sugars reported in the Food File were summed (NDSR output file 2). To determine consumption of SSB, in eight fluid ounce servings per day, subgroup category serving counts of sweetened soft drinks, sweetened fruit drinks, sweetened tea and coffee, sweetened coffee substitutes, sweetened water, and nondairy-based sweetened meal replacements were summed using the Serving Count Food File (NDSR output file 7). Consumption of 100% fruit juice, in four fluid ounce servings, was determined by summing subgroup category serving counts of citrus juice and fruit juice excluding citrus. Finally, eating frequency, a count of all self-reported eating occasions, was determined from the Serving Count Meal File (NDSR output file 8).

The 81-item Block Kids' FFQ, which was also administered to the child's primary caregiver, captures usual intake over the prior six months²⁴. The FFQ data were analyzed to generate average daily intakes for added sugars from all foods and beverages, sugar-sweetened beverages, and 100% fruit juice. Standard portion sizes provided in the Block output differed from those in the NDSR output, so conversions were made to allow for comparison across dietary assessment methodologies. Specifically, Block provides average consumption of grams of sugary beverages, cup equivalents (eight fluid ounce) of 100% fruit juice, and grams of added sugar. To convert grams of sugary beverages to eight fluid ounce servings, 2004-2005 NHANES data was used to identify the most commonly consumed sugar-sweetened beverages and an average gram weight was created from those beverages (249g per eight fluid ounce serving).

Statistical Analysis

All statistical analyses were conducted using Statistical Analysis Software (version 9.2, 2008, SAS Institute, Cary, NC), with statistical significance set at an alpha level of $p < 0.05$. To determine if specific dietary intake behaviors differed between those with and without S-ECC, two-sample t-tests as well as multivariate logistic regression analyses were conducted. In addition to the inclusion of recruitment site, for all multivariate analyses, we assessed the need to control for potential confounding variables including age, sex, race/ethnicity, maternal education, family size, and insurance type. Given that the literature suggests that the number of caries is due to the frequency of sugar consumption^{21, 25}, using data from the 24-hour dietary recalls, we present additional multivariate models that control for the total number of eating occasions. We also evaluated how eating frequency differed in the two groups, controlling for sociodemographic factors as appropriate.

Results & Discussion

A total of 808 children completed an FFQ and 24-hour recall at the enrollment visit (381 children with S-ECC and 427 caries-free children). Children with S-ECC were statistically significantly more likely to be older (4.32 years versus 3.77 years, $p < 0.0001$), male (54% versus 44.5%, $p < 0.0001$), non-Hispanic white (59.7% versus 21.8%, $p < 0.0001$), and have larger family size (4.5 people versus 4.0 people, $p < 0.0001$). Caries-free children were statistically significantly more likely to have a mother who graduated from college (14.5%

versus 6.0%, $p<0.0001$). Eighty-percent of all participants received Medicaid insurance. The racial distribution in this study is related to the fact that the Columbus, OH site, which serves children who were predominantly low income, non-Hispanic Whites, contributed numerous S-ECC cases, while the Washington, D.C. site contributed considerably more non-Hispanic Black, caries-free children.

Table 1 displays the dietary intake patterns for SSB, added sugars, and 100% fruit juice between children with and without S-ECC for each dietary assessment method. On average, children with S-ECC consumed 3.2 to 4.8 additional fluid ounces of SSB per day, depending on dietary assessment method, as compared with caries-free children ($p<0.0001$). Children with S-ECC also consumed significantly more added sugars from food and beverages as compared to caries-free children (24HR: 66.07 grams versus 58.44 grams; $p=0.04$; FFQ: 61.08 grams versus 43.56 grams; $p<0.0001$). There were no significant differences in consumption of 100% fruit juice using either dietary assessment method.

Separate logistic regression models were run for each dietary intake behavior and dietary assessment method (Table 2). Overall, the results show that, after controlling for age, sex, race/ethnicity, maternal education, recruitment site and family size, each additional serving of SSB was associated with a 14% and 139% increased odds of having S-ECC based on the 24-hour recall and FFQ, respectively. Similarly, when children were grouped by tertiles of SSB intake, children in the third tertile were 2.0 to 4.6 times more likely to have S-ECC as compared to those in the first tertile for the 24-hour recall and FFQ, respectively (Table 3). Intake of 100% fruit juice did not differ between those with and without S-ECC based on either dietary assessment method.

These findings are consistent with those from studies in other pediatric populations, which have shown that SSB, soda in particular, are associated with caries and caries development^{19, 21}, while consumption of 100% fruit juice either has little effect on caries experience or may be protective^{17, 18}. The present finding that children who consume 5oz of SSB per day are up to 4.6 times more likely to have S-ECC as compared to those who consume 1oz or less per day highlights the need for early dietary intervention in young children from low-income families. While SSB and 100% fruit juice may have similar absolute amounts of sugar, SSB likely have greater cariogenic potential because they are very acidic, which can lead to demineralization of tooth enamel and caries formation²⁶.

Whereas the relationship between caries-status and grams of added sugars was statistically significant using data from the FFQ, it was not significant using the 24-hour recall data. The FFQ results suggest that for every 1 gram increase in added sugar intake, odds of having S-ECC increases by 2%. This finding is consistent with a previous observational study in young Brazilian children, which showed that odds for ECC were greater in those with higher total sugar exposure²⁷. The fact that the findings between the 24-hour recall and FFQ were inconsistent may be due to the fact that using only one 24-hour recall to estimate added sugar intake may not reflect usual or long-term intake, while the FFQ estimates long-term, relative intake.

Finally, although it was hypothesized that eating frequency would be associated with S-ECC in this cohort, only the univariate analysis showed that children with S-ECC had a statistically significant additional 0.5 eating occasions per day (5.26 occasions versus 4.72 occasions; $p < .0001$). Unlike previous research, after controlling for age, sex, race/ethnicity, maternal education, recruitment site and family size, the multivariate analysis suggested no meaningful statistical or clinical relationship between eating frequency and (OR: 1.01; 95% CI: 0.89, 1.14)^{21, 25}. Findings from the Iowa Fluoride Study, a study of 634 primarily non-Hispanic white children, suggest that those with higher daily total eating events had increased caries risk ($p < 0.05$)²⁵. This discrepancy may be due to differences in sample demographics or to dietary assessment methods used in this study. The Iowa study was longitudinal and relied on multiple years of three-day diet records, which provide a better estimate of usual dietary intake patterns than a single 24-hour recall.

The primary strengths of this study are the large sample of young children from low-income, racially diverse families and the use of two different dietary assessment methods, the 24-hour recall and FFQ. Use of a single 24-hour recall is a limitation of this analysis. For the other dietary intake behaviors, using data from the Block FFQ, which addresses usual intake over the past six months, helped to address this limitation. Another limitation of this study is that in obtaining dietary assessments from parents, they can be accurate only to the extent that parents are with their children throughout the day. It is possible that the observed differences in mean intakes between the 24-hour recall and FFQ may be subject to some social desirability bias in that parents report a healthier diet over the long term, but may not do so for a single day's recall²⁸. Further, the data used in this study are five to nine years old; however, the increased prevalence of SSB in children's diets would not change the nature of the association. Instead, it emphasizes the public health implications of these findings. Additionally, given that this was a secondary data analysis, no information on the presence of specific bacterial plaque was available, which has been shown to play a significant role in caries development²¹. Finally, the cross-sectional nature of this study does not exclude the possibility of reverse causation: it is possible that the presence of S-ECC may have altered patterns of dietary intake.

Conclusions

Given the strong and often publicized relationship between SSB consumption and childhood obesity risk, SSB intake in young children is a public health concern. This analysis shows that SSB and added sugars from both foods and beverages play a significant role in S-ECC in young children from low-income racially diverse families. Given the substantial and immediate consequences of untreated caries, specific dietary guidance on consumption of added sugars and SSB in the context of their role in both caries and childhood obesity risk may be effective. Specifically, given these findings, counseling low-income parents with young children on consumption of added sugars from foods and SSB is needed to reduce the prevalence of S-ECC, an entirely preventable disease. Future prospective studies are needed in low-income, very young children to better understand how these dietary intake behaviors contribute to caries development while controlling for oral microflora.

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Table 1
Dietary intake in children with severe early childhood caries (S-ECC) and caries-free children

Dietary Assessment Method	Dietary Intake	S-ECC (n=381)	Caries-Free (n=427)	p-value ^a
		←-----	-----→	
Mean (SD)				
24-Hour Recall	100% Fruit Juice ^b	0.94 (0.79)	1.07 (0.95)	0.08
FFQ ^c	100% Fruit Juice ^b	1.59 (1.42)	1.67 (1.38)	0.45
24-Hour Recall	Sugar-sweetened beverages ^d	1.80 (2.21)	1.17 (1.66)	<.0001
FFQ ^b	Sugar-sweetened beverages ^d	0.82 (0.87)	0.39 (0.49)	<.0001
24-Hour Recall	Added Sugar (g/day)	66.07 (45.48)	58.44 (50.07)	0.04
FFQ ^b	Added Sugar (g/day)	61.08 (34.28)	43.56 (23.52)	<.0001
24-Hour recall	Eating Frequency	5.26 (1.64)	4.72 (1.59)	<.0001

^a p-value from a two-sided t-test

^b 100% Fruit Juice: 4 fluid ounce serving

^c Block 2004 Kid's Food Frequency Questionnaire (FFQ)

^d Sugar-sweetened beverages: 8 fluid ounce serving

Table 2
Dietary intake logistic regression analysis for young children with severe early childhood caries (S-ECC) versus caries-free children^a

Dietary Assessment Method	Dietary Intake	Odds Ratio ^b	95% CI	Ratio ^c	95% CI
24-hour Recall	100% Fruit Juice	0.92	[0.81, 1.04]	0.92	[0.81, 1.04]
FFQ ^d	100% Fruit Juice	0.96	[0.85, 1.09]		
24-hour Recall	Sugar-sweetened beverages	1.14	[1.03, 1.25]	1.14	[1.03, 1.25]
FFQ ^d	Sugar-sweetened beverages	2.39	[1.71, 3.34]		
24-hour Recall	Added Sugar (g)	1.00	[0.99, 1.00]	1.00	[0.99, 1.00]
FFQ ^d	Added Sugar (g)	1.02	[1.01, 1.03]		
24-hour Recall	Eating Occasions	1.01	[0.89, 1.14]		

^a Separate models were used for each dietary intake exposure
^b Controlling for age, sex, race/ethnicity, maternal education, recruitment site, family size
^c Controlling for age, sex, race/ethnicity, maternal education, recruitment site, family size and eating frequency
^d Block 2004 Kid's Food Frequency Questionnaire (FFQ)

Table 3

Odds of having severe early childhood caries by tertiles of sugar-sweetened beverage intake in low-income, pre-school age children.

Dietary Assessment Method	Tertile (n=)	SSB Intake (number of 8 fluid Oz servings/day)	Tertile Comparison	Odds Ratio ^a [95% CI]	p-value for trend
2004 Block Kid's Food Frequency Questionnaire	1 (n=246)	0 Servings < 0.16	Reference	--	p<0.0001
	2 (n=269)	0.16 Servings < 0.63	2 versus 1	2.65 [1.68, 4.19]	
	3 (n=254)	0.63 Servings < 7	3 versus 1	4.63 [2.86, 7.49]	
24-Hour Recall	1 (n=301)	Servings = 0	Reference	--	p=0.37
	2(n=240)	0 Servings < 1.7	2 versus 1	1.21 [0.79, 1.85]	
	3 (n=263)	1.7 Servings < 14	3 versus 1	2.02 [1.33, 3.06]	

^aSeparate logistic regression models for each dietary assessment method controlling for age, sex, race/ethnicity, maternal education, recruitment site, family size