Received: 9 March 2022 | Revised: 7 December 2022 | Accepted: 8 December 2022

DOI: 10.1111/jphd.12559

ORIGINAL ARTICLE

Food insecurity and consumption of cariogenic foods in mothers and their two-year-old children in Appalachia

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Funding information
National Institute of Dental and Craniofacial Research, Grant/Award Numbers: F31-DE027859, F99-DE030387, R01-DE014899

[Correction added on 6 February 2023, after first online publication: Dr. McNeil's affiliations have been corrected in this version.]

[Correction added on 10 February 2023, after first online publication: The appendix that was originally published in the main text has been removed and captured as supporting information in this version.]

Abstract

Objectives: To describe the association between household food insecurity and intake of cariogenic foods that increase risk of dental caries.

Methods: Cross-sectional analysis of 842 mothers in Appalachia and their children participating in the Center for Oral Health Research Cohort 2 between 2011 and 2017 when their children were ~ 24 months of age. Mothers completed a telephone interview regarding cariogenic food consumption and food insecurity. Associations between food insecurity and daily food intake were adjusted for education, income, state residence, and daily snacking.

Results: After adjustment for household income, state residence, daily snacking, and maternal education, mothers from moderately/severely food insecure households drank on average ½ more sugar-sweetened beverage servings per day ($p = 0.005$) and children drank almost 1/3 servings more ($p = 0.006$). Further, mothers and children from moderately/severely food insecure households had lower, but not statistically significant, daily average consumption of vegetables (mothers: 1/5 less of a vegetable serving per day, children: ~1/10 less) and fruits (mothers: 1/5 less of a fruit serving per day, children: ~ 1/10 les) and elevated consumption of sweets (mothers: ~ 1/25 more sweet servings per day, children: ~ 2/25 more); differences based on state residence were noted.

Conclusions: Food insecurity is associated with higher consumption of foods that increase risk of dental caries, but this association is modified by maternal education, income, and state residence. Food insecurity, and its socioeconomic determinants, should be considered when designing and implementing interventions to prevent dental caries.

INTRODUCTION

Dental caries are the most common chronic disease of childhood in the United States (US) [1, 2] and children

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with untreated dental caries experience adverse outcomes affecting their overall health and quality of life extending into adulthood [3]. Dental caries occur from the interaction between microbes present in the oral cavity and diet [4]. Sheiham and James described caries as a "diet-mediated disease" noting that sugars are essential to the disease process [5]. In addition to serving as a substrate for oral bacteria, the dietary carbohydrate profile is associated with colonization of the oral cavity by cariogenic bacteria [6]. Bacterial fermentation of carbohydrates produces acid, which progressively dissolves the tooth surface leading to a carious lesion. Both the nature of the carbohydrate and the length of oral exposure to the carbohydrate impact caries risk. Readily fermentable carbohydrates include sugars and short chain oligosaccharides that occur more often in highly processed (i.e., sugar-sweetened beverages (SSBs), candies, refined grains) than minimally processed foods (i.e., milk, fruits) [4]. Frequent eating (snacking) and holding food in the mouth prolong exposure to carbohydrates increasing risk of fermentation [7].

Dietary practices depend, in part, on a family's ability to locate, buy, and prepare sufficient, safe, and nutritious food to meet their dietary needs and food preferences for a healthy and active life [8]. When a family has insufficient resources (monetary or otherwise) such that dietary intake or food patterns are disrupted, the family is considered food insecure [9]. While food insecurity is associated with socioeconomic factors [10], living in areas that lack access to affordable healthy foods exacerbates the problem: food insecurity is more common in large cities and rural areas than in suburban areas and exurban areas around large cities [11]. Among households with children, the prevalence of food insecurity in the United States increased from 13.6% in 2019 to 14.8% in 2020 [11].

Food insecure households are more likely than food secure households to have diets that include energy-dense, nutrient poor foods such as refined grains and foods high in added sugars and saturated fats [12]. These foods provide more calories and are less expensive than fruit, vegetables, lean meats, and foods high in fiber [13]. In addition to being less nourishing, foods high in sugar increase risk of dental caries. We hypothesize that food insecurity is associated with higher consumption of cariogenic foods, ultimately increasing risk of dental caries. Specifically, we focus on understanding the food patterns and dietary behaviors of households with moderate and severe levels of food insecurity.

We explore this hypothesis using data from the Center for Oral Health Research in Appalachia Cohort 2 (COHRA2), a longitudinal investigation of mother–child pairs in the northern Appalachian region: rural West Virginia (WV) and urban greater Pittsburgh, Pennsylvania (PA). COHRA2 mother–child pairs are followed from the child's birth through early childhood to investigate the associations between genetic, microbial, and environmental factors (including diet) and risk of caries [14]. We test our hypothesis in a cross-sectional analysis of 842 COHRA2 mother–child pairs who completed the 24-month visit, and explore the effects of household income, maternal education, and urban/rural differences on the association between dietary behaviors and levels of food security.

METHODOLOGY

Design

We analyzed dietary and behavioral data from mother–child pairs participating in the Center of Oral Health Research in Appalachia cohort 2 (COHRA2). COHRA2 recruited healthy White women aged 18 years or older in the third trimester of pregnancy, living in the northern Appalachian region: West Virginia (n = 555) and Pittsburgh, Pennsylvania (n = 617). Women with multiparous pregnancy, premature delivery (i.e., <35 weeks), or the presence and/or development of a chronic medical condition were excluded. At enrollment, extensive sociodemographic and medical history data were collected. For this study, we included the 842 women who completed the 24-month telephone interview (when children were approximately 24 months of age) between 2011 and 2017. This interview included a 7-day food frequency questionnaire focused on cariogenic foods, dietary behaviors, and a food insecurity screening battery [14]. Telephone interviews were conducted by trained staff from the University of Pittsburgh Center for Social and Urban Research (https://ucsur.pitt.edu). The study was approved by the Institutional Review Boards at the University of Pittsburgh and West Virginia University. Written informed consent was obtained from mothers at their initial appointments and subsequent research assessments.

Variables: With the exception of sociodemographic information, which was collected at time of enrollment in COHRA2, all data included in this analysis were collected via the 24-month telephone interview.

Sociodemographic information

Mother's age, income, ethnicity, education, (dichotomized as high school degree or less and more than high school), and employment status were collected at enrollment.

Beverage exposures

Mothers were asked their and their child's weekly frequency of consuming: plain water, flavored water, cows'/animals' milk, plant milks, sports drinks, 100% juice, juice drinks, powdered beverages (i.e., Kool-Aide®), soda-pop, coffee, tea, meal-replacement drinks, energy drinks, and for mothers only, beer, wine, and other liquors. Assessments of the children's intakes of 100% juice and 100% juice diluted with added water was included starting in 2015. For consumed beverages, the participant was asked if the beverage generally consumed was sugar sweetened, artificially sweetened, or unsweetened. The milk category included cow/animal milks, infant formula, and breastfeeding. The SSB category included plant-derived milks, flavored waters, sports drinks, juice drinks (other than 100% juice), powdered beverages, soda-pop, coffee, tea, meal-replacement drinks, and other beverages sweetened with sugars. The water/other sugar-free beverages (OSF) included plain water and either unsweetened or artificially sweetened plant milks, flavored waters, sports drinks, juice drinks, powdered beverages, soda-pop, coffee, tea, meal-replacement drinks, and other beverages. Beverages were combined based on their composition and/or the presence of added sugars as follows: milk, 100% juice, 100% juice with water, SSB, water/OSF beverages, and alcohol. The weekly frequency responses were assigned values (i.e., never/once = 0.5; every few days = 3, once a day = 7, and several times a day = 17), and divided by 7 to estimate daily intake frequency [15, 16].

Food exposures

Mothers were asked their and their child's weekly frequency of consuming cariogenic foods. Participants were asked if categories were consumed, "never/once, every few days, once a day, or several times a day," and daily exposure frequency was quantified similarly to beverages. Food groups were defined using ChooseMyPlate [17] and foods within groups were queried together. Relatively unprocessed grains were queried as "cereals, rice, pasta" or "spaghetti, polenta, quinoa;" minimally processed grains as "crackers, bread, biscuits;' and highly processed grains with minimal sugars as 'chips, pretzels, popcorn." An additional grains group was added in 2015 to better query processed grains with sugars as "cold cereal and granola bars." Fruits were queried as "fruits including applesauce" and vegetables as "potatoes" and "other vegetables." Dairy food was queried as "cheese, yogurt." The protein group was queried as "meat, poultry, fish, seafood, eggs" and "nuts, nut butter (peanut butter), beans, hummus; seeds, soy products (tofu), veggie meats, and protein bars or supplements." Sweets included "desserts, pastries, cookies, cakes, ice cream, popsicles" and "candies, fruit snacks." The food "pizza" was added in 2015 as a separate food group, and coded as both a grain (i.e., minimally processed) and a dairy food. An "other" category was used to query additional items, which were then coded in the respective food group. Beverage milk frequency was combined with dairy frequency, and 100% juice frequency was combined with fruit frequency (watered down juice was counted as a half fruit). The final food groups consisted of grains, vegetables, fruits, dairy food, protein, and sweets.

Dietary behaviors

The frequency of daily eating events was defined as the sum of the number of meals and number of snacks usually consumed daily. Meal structure was queried as structured (i.e., "meals and snacks at about the same time most days" or "meals and snacks at different times most days") or unstructured (i.e., "snacking throughout the day with few, if any meals").

Household food insecurity

We identified food insecure households using the two-item household food insecurity screener developed and validated by Hager et al. [18] in Children's Health-Watch participants and subsequently validated in pediatric dental clinic participants by Radandt et al. [19]. The two screening questions were "Within the past 12 months we worried whether our food would run out before we got money to buy more" and "Within the past 12 months the food that we bought just didn't last and we didn't have money to get more." Possible responses were never true, sometimes true, often true or do not know, not applicable or refused. Food secure (FS) was defined as a response of "never true" to both questions, mildly food insecure (MFI) was a response of either "sometimes" or "often true" to either one but not both questions, and moderately/severely food insecure (MSFI) a response of "often true" to both questions.

Statistical analyses

We described demographic, beverage exposure, food exposure, and dietary behavior variables, by state residence and food insecurity status using *t*-tests for continuous variables (e.g., mother and child's age) and Chi-square tests for categorical variables (e.g., mother's education, child's gender). Spearman correlations were used to identify associations between mothers' and children's beverage and food exposures.

We fit a series of multivariable linear regressions predicting average daily intake of selected food categories for mothers and children separately, while adjusting for the mothers' education (low: high school degree or less; high: More than high school degree), household income (categorical), state of residence (PA vs. WV), and daily snacking (number of snacks consumed per day). We also fit a series of multivariable regressions predicting change in number of meals per day for mothers and children and fit a logistic regression predicting odds of unstructured meal pattern, adjusting for the same covariates listed above. To account for participants for whom values for education and income were missing, we used hierarchical multiple imputation. With multiple imputation, replacements for the missing data are drawn from the distribution of the missing values, given the observed data and an imputation model. As a sensitivity analysis, we re-analyzed excluding those with missing values; this did not significantly change the findings from the results using the imputed values so only imputed model results are shown (Tables A2 & A4). All statistical analyses were performed using the SPSS (IBM) software, version 27 (Armonk, NY) and R version 4.1.0. A p value <0.05 was considered statistically significant.

RESULTS

Demographic characteristics (Table 1)

All 842 mothers self-identified as White, per the COHRA2 eligibility criterion. Most mothers identified their children as White and non-Hispanic or Latino, although children in West Virginia were more likely to be White than in Pittsburgh ($p < 0.001$), consistent with population demographics. Forty-six percent of children were female, and the mean age at questionnaire completion was 24.1 months (SD: 1.10). The mean age for mothers at questionnaire completion was 32.1 years (SD: 5.0). Less than half of mothers had attained a high school degree of less. Mothers with lower educational attainment were more likely to be food insecure. Over half of mothers had attained a four-year college degree or more. Educational attainment and household income was higher among Pittsburgh than West Virginia mothers ($p < 0.001$.)

Beverage and food consumption varied by state residence (Table A1)

In descriptive analyses, water/OSF beverages, SSB, milk and juice consumption varied by state of residence. Water/OSF beverage intakes were inversely correlated between mothers and their children ($r = -0.103$; $p = 0.003$), while milk ($r = 0.186$; $p < 0.001$), 100% juice ($r = 0.379$; $p < 0.001$) and SSB (r 0.157; $p = 0.024$) intakes were positively correlated. Consumption of fruit, vegetables, grains, and dairy also varied by state of residence. Pittsburgh mothers consumed protein foods significantly more often than mothers from West Virginia (mean: 2.20, 2.00, respectively; $p = 0.006$) and children from West Virginia consumed sweets significantly more often than Pittsburgh children (mean: 0.89, 0.70, respectively; $p < 0.001$). Mothers' and children's intakes of all food groups were positively correlated ($r = 0.307$–0.479; all $p < 0.001$).

Daily food intake was associated with income, maternal education, snacking and state residence (Figure 1, Tables A2)

Mothers with high school education or less and their children were more likely to be food insecure, engage in daily snacking, and have higher consumption of sugar sweetened beverages (SSBs) than mothers with more than a high school education and their children (Figure 1). Greater household income and higher maternal education were statistically significantly associated with mothers consuming less 100% juice and fewer SSB, and more water/OSF beverages. Higher maternal education was also significantly associated with higher maternal consumption of vegetables and protein. There were no statistically significant associations of household income with average consumption of foods by children. However, children of mothers with higher education were more likely to consume more water/OSF beverages, and less like likely to consume 100% juice and SSB. Increased snacking was significantly associated with higher consumption of 100% juice, SSB, fruits, and sweets by mothers, and SSB and sweets by children. Compared to residents of Pittsburgh, mothers residing in West Virginia had a significantly lower consumption of water/OSF beverages and higher consumption of milk, and children a significantly higher consumption of 100% juice, SSB, and sweets.

Beverage and food consumption and dietary behaviors varied by food insecurity status (Figure 2, Tables A2, A3) after adjustment for confounders

When adjusted for household income, state residence, daily snacking, and maternal education, both mothers and children in moderately/severely food insecure households consumed about 1/2 of a SSB serving more per day compared to those in food secure households (mothers: $p = 0.005$; children: $p = 0.006$). Further, after adjustment, mothers and children from moderately/severely food insecure households had lower average consumption of vegetables and fruits and elevated consumption of sweets. Mothers from mildly food insecure households consumed about 1/3 of a fruit serving less per day than mothers from food secure households ($p = 0.032$). By contrast, mothers from moderately/severely food insecure households had a higher average consumption of milk than mothers from food secure households. When adjusted for state of residence, income, the mother's education and snacking, mothers in moderately/severely food insecure households—but not mildly food insecure—

TABLE 1 Demographic characteristics of 842 mother child pairs participating in the Center for Oral Health Research in Appalachia Study 2 (COHRA2) [14] by food insecurity[a]

	Food secure	Mildly food insecure	Moderately/severely food insecure	*p*-value[b]
N[c]	722	48	71	
State residence (*N*, row %)				
Pennsylvania	427 (88.0%)	21 (4.3%)	37 (7.6%)	0.069
West Virginia	295 (82.9%)	27 (7.6%)	34 (9.6%)	
Mother's age (mean (SD))	32.21 (4.87)	32.00 (6.02)	30.32 (5.52)	0.01
Mother's ethnicity (*N*, row %)				
Not Hispanic or Latino	701 (85.8%)	46 (5.6%)	70 (8.6%)	0.056
Hispanic or Latino	20 (95.2%)	1 (4.8%)	0 (0.0%)	
No response	1 (33.3%)	1 (33.3%)	1 (33.3%)	
Mother's education (*N*, row %)				
< High school degree	23 (69.7%)	4 (12.1%)	6 (18.2%)	<0.001
High school degree	81 (70.4%)	17 (14.8%)	17 (14.8%)	
Some college	122 (74.4%)	12 (7.3%)	30 (18.3%)	
College degree	273 (91.3%)	10 (3.3%)	16 (5.4%)	
Advanced degree	223 (97.4%)	5 (2.2%)	1 (0.4%)	
No response	0 (0.0%)	0 (0.0%)	1 (100.0%)	
Prior live births (mean (SD))	0.77 (0.98)	1.02 (1.09)	1.37 (1.65)	<0.001
Annual household income (*N*, row %)				
< 10 K	43 (67.2%)	10 (15.6%)	11 (17.2%)	<0.001
10 K–24,999	80 (66.1%)	11 (9.1%)	30 (24.8%)	
25 K–49,999	149 (78.8%)	18 (9.5%)	22 (11.6%)	
50–99,999	274 (95.5%)	7 (2.4%)	6 (2.1%)	
100 K+	148 (100.0%)	0 (0.0%)	0 (0.0%)	
No response	28 (87.5%)	2 (6.2%)	2 (6.2%)	
Child's sex (*N*, row %)				
Male	385 (85.2%)	30 (6.6%)	37 (8.2%)	0.448
Female	337 (86.6%)	18 (4.6%)	34 (8.7%)	
Child's age, months (mean (SD))	24.06 (1.07)	24.08 (0.94)	24.04 (0.80)	0.978
Child's race (*N*, row %)				
White/Caucasian	649 (87.0%)	40 (5.4%)	57 (7.6%)	0.024
Other	73 (76.8%)	8 (8.4%)	14 (14.7%)	
Child's ethnicity (*N*, row %)				
Not Hispanic or Latino	682 (85.9%)	44 (5.5%)	68 (8.6%)	0.086
Hispanic or Latino	39 (88.6%)	3 (6.8%)	2 (4.5%)	
No response	1 (33.3%)	1 (33.3%)	1 (33.3%)	

[a]Food insecurity defined as response of never true to "Within the past 12 months we worried whether our food would run out before we got money to buy more" and "Within the past 12 months the food that we bought just didn't last and we didn't have money to get more." Mildly food insecure was a response of either sometimes or often true to either one but not both questions, and moderately/severely food insecure was defined as often true to both questions.
[b]Chi-squared test for categorical variables, Student's *t*-test for continuous variables.
[c]$N = 1$ mother and N = 1 child with missing food security status and were omitted from results.

households ate significantly fewer meals than those in food secure households ($p < 0.001$); this was also true for children, but not statistically significant ($p = 0.266$). However, after adjustment, mothers in mildly and moderately/severely food insecure households were significantly more likely to have an unstructured meal pattern; this was not true for children.

DISCUSSION

In this cross-sectional study of 842 mother–child pairs from Northern and North Central Appalachia interviewed when the child was 24 months old, mothers and children in moderately/severely food insecure households were more likely to consume a diet high in SSBs and were

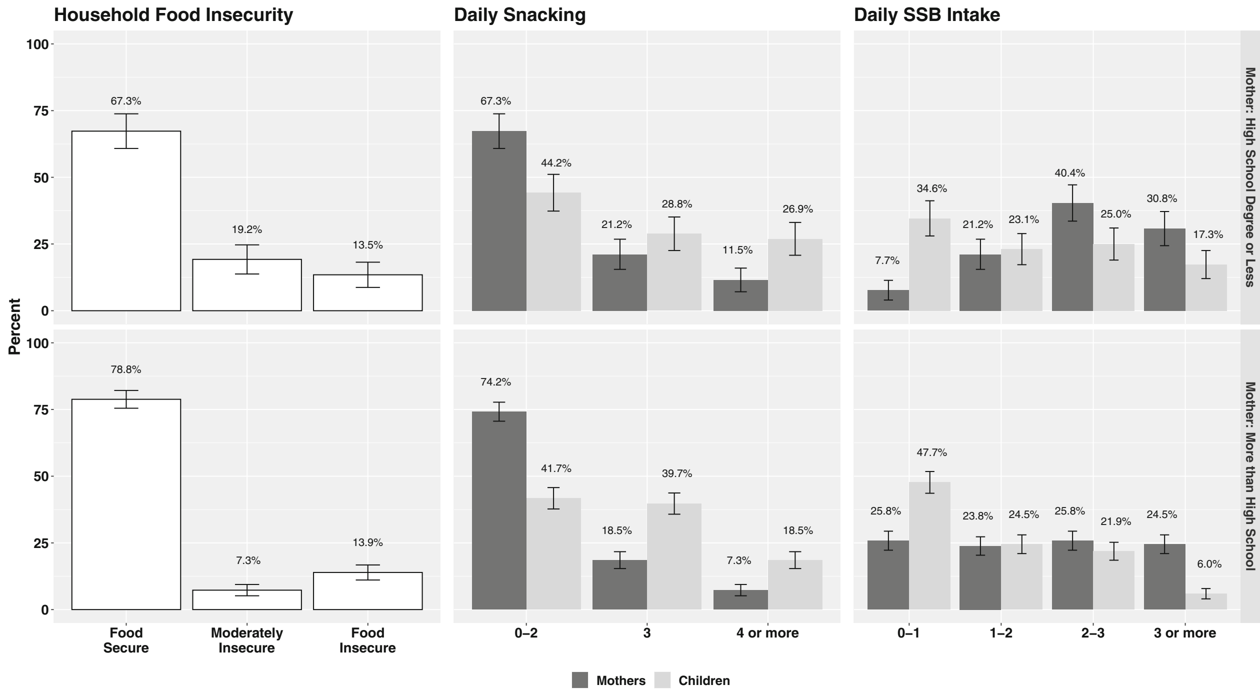

FIGURE 1 Mothers with high school education or less and their children (top row) were more likely to be food insecure, engage in daily snacking, and have higher consumption of sugar sweetened beverages (SSBs) than mothers with more than a high school education and their children (bottom row). Daily Snacking and Daily SSB intake are reported for all mothers and children. 842 mother child pairs participating in the Center for Oral Health Research in Appalachia Study 2 (COHRA2) [14].

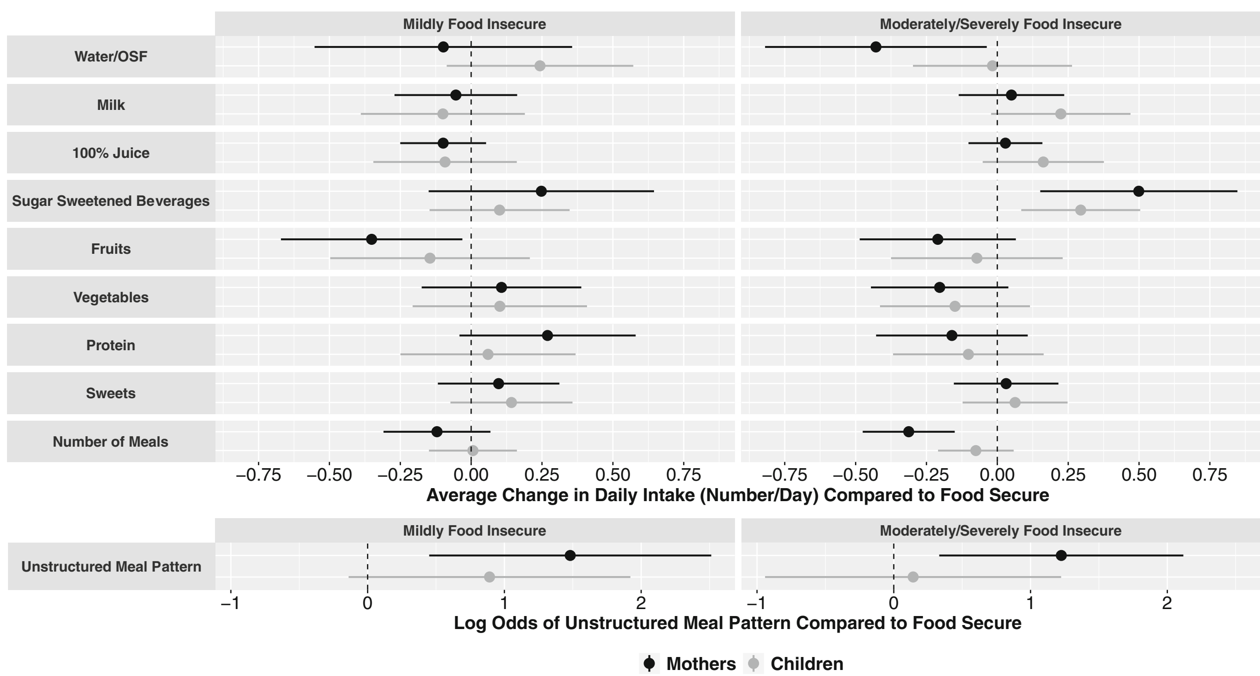

FIGURE 2 Forest plot showing the average change in daily food intake of selected foods among mothers and children in mild, or moderate/severe food insecure households compared to mothers and children in food secure households. Results are adjusted for education, income, state of residence (Pittsburgh primarily urban, West Virginia primarily rural), and daily snacking. Food frequency was measured via telephone interview at the 24-month post-partum visit. 842 mother child pairs participating in the Center for Oral Health Research in Appalachia Study 2 (COHRA2) [14].

less likely to have structured meal patterns. These associations were modified by maternal education, household income, and state residence. Mothers' and children's food intakes were highly correlated. Socioeconomic factors are an important predictor of diet and should be considered when designing and implementing dietary interventions to reduce dental caries.

The 2020–2025 Dietary Guidelines for Americans and the American Academy of Pediatrics state that SSBs are not necessary during childhood and should be avoided to allow for a healthy dietary pattern [20]. Notably, previously reported children's SSB intakes [21] and COHRA2 children's SSB intakes are not consistent with these guidelines. SSBs are a vehicle for added sugars and associated with lower diet quality, dental caries, and obesity in adults and children [22–24]. Marshall et al. reported that children in the highest level of SSB consumption (fourth quartile) compared to the lowest (first quartile) at 2, 3, and 4 years of age were more likely to experience caries at 5 years of age [24]. We also observed that moderately/severely food insecure children were more likely to drink 100% juice. Palmer et al. reported that three-year old children with severe early childhood caries are more likely to consume juice either at or between meals than their caries-free peers [25]. A comprehensive review by Jackson et al. of sixteen studies on the US children and food-security assessment reported that food insecurity had a strong dose–response relationship with lower vegetable intake compared with food security among children aged 1–5 years [26].

Lower maternal education and household food insecurity have previously been associated with higher sugar intakes in children [27, 28]. High calorie, energy-dense foods such as SSBs are less expensive than more nutritious foods [28–30] and are easily accessible [10]. Further, low-income families of young children may be receiving the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), which includes up to 128 ounces of juice per month within the child food package [28]. In our study, food insecurity was associated with a higher mean daily intake of SSBs among mothers and children, but average child consumption was lower than mothers regardless of food insecurity. Notably, mothers with higher education reported lower consumption of daily SSBs for themselves and their children after adjusting for income. That children model or mimic their mother's or other caregiver's beverage behaviors has been reported previously. Parental intake and home availability of SSBs were significantly associated with SSB intake among 8–12 year-olds [27].

Consumption of SSBs increased with food insecurity, but the average intakes for all mothers and children exceeded the World Health Organization and the 2020–2025 US Dietary Guidelines' recommendations for added sugars intake [31, 32]. Approximate energy requirements of an average 32-year-old inactive woman are 2000 kcal/day [17]; a threshold of 200 kcal is recommended for added sugars from all sources. In moderate- to high-added sugar consumers, SSBs intakes contribute 23%–51% to total added sugars [33], suggesting an upper threshold of added sugar intakes of 50–100 kcal from SSB for an average 32-year-old inactive woman. Assuming an average 12.5 kcal from added sugars/oz SSBs, then the threshold of SSB intakes for the 32-year-old women range from 4 to 8 oz. Although we did not quantify beverage intake estimates in this study, a typical SSB serving of 12–20 oz exceeds this threshold, and our participants consumed SSBs approximately twice daily.

Mothers but not children who were mildly or moderately/severely food insecure averaged fewer meals per day compared to food secure households and had less structured meal patterns. This is consistent with an analysis of USDA surveillance data demonstrating that mothers in food insecure households shield their young children from the impacts of food insecurity: children under 4 years of age were 50% less likely to experience food insecurity than teenage children [34].

Unique aspects of our study include an analysis of individual in urban and rural environments and the identification of shielding of children by mothers in food insecure households. Although all participants lived in Appalachia, roughly half live in Pittsburgh, PA (a more urban area), and the other half in the state of West Virginia, (which includes a range of rural areas). Mothers in Pittsburgh had higher household income and greater educational attainment than mothers in West Virginia. However, even after adjustment for household income and education mothers from West Virginia had higher levels of food insecurity.

The present study has a few limitations. Mothers and children from Northern and North Central Appalachia participating in our study were primarily White; thus, the results may not be generalizable to other ethnic/racial populations or other locations in the USA. Given the oral and other health disparities and inequities in this region [35], however, it is an important region to focus upon. The dietary data were self-reported and might not reflect actual behaviors and the questionnaire focused on cariogenic foods and assessed averaged weekly consumption. Results of clinical oral examinations were not analyzed in this study. Further, we did not assess the impact of WIC nor did we collect data on the usage of food pantries, which could influence access to certain foods. Future research should evaluate diet as a mediator in the mechanistic pathway between food insecurity and dental caries.

Conclusions

We described diet-related caries risk factors of mothers and their two-year-old children from Northern Appalachia. Mothers and children living in moderately/severely food insecure households were more likely to consume

SSBs and have unstructured meal patterns putting them at higher risk of future dental caries. These associations were confounded by mothers' education, income, and whether participants lived in Pittsburgh or West Virginia. Food insecurity and its socioeconomic determinants should be considered when designing and implementing interventions to prevent dental caries.

ACKNOWLEDGMENTS

The authors thank the women, children, and families who participate in the COHRA2 project. Also, sincere thanks are expressed to the field staff, past and present, in West Virginia and Pennsylvania for their dedicated efforts. The authors also thank our colleagues in the Center for Molecular and Clinical Epidemiology (MAC-EPID) at the University of Michigan School of Public Health and in the Center for Oral Health Research in Appalachia (COHRA) for their comments and guidance on this work.

FUNDING INFORMATION

Funded by the National Institute of Dental and Craniofacial Research (NIDCR), grant numbers R01-DE014899, F31 DE027859 and F99 DE030387.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

INFORMED CONSENT STATEMENT

Written informed consent was obtained from mothers.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Bhaumik D, Wright CD, Marshall TA, Neiswanger K, McNeil DW, Jones AD, et al. Food insecurity and consumption of cariogenic foods in mothers and their two-year-old children in Appalachia. J Public Health Dent. 2023;83(2):127–35. https://doi.org/10.1111/jphd.12559