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The association between food insecurity and dental caries among U.S. adults: Data from the National Health and Nutrition Examination survey

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Abstract

Objectives: The purpose of this study was to examine the association between food insecurity and untreated dental caries using a nationally representative sample of US adults.

Methods: Data from the National Health and Nutrition Examination Survey (NHANES) cycles 2011-2012 and 2013-2014 on adults aged 18 years and older were analysed (n = 10 723). Primary predictors were overall food security (food-secure/food-insecure) and household food security (full, marginal, low and very low). The main outcome was any untreated dental caries (none/ ≥ one). Multiple logistic regression analyses were done to estimate the adjusted odds ratio after controlling for confounders.

Results: Food-insecure adults were more likely to have untreated dental caries than food-secure adults after adjusting for potential confounders (OR: 1.2; 95% CI: 0.9-1.5). Adults from households with marginal (OR:1.4; 95% CI:1.5-2.2), low (OR:1.3, 95% CI:1.3-2.0) and very low food security (OR:1.3; 95% CI:0.9-1.5) had higher odds of untreated caries than adults from households with full food security. Following age stratification, marginal, low and very low food-secure adults had higher prevalence of untreated dental caries than full food-secure adults across all age groups.

Conclusions: Our findings suggest that food-insecure adults had higher odds of untreated dental caries than food-secure adults. These findings highlight the importance of assessing food insecurity as a risk factor for dental caries. Longitudinal cohort studies are recommended to determine causal mechanisms.

KEYWORDS

dental caries, food insecurity, NHANES, oral health

1 | INTRODUCTION

Dental caries is a prevalent chronic multifactorial disease. In spite of efforts to reduce its prevalence, it remains a significant public health problem.[1] More than one in four US adults have untreated dental caries.[2] Behavioural, cultural and social factors are the main potential risk factors that play roles in dental caries development. The impact of dietary habits and diet quality on oral health have been broadly studied; however, research on food insecurity is limited.[3]

Food insecurity is defined as *'a situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life'*.[4] Evidence indicates that food insecurity is associated with chronic diseases and poor general health in adults. Food insecurity is related to heart disease, diabetes, poor mental and physical health, and fair to poor self-rated overall health.[5-7] Mounting evidence suggests that adherence to dietary guidelines prevents major chronic diseases, which is essential to maintaining good overall health. Nutrient deficiencies may lead to infectious and chronic diseases such as obesity, diabetes, cardiovascular disease, depression, osteoporosis and oral diseases.[8-12]

Oral health is related to diet and nutrition as they play key roles in the demineralization and remineralization of teeth.[13] It has been shown that diet quality was negatively associated with food insecurity among adults.[14] Very few studies have investigated the effect of food insecurity on oral health among adults. A cross-sectional study showed that food insecurity was associated with poor self-reported oral health among older US adults.[15] Food insecurity was associated with poor self-reported oral health status in poor working-class Canadians. Food-insecure individuals had double the odds of being denture wearers and having dental pain in the past month, and triple the odds of poor/very poor self-reported oral health than food-secure individuals.[16]

To the best of our knowledge, prior studies have examined the association between food insecurity and self-reported oral health measures among adults, but no study thus far has examined clinically measured dental caries. Accordingly, our aim is to determine whether food insecurity is associated with dental caries among US adults. We hypothesize that food-insecure adults are more likely to have untreated dental caries than food-secure adults.

2 | METHODS

2.1 | Data source

Our data were selected from the National Health and Nutrition Examination Survey (NHANES) cycles 2011-2012 and 2013-2014. Each NHANES cycle provides data to assess the health and nutrition of about 10 000 children and adults residing in all 50 states and Washington DC. Selection of participants is based on a complex, multistage, probability sampling design in order to represent the noninstitutionalized US civilian population.[17]

Oral health examinations were conducted in the mobile examination centre by licensed dentists. All teeth are examined except third molars. Oral health examinations were performed using a mirror and #23 dental explorer. The oral examination subcomponents included tooth count, dental caries, root caries, dental sealants and miscellaneous report of findings.[18]

Our sample included adults aged 18 years and older who completed the food security questionnaire, dental examination, and had at least 2 teeth (excluding the third molars).

2.2 | Covariates

We used the Directed Acyclic Graph (DAG) by 'DAGitty' software to identify potential confounders for statistical adjustment (Appendix S1). To control for potential confounding effect, we included all the following covariates in our multivariable models: age (categorized as 18-39, 40-59, and 60 + years), gender (male/female), race/ethnicity (White, Black, Hispanic and other races), marital status (single, married/living with partner and widowed/divorced), education (<high school or ≥high school), annual family income (<$20 000 or ≥$20 000), household size, household Women, Infants and Children programme (WIC) participation (yes/no), household Supplemental Nutrition Assistance Programme (SNAP) participation (yes/no), total number of teeth and unmet dental need (needed dental care in the past year but couldn't get it, (yes/no)).

2.3 | Primary predictors

The US Household Food Security Survey Measure (HFSSM) is a valid and reliable tool that used to measure household food security nationally. The Pearson correlation coefficient of the respondents measures over time was $r = 0.75$ ($P < .01$).[19] The HFSSM consists of 18 questions to assess the household's food security status over a period of 12 months. All the questions are explicit to the adult's experience, while eight questions are explicit only to the experience of children under the age of 18. The components of the survey range from worrying about running out of food, reducing food quality or relying on low-cost food to cutting size of meals or skipping meals due to lack of money. The survey is used to classify individuals as full, marginal, low or very low food-secure according to the number of affirmative responses. Households with no affirmative responses from individuals are classified as full level food-secure households. Households with 1 or 2 affirmative responses are classified as marginal level food-secure households, low level food-secure households are those with 3-7 affirmative responses (3-5 for households without children under the age of 18) and very low level food-secure households are those with 8 or more affirmative responses (6-8 for households without children under the age of 18).[20,21] For our analyses, we further defined overall household level food security as either food-secure (full food security) or food-insecure (marginal, low and very low food security).

2.4 | Primary outcome

The primary outcome was any untreated caries vs. no untreated caries.[18,22] This binary outcome measure was derived from the decayed teeth (DT) component of the Decayed, Missing and Filled Teeth Index (DMFT). Specifically, dental examiners used the diagnostic criteria by Radike and colleagues.[22] Each tooth was examined to allow for the calculation of the DMFT. Teeth were defined as decayed if there was softness of the area and or, opacity adjacent to the area,

TABLE 1 Descriptive statistics of the full sample and bivariate analysis showing characteristics by household food security level category

Characteristics	Full sample (n = 10 723)	Full food security[a] (n = 7309)	Marginal food security[a] (n = 1228)	Low food security[a] (n = 1302)	Very low food security[a] (n = 815)	*P*-value
		N (weighted %) or mean ± SD				
Age						
18-39	4145 (39.6)	2516 (34.5)	580 (49.4)	619 (52.2)	391 (49.8)	<.0001
40-59	3369 (36.1)	2261 (36.1)	390 (36.7)	423 (34.8)	282 (39.0)	
≥60	3209 (25.3)	2532 (29.5)	258 (13.8)	260 (13.0)	142 (11.3)	
Gender						
Male	5259 (48.8)	3644 (49.1)	575 (47.0)	615 (48.0)	390 (48.8)	.7
Female	5464 (51.2)	3665 (50.9)	653 (53.0)	687 (52.0)	425 (51.2)	
Race/ethnicity						
White	4274 (66.5)	3182 (72.1)	375 (51.1)	373 (44.9)	317 (54.7)	<.0001
Black	2524 (11.5)	1548 (9.3)	358 (17.5)	369 (18.1)	237 (18.6)	
Hispanic	2278 (14.3)	1282 (10.7)	327 (23.0)	460 (30.8)	194 (19.2)	
Others	1647 (7.8)	1297 (7.9)	168 (8.4)	100 (6.3)	67 (7.4)	
Marital status						
Single	2407 (23.4)	1452 (20.0)	309 (31.1)	365 (34.5)	259 (38.2)	<.0001
Married/ with partner	5054 (59.2)	3853 (63.6)	466 (48.6)	487 (48.0)	221 (33.8)	
Widowed/ divorced	1872 (17.4)	1253 (16.4)	213 (20.4)	208 (17.5)	190 (28.0)	
Education						
<High school	2205 (15.4)	1218 (11.5)	315 (22.2)	438 (33.6)	234 (25.6)	<.0001
≥High school	7837 (84.6)	5754 (88.5)	793 (77.9)	757 (66.4)	533 (74.5)	
Annual family income						
<$20 000	2702 (19.0)	1296 (12.6)	443 (32.3)	527 (36.4)	436 (48.8)	<.0001
≥$20 000	7513 (81.0)	5682 (87.4)	746 (67.2)	725 (63.6)	360 (51.2)	
Mean household size	2.9 ± 0.04	2.8 ± 0.04	3.1 ± 0.1	3.6 ± 0.1	2.7 ± 0.1	<.0001
WIC participation						
Yes	1051 (10.7)	421 (6.3)	222 (19.4)	295 (27.8)	113 (17.5)	<.0001
No	6408 (89.3)	4403 (93.8)	738 (80.7)	759 (73.2)	507 (82.5)	
SNAP participation						
Yes	2471 (17.5)	947 (9.02)	460 (34.1)	616 (43.0)	448 (55.8)	<.0001
No	8159 (82.6)	6344 (91.0)	761 (65.9)	686 (57.0)	367 (44.2)	
Unmet dental need						
Yes	2206 (17.2)	999 (11.3)	335 (24.7)	483 (37.2)	389 (47.6)	<.0001
No	8272 (82.8)	6221 (88.7)	856 (75.3)	787 (62.8)	408 (52.4)	
Mean number of teeth	23.1 ± 0.2	23.4 ± 0.2	22.9 ± 0.4	22.9 ± 0.4	20.9 ± 0.5	<.0001
Decayed teeth (DT)						
Yes	2936 (23.3)	1602 (18.7)	430 (33.7)	521 (39.6)	359 (43.0)	<.0001
No	7787 (76.3)	5707 (81.3)	798 (66.3)	781 (60.4)	456 (57.0)	

[a]Full food security: no affirmative responses, marginal food security: 1 or 2 affirmative responses, low food security: 3-7 affirmative responses (3-5 for households without children) and very low food security: 8 or more affirmative responses (6-8 for households without children).

or white spots on smooth areas; restored if there was a permanent or temporary restoration placed because of caries; or missing if the tooth was missing due to dental disease. Participants with DT component of DMFT greater than 0 are defined as having any untreated caries.

2.5 | Statistical analysis

All statistical analyses were conducted using SAS Software version 9.4 and survey procedures to account for complex sampling design.[23] Sample weights were used to enable generation of results

on a national level. Significance level was defined as *P*-value < .05. Bivariate analysis was performed to compare the characteristics of the population in each of the household-level food security groups. Multiple logistic regression analysis, controlling for potential confounding variables, was used to predict dental caries from overall and household-level food security. Age-stratified associations were also explored to compare the odds ratio for the dental caries-household food security level relationship between different age groups.

3 | RESULTS

The study sample was comprised of 10 723 adults aged 18 ≥ years. About 51% of participants were female, more than two-thirds of the sample were Whites and almost two-thirds were married or living with a partner. The majority of the study population had an annual family income ≥$20 000. Around 11% of households participated in WIC and 17% participated in SNAP in the past year. Approximately, 83% of adults had met their dental need in the past 12 months, and 76% of adults did not have any untreated caries.

Table 1 shows that full level food-secure households were more likely to be White, while food-insecure marginal, low and very low households were more likely to be Black or Hispanic. Almost half of adults in marginal, low and very low food security groups were aged 18-39 years. Very low food security was more frequent among single, widowed or divorced adult households, while individuals who were married/ living with a partner were most likely to be full food-secure. Food-insecure households were more likely to have lower educational attainment, and were more likely to have an annual family income of <$20 000. The highest proportion of WIC participation was among families with low food security, and SNAP participation was greater among families with more severe food insecurity. In addition, the prevalence of unmet dental needs in the past year was higher among those with more severe food insecurity. The mean total number of teeth was lower among those with more severe food insecurity. While 19% of adults in fully food-secure households had at least one carious tooth, 34% with marginal food security, 40% with low food security and 43% with very low food security had at least 1 untreated carious tooth.

Table 2 shows the association between overall food insecurity, severity of household food insecurity and untreated dental caries after adjusting for covariates. Food-insecure adults had higher odds of having dental caries than food-secure adults (OR: 1.2; 95% CI: 0.9-1.5). Adults from marginal, low and very low food-secure households had higher odds of having untreated caries than fully food-secure households after controlling for sociodemographic characteristics (OR: 1.6; 95% CI: 1.2-2.2, OR: 1.9; 95% CI: 1.5-2.4 and OR: 2.3; 95% CI: 1.8-3.0, respectively). These associations were attenuated after adding the food assistance programmes participation and dental factors to the model (OR: 1.4; 95% CI: 1.5-2.2, OR: 1.3; 95% CI: 1.3-2.0 and OR: 1.3; 95% CI: 0.9-1.5, respectively).

TABLE 2 Multiple logistic regression analysis predicting overall food security and household food security level on dental caries

	Untreated dental caries		
	Model 1[a]	Model 2[b]	Model 3[c]
Characteristics	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Overall food security status			
Fully food-secure	Ref	Ref	Ref
Food-insecure	1.9 (1.5-2.2)	1.6 (1.3-2.0)	1.2 (0.9-1.5)
Household food security level			
Full food security	Ref	Ref	Ref
Marginal food security	1.6 (1.2-2.2)	1.6 (1.1-2.3)	1.4 (1.5-2.2)
Low food security	1.9 (1.5-2.4)	1.7 (1.3-2.3)	1.3 (1.3-2.0)
Very low food security	2.3 (1.8-3.0)	2.1 (1.5-2.7)	1.3 (0.9-1.5)

[a]Controlled for sociodemographic factors: age, sex, race, education, marital status, annual family income and household size.

[b]Controlled for sociodemographic factors and food assistance programme participation (household WIC participation and household SNAP participation).

[c]Controlled for sociodemographic factors, food assistance programmes participation (household WIC participation and household SNAP participation) and dental factors (total number of teeth and unmet dental need).

Table 3 presents the age-stratified analysis. Adults across all age categories who were from marginal, low and very low food-secure households had higher odds of untreated caries than adults from full food-secure households.

4 | DISCUSSION

The objective of the current study was to examine the association between food insecurity and untreated dental caries among US adults aged 18 ≥ years using a population-based sample. Our main finding suggests that food insecurity is associated with untreated dental caries. Food-insecure adults had 1.2 times higher odds of having untreated dental caries than fully food-secure adults after adjusting for potential confounders. In further examination of the relationship utilizing severity of food insecurity, adults from households at all levels of food insecurity were more likely to have untreated caries than food-secure adults.

Our findings are in agreement with previous studies that document the harmful effects of food insecurity on overall health and its relationship with chronic diseases and self-reported oral health.[5-7,24-26] A cross-sectional study found that food insecurity was associated with poor self-reported oral health (prevalence ratio (PR) = 1.1, 95% CI: 1.0-1.2).[15] However, this latter study was focused on adults aged ≥ 50 years and did not stratify by age. Another study by Muirhead and colleagues showed that food insecurity was associated with poor self-reported oral health status

TABLE 3 Age-stratified logistic regression analysis of household food security level with untreated dental caries

	18-39 years	40-59 years	≥60 years
Household food security level	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Full food security	Ref	Ref	Ref
Marginal food security	1.2 (0.8-2.0)	1.5 (0.9-2.6)	1.5 (0.7-3.1)
Low food security	1.3 (0.9-1.9)	1.2 (0.8-2.0)	2.1 (0.9-5.1)
Very low food security	1.1 (0.7-1.8)	1.4 (0.9-2.1)	1.6 (0.5-4.7)

Note: Controlled for sex, race, education, marital status, annual family income, household size, household SNAP participation, household WIC participation, total number of teeth and unmet dental need.

in poor working-class Canadians.[16] Food-insecure individuals had double the odds of being denture wearers ($P < .002$) and having dental pain in the past month (OR: 1.9; $P = .003$). They also had triple the odds of poor or very poor self-reported oral health than food-secure individuals ($P < .001$).[16] However, the study population is different; hence, their findings are not generalizable to the US population.

An NHANES 2011-2012 analysis by Wiener and colleagues showed that food-insecure adults were more likely to have unmet dental needs than food-secure adults after adjusting for potential confounders (OR: 1.6; 95%CI: 1.2, 2.1).[26] However, these studies used self-reported oral health measures rather than clinical measures such as untreated dental caries to examine the impact of food insecurity on oral health. In our study, the outcome variable was dental caries and we controlled for unmet dental need to be able to resolve the subjectivity of unmet dental need. Our findings are similar to the Chi and colleagues study which revealed that children from low and very low food-secure families had higher odds of untreated dental caries than children from full food-secure families.[27] However, in addition to studying a different age group, they didn't control for SNAP or WIC participation, number of teeth and unmet dental needs.

Another important finding in our study was that in age-stratified models, food-insecure adults were more likely to have untreated caries than food-secure adults, irrespective of age group. This finding is consistent with the Canadian study which showed that food-insecure adults aged 18-64 years had 3.5 times the odds of poor/very poor self-reported oral health than food-secure adults.[16] Moreover, a national study of US older adults aged ≥ 50 years revealed that food-insecure adults had 1.1 times the odds of poor self-reported oral health than food-secure individuals.[15]

There are several explanations for our findings. One possibility is that food-insecure individuals are more likely to consume a poor quality diet. A review of the literature concluded that food insecurity was negatively associated with diet quality among adults[14] as they had lower consumption of fruits, vegetables,[28,29] dairy products,[29,30] vitamins A and B-6, calcium, magnesium and zinc.[29-32] Food-insecure individuals also tend to consume high amounts of energy dense food and to adopt bad eating habits to cope with food deficiencies.[28] Earlier work reported the negative effect of poor diet quality on oral health.[33-35]

Food and food security are considered to be basic human rights. Maslow's Hierarchy of Need (basic human needs pyramid) categorized food into the base of the pyramid, along with water and breathing; all of which are required for survival.[36] One of the Healthy People 2020 objectives is to reduce the prevalence of food-insecure households from the 2008 baseline of 14.6% to 8.6% in 2020, a goal which was not achieved in Healthy People 2010. Achieving this goal would mean an additional 94% increase in the proportion of full food-secure households would occur.[37] Unfortunately, our NHANES analysis suggests that this target is not being achieved, with the prevalence of households with food insecurity was about 25%.

Our study has a few limitations. First, the study design is cross-sectional, which has the inherent limitation of being unable to establish temporality and hence causality, because we cannot determine the sequence of the exposure and the outcome. In addition, we cannot determine the effect of food insecurity on dental caries incidence and increment. Second, food security status was measured during the past 12 months; therefore, some misclassification bias could have occurred due to the fact that food security status is not stable throughout life. Third, due to the skewed distribution of untreated dental caries, it was measured as a binary variable that did not take into account the severity of dental caries. Fourth, annual family income was self-reported which could be subjected to underestimation or overestimation.

A major strength in our study is the large and diverse sample size which increases the validity of our findings. Also, due to the comprehensive nature of NHANES dataset, we were able to control for multiple confounders. Moreover, the use of sample weights allowed us to produce national estimates. In addition, we used the HFSSM a valid and reliable tool to assess food insecurity experience. Using such tool will ensure proper identification of households with different levels of food insecurity and facilitate tailored interventions for the most vulnerable households. Unlike previous research that studied self-reported oral health outcomes, in our study dental caries was assessed clinically by licensed and calibrated dentists. Additionally, we were able to control for dental factors in our analysis such as number of teeth and unmet dental need.

Efforts to reduce food insecurity can be carried out on both macro and micro levels. Public policies on the macro level include taxing unhealthy food and financially assisting high quality food

production.[38,39] Examples for micro-level policies include supporting the nutritional assistance programmes financially such as increasing the Supplemental Nutrition Assistance Programme (SNAP) benefit, and encouraging local food markets to provide and advertise affordable nutritious food. Furthermore, public health interventions and educational programmes to help individuals choose healthier options are crucial to reducing the proportion of food-insecure households, and perhaps improve their oral health.[39,40] Future studies should examine additional environmental factors that could affect the association between food insecurity and untreated dental caries, such as social deprivation and social cohesion.

In conclusion, our findings suggest that food insecurity is associated with untreated dental caries, after adjusting for potential confounders. Additional cross-sectional and prospective cohort studies are needed to confirm this association and to investigate the underlying mechanism between food insecurity and untreated dental caries.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest. The authors received no specific funding for this work.

AUTHOR CONTRIBUTION

Lina Bahanan contributed to conception, design, data acquisition, data analysis and interpretation, and critically revised the manuscript. Astha Singhal, Yihong Zhao, Thayer Scott, and Elizabeth Kaye contributed to study design, interpretation, and review the article. Yihong Zhao and Elizabeth Kaye assisted in data analysis. All authors gave their final approval and agree to be accountable for all aspects of the work.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in the National Center for Health Statistics at https://www.cdc.gov/nchs/data/nhanes/nhanes_13_14/2013-14_overview_brochure.pdf, reference number.[17]

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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