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Association between asthma and severe tooth loss in the adult population of the United States

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ABSTRACT

Objective: This study aimed to investigate the association between asthma and severe tooth loss in the U.S. (United States) adult population.

Methods: Data were analyzed from the national health and nutritional examination survey (NHANES), 2009–2014. Study-participants were classified into current, former, and never asthmatics based on their asthma status. Former-asthmatics were excluded. The case definition of severe tooth loss (outcome variable) was having 9 or fewer remaining permanent teeth. Characteristics of our study-sample were identified based on the descriptive statistical analyses. Logistic regression analyses were performed to examine the association between asthma and severe tooth. Multivariable models were constructed to control for the known common clinical, demographic, and lifestyle factors. Each analysis accounted for the examination sample weights and the complex clustered design of the continuous NHANES.

Results: Total study-participants were 14,184 representing ≈ 185.77 million U.S. adults. Prevalence of asthma was 8.99% in our study-sample, and 8.78% had severe tooth loss. Current-asthmatic adults had 34% higher odds of severe tooth loss as compared to their reference group of never-asthmatics adults in the U.S. after controlling for age, race or ethnicity, gender, diabetes, smoking, body mass index, education, and family income-to-poverty ratio.

Conclusion: In the United States, as compared to never-asthmatic adults, current-asthmatic adults were more likely to have severe tooth-loss. Oral health promotion is therefore recommended through medical-dental integration to ensure overall health for asthmatic adults.

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Introduction

Tooth loss is the terminal outcome which reflects affected individual's history of dental diseases, attitude toward oral health, and access-to-care status. It is an important public health issue because it impacts the overall health and the quality of life (1–4). Beyond damaging the masticatory function, phonation, and esthetics, severe tooth loss may lead to poor diet and nutrition (5–8). Not only does it affect the oral cavity, tooth loss is also associated with poor health outcomes like cardiovascular diseases (9–11), cognitive impairment (12), nonalcoholic fatty liver diseases (13), and malnutrition in chronic kidney disease (14). According to a report from the National Center for Health Statistics, more than half of the U.S. adults aged 20–64 years did not have all of their permanent

teeth (excluding third molars) in 2011–2012 (15). Overall, nearly 1 in 6 older adults aged ≥ 65 years in the U.S. had lost all of their teeth during 2011–2016 (16).

There are various risk factors associated with tooth loss and declining oral health, such as low educational background, poor personal income, deprived living conditions, poor housing, tobacco, and excessive alcohol consumption (17–19). In addition to these demographic and behavioral risk-factors, tooth loss is related to many systemic diseases (20). Several common chronic diseases including diabetes (21), osteoporosis (22), rheumatoid arthritis (23), and obstructive pulmonary diseases (24) have been commonly found to be associated with tooth loss. Similarly, asthma is another highly prevalent chronic

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inflammatory systemic disease in the US, which deteriorates the quality of life of those who are affected (25). Because of the chronic inflammation, mouth breathing, and the adverse effects of the anti-asthmatic drugs, current-asthmatic adults may experience poor oral health, as measured by number of missing teeth. However, only a few studies specifically examined the association of asthma with tooth loss in the representative samples of all adults (26,27).

Asthma has been linked to dental caries and periodontitis (28–31), the major risks for tooth loss (32). As a result of the inhalation therapy and the effects of anti-asthmatic agents, current-asthmatic individuals are likely to suffer from xerostomia (33,34), which may increase their susceptibility to dental caries (35). Further, a study conducted in the Korean population revealed that tooth loss in asthmatic adults may be attributable to decrease in bone mineral density resulting from the use of inhalation corticosteroid, commonly prescribed in the management of asthma (36).

Apparently, one large observational study revealed significant increase in tooth loss due to caries after early age asthma diagnosis in the Korean population (27). Another cross-sectional study, conducted in a similar population, showed the inverse association between total serum IgE, an antibody that plays a pivotal role in allergic asthma, and number of natural teeth (37). While a number of population-based studies observed significantly higher odds of tooth loss in asthmatic adults as compared to non-asthmatic adults (26,38), findings from a few studies were not statistically significant after controlling for common covariates (39,40).

There is a paucity of large population-based studies examining the association between asthma and severe tooth loss. Furthermore, research examining the link between asthma and severe tooth loss measured by reliable objective clinical dental data particularly in a nationally representative sample of US adults is not yet available. It is important to understand this relationship because the proportion of the adults in the U.S. population is growing (41), and is significantly affected by both, asthma (25) and an increasing number of missing teeth (15,16). Therefore, the purpose of this study was to investigate the association between asthma and severe tooth loss in the U.S. adult population.

Methods

An observational, population-based, cross-sectional study was conducted by analyzing the NHANES data

to examine the association between asthma and severe tooth loss in the U.S. adult population.

Study-population

A sample for this study was drawn from the population that participated in the continuous NHANES from 2009 to 2014 (42). In this study, we included adults ≥ 18 -years old at the time of screening with exam survey weights who received oral health-dentition assessment. Incomplete dental examination and unknown asthma status were exclusion criteria.

The continuous NHANES is an ongoing, nationally representative survey conducted by the National Center for Health Statistics at the Centers for Disease Control and Prevention (CDC) that collects data on the health and nutritional status of the non-institutionalized civilian U.S. adults and children (43). These cross-sectional surveys have been conducted annually on a continuous basis and publicly released in 2-year cycles since 1999. The NHANES data collection protocols were approved by the CDC's National center for Health Statistics (NCHS) Research Ethics Review Board (44). Complete information about the NHANES is available on the CDC website (43). Accordingly, individuals participating in this survey provided written informed consent. Each survey cycle includes deidentified data of approximately 10,000 individuals from several representative areas in the United States. The survey employs a multi-stage probabilistic design to collect a wide range of health information through questionnaire-based household interviews, physical examinations, and laboratory tests.

Asthma

Asthma was the independent variable. It was defined based on study-participants' responses to the following two questions related to asthma from the medical condition questionnaire in the NHANES (45):

1. Has a doctor or other health professional ever told you that you have asthma?
2. Do you still have asthma?

Individuals who responded "yes" to both of these questions in the NHANES were classified as current-asthmatics, and those who had never been told that they had asthma were classified as never-asthmatics. Former-asthmatics, who reported being told that they had asthma but did not currently have it, were excluded because they were neither equivalent to

individuals currently suffering from asthma nor could they have been categorized into never-asthmatic reference group.

Severe tooth loss

The case definition of severe tooth loss was having 9 or fewer remaining permanent teeth, which by default, included those with severe tooth loss (i.e. 1–9 remaining teeth) as well as those with total tooth loss (46). Reliable objective clinical data obtained from dental examinations of the NHANES study-participants were utilized to measure this dichotomous outcome.

Covariates

Sociodemographic, clinical and lifestyle factors considered by previous studies as covariates were included (26,28,30). Demographic characteristics of our study-participants were obtained from the demographic file of each cycle of the continuous NHANES. Two categories of educational attainment (< High School, and $\geq$ High School), and 2 categories of ratio of family income-to-poverty (< 1, and $\geq$ 1) were formed. BMI was grouped into 3 categories: normal, overweight, and obese (47). Diabetic status was categorized into non-diabetic, borderline-diabetic, and diabetic based on the study-participants' responses to diabetes questionnaire. Smoking status was classified as current, former, and never smokers.

Statistical analysis

Descriptive statistical analyses were conducted to specify the baseline characteristics of the study-participants, and to compute the prevalence of asthma and severe tooth loss. Chi-square test was used to examine the association between each independent variable of interest and severe tooth loss. Logistic regression was performed to examine the association between asthma and severe tooth loss. Crude model and those adjusted for age, race or ethnicity, gender, diabetes, smoking, BMI, education, and family income-to-poverty ratio were constructed. Unadjusted and adjusted odds ratios and respective 95% confidence intervals were calculated. Interactive effects of asthma and each individual covariate were studied on severe tooth loss.

In order to ensure the correct estimation of sampling error, each analysis accounted for the sample weights, stratification and clustering design variables. Following the NHANES analytic and reporting guidelines, a 6-year MEC subsample weight was calculated

for the combined data of 2009–2014 by assigning one-third of the subsample weight for each 2-year data cycle (48). All data management and statistical analyses were conducted in SAS software, version 9.4 (SAS Institute, Inc, Cary, North Carolina).

Results

Our sample included 14,184 participants, representing $\approx$ 185.77 million U.S. adults after applying the NHANES sample weights, which was described and analyzed in this study. Average age of the study-participants was 47.58 years (Standard Error = 0.39). There was an almost equal distribution of both genders.

Descriptive statistical analyses revealed the characteristics of our study-population (Table 1). Overall, prevalence of asthma was 8.99% in our study-sample, and 8.78% had severe tooth loss. Compared to the younger age groups (< 65 years old), older adults ($\geq$ 65 years old) had higher prevalence of severe tooth loss (< 10% vs 27%). The prevalence of severe tooth loss was almost equal in both genders. It was more prevalent in non-Hispanic Blacks, less educated people, those living in poverty, diabetics, and smokers. There was, however, no significant association between BMI and severe tooth-loss in our study population (p values = 0.13). Current-asthmatic adults had considerably higher prevalence of severe tooth-loss (13.14%) as compared to never-asthmatics (8.34%). There was a statistically significant association between asthma and severe tooth loss (p value < 0.0001).

The odds of having severe tooth loss, obtained from logistic regression analyses, are shown in Table 2. Model 1 revealed crude association between asthma and severe tooth loss (Unadjusted OR, 1.661; 95% CI, 1.322 – 2.088). The OR depicted in model 2 was adjusted for the age, race or ethnicity, gender, smoking, diabetes, and BMI, according to which, current-asthmatics had significantly higher odds of severe tooth loss (Adjusted OR, 1.538; 95% CI, 1.180–2.003). The odds ratio remained statistically significant in model 3 as well which was further adjusted for education (Adjusted OR, 1.512; 95% CI, 1.138–2.007). The final model 4 was a fully adjusted model, in which the OR was further adjusted for the income-to-poverty ratio. Overall, in reference to never-asthmatic adults, current-asthmatic adults in the US had 34% higher odds of having severe tooth loss (Adjusted OR, 1.341; 95% CI, 1.002–1.795).

There was no significant interaction of asthma with any covariate on severe tooth loss in this study.

Table 1. Characteristics of study-population, overall and by severe tooth loss^{a,b}.

Category	Total (study-population) N = 185,778,939 (100%)		No severe tooth loss n = 169,475,418 (91.22%)	Severe tooth loss n = 16,303,521 (8.78%)	p-value ^c
	(N)	(%)	(%)	(%)	
Age (Years)					<.0001
18-30	34,641,218	18.65	99.82	0.18	
31-44	48,491,637	26.10	98.29	1.71	
45-64	69,035,420	37.16	90.84	9.16	
>=65	33,610,664	18.09	72.96	27.04	
Gender					0.61
Male	90,928,197	48.94	91.37	8.63	
Female	94,850,742	51.06	91.08	8.92	
Race/Ethnicity					<.0001
Mexican American	15,628,584	8.41	96.93	3.07	
Other Hispanic	10,580,037	5.69	92.66	7.34	
Non-Hispanic White	124,649,066	67.10	90.59	9.41	
Non-Hispanic Black	21,031,995	11.32	88.99	11.01	
Others/Multi-Racial	13,889,257	7.48	92.76	7.24	
Nativity					0.001
Foreign-Born	33,107,210	17.83	93.53	6.47	
US Born	152,585,314	82.17	90.72	9.28	
Educational Attainment					<.0001
<High School	32,100,012	17.29	80.52	19.48	
High School	40,562,171	21.85	87.85	12.15	
>High School	112,965,151	60.86	95.48	4.52	
Ratio of family income:poverty					<.0001
< 1	27,156,734	15.69	85.92	14.08	
>=1	145,929,152	84.31	92.25	7.75	
Marital Status					<.0001
Never Married	29,634,164	16.56	95.63	4.37	
Married	102,244,604	57.12	92.42	7.58	
Others	47,117,923	26.32	84.59	15.41	
BMI					0.13
Normal	56,152,141	30.45	92.18	7.82	
Over-weight	61,693,625	33.45	91.53	8.47	
Obese	66,590,618	36.10	90.45	9.55	
Diabetic Status					<.0001
Non-diabetic	155,895,889	83.99	92.97	7.03	
Pre-diabetic	12,147,143	6.54	87.53	12.47	
Diabetic	17,573,176	9.47	78.26	21.74	
Smoking					<.0001
Current	34,328,167	18.91	84.39	15.61	
Former	44,725,190	24.64	86.49	13.51	
Never	102,430,799	56.44	95.22	4.78	
Asthma					<.0001
Current-asthmatics	16,708,176	8.99	86.86	13.14	
Never-asthmatics	169,070,763	91.01	91.66	8.34	

^aWeighted N/Weighted %.^bColumn % in "Total" column; row % in other columns.^cRao-Scott Chi-Squared test of association between each independent variable and severe tooth loss.

Discussion

Findings from this study revealed significant association between asthma and severe tooth loss in US adult population (p value < 0.0001 by Chi-squared test). Accordingly, by logistic regression analysis, current-asthmatic adults in the US have 34% higher odds of severe tooth loss in reference to never-asthmatic adults after controlling for the important known confounding factors including age, race or ethnicity, gender, diabetes, BMI, smoking, education, and family income-to-poverty ratio.

Our findings are supported by previous studies conducted in a number of different populations (26,27,38,40). However, the use of self-reported data

to measure tooth loss in the many of those studies (26,38,40) was a major limitation. While findings from our study are compatible with prior research, they are not consistent with a few studies revealing non-significant observations from their fully adjusted models (39,40).

Overall, only a few studies have examined the association between asthma and tooth loss, and their findings are not consistent. Such inconsistencies in findings from previously conducted studies could be attributable to differences in study-populations' characteristics and variations in measuring and categorizing the tooth loss. Further, the differences in the age-groups of study populations may be directly related to differences in prevalence of asthma and/or

Table 2. Association between asthma and severe tooth loss.

Models		Severe tooth loss Odds ratio (95% Confidence interval)
Model 1: Crude	Never-asthmatic	Reference
	Current-asthmatic	1.661 (1.322 – 2.088)
Model 2: Adjusted	Never-asthmatic	Reference
	Current-asthmatic	1.538 (1.180 – 2.003)
Model 3: Adjusted	Never-asthmatic	Reference
	Current-asthmatic	1.512 (1.138 – 2.007)
Model 4: Adjusted	Never-asthmatic	Reference
	Current-asthmatic	1.341 (1.002 – 1.795)

Model 1: Unadjusted.

Model 2: Adjusted for age, race or ethnicity, gender, smoking, diabetes and BMI.

Model 3: Adjusted for age, race or ethnicity, gender, smoking, diabetes, BMI and education.

Model 4: Adjusted for age, race or ethnicity, gender, smoking, diabetes, BMI, education and family income:poverty ratio.

severe tooth loss. Nonetheless, collectively, the findings from published studies and our study emphasize the need for oral health promotion and risk assessment activities to prevent severe tooth loss and its consequences in the adult population currently suffering from asthma.

Asthma is a chronic disease (49), and the resulting morbidity may cause difficulties to follow regular dental appointment and maintaining good home care protocol. Primary care professionals can play a vital role in educating the asthmatic patients about their higher odds of severe tooth loss and the importance of its prevention by maintaining optimal oral health. Interprofessional collaboration and better medical-dental integration thus could improve overall health-care outcomes for current-asthmatic adults.

Our study has number of strengths. It was conducted exclusively in the adult population. The study-sample that we utilized was nationally representative. In contrast to the majority of the previously conducted studies (26,38,40), which measured tooth loss by using self-reported data, we used objective clinical data collected by the calibrated licensed dental professionals to measure severe tooth loss. The NHANES data provided a unique opportunity to study the relationship between asthma and severe tooth-loss in a large sample of multiethnic US adults. In addition, this study addresses a number of known potential confounders by controlling for age, race or ethnicity, gender, diabetes, smoking, BMI, education, and income to poverty ratio in this population. To the best of our knowledge, this is the first large population-based study conducted in the nationally representative sample of the US adult population, especially by utilizing reliable objective clinical dental examination data from the NHANES, to examine the association between asthma and severe tooth-loss.

However, there are several limitations of this study. Given the cross-sectional nature of the NHANES, we could not assess duration, control, and severity of asthma in this study. Furthermore, this study was limited by the absence of information about treatment of asthma - an underlying plausibility for poor oral health in current-asthmatics. Many potential explanatory variables such as C-reactive protein level, genetics, nutrition, fluoride, access to healthcare were not included because those data were either not available or limited to data collected in the NHANES in specific years only. Therefore, the regression analyses in this study were limited to only those important variables, namely, common demographic factors, BMI, diabetes, smoking, and socioeconomic status, which were consistently available directly from all three NHANES datasets released in 2009–2010, 2011–2012, and 2013–2014 cycles. Moreover, diet and oral hygiene status were not considered, and hence confounding by these variables might be present in the regression models. Lastly, although physician-diagnosis of asthma was directly reported by the study-participants, it is considered to have a high level of validity and reliability (50,51).

Our study could not establish the biological plausibility between asthma and severe tooth loss. Several hypotheses link asthma and poor oral health through chronic inflammatory mediators, combination of mouth breathing and xerostomia, adverse effects of anti-asthmatic agents, dysbiotic oral flora, and decrease in bone mineral density resulting from the long-term use of inhalation corticosteroids - commonly used in the management of asthma. Asthma per se may not directly cause severe tooth loss, however, severe tooth loss could be a marker of untreated past periodontal disease and/or dental caries in current-asthmatic adults. Additionally, both asthma and tooth loss are related to low socioeconomic status (52,53). Therefore, another rationale for the association between asthma and severe tooth loss could be inadequate or lack of access to healthcare.

This is a cross-sectional study, and therefore, no claim can be made regarding the causation between asthma and severe tooth loss. Longitudinal research, examining the impact of duration, control, and severity of asthma on dentition using reliable objective clinical data is warranted to further understand this relationship.

Conclusion

Findings from this study suggest a link between asthma and severe tooth loss in the US adult

population. Current-asthmatic adults are more likely to have severe tooth loss as compared to never-asthmatic adults. Our research highlights the need for the continued interprofessional collaboration to address oral health for asthmatic adult patients. It opens a new direction for prospective research to clarify the potential role of asthma in severe tooth loss.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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