Impact of Socioeconomic and Behavioral Factors on Oral Health of Adult Americans: Analysis of the 2011-2016 NHANES Data

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ABSTRACT

Oral health is a critical determinant of overall health with reported links to adverse chronic conditions such as cardiovascular disease. Several risk factors related to lifestyle behaviors and socioeconomic characteristics have direct influence on the oral health status. In order to establish specific oral health care measures the relationship of demographics and behavioral factors specifically dietary and smoking habits with oral health was examined. The individual socio-demographic and major dietary characteristics were analyzed using univariate models, while the interaction of these factors with general oral health was evaluated as a multivariate model using a binary logistic regression. The dataset from 2011-2016 National Health and Nutrition Examination Survey targeting civilian, non-institutionalized adults living in the 50 States of USA and the District of Columbia was used to conduct this secondary analysis. Findings indicate health insurance was associated with a lower risk for urgent dental treatment [$F(1, 47)=212.2$, $P< 0.001$] and untreated dental caries ($OR = 1.6$, $P<0.001$). Older age group was found to experience more tooth loss ($OR =19.9$, $P< 0.001$) and less likely to suffer from dental decay ($OR =077$, $P=0.007$), while African-Americans were more likely to experience both dental decay and tooth loss ($OR =1.75$, $P<0.001$, $OR =2.2$, $P<0.001$, respectively). The prevalence of tooth decay in U.S adults aged 20 years and above was approximately 21%. Current smokers [$F(2, 94) = 143$, $P < 0.001$] and males [$F(1, 47)=64.4$, $P < 0.001$] were more likely to need urgent dental care. Higher sugar intake was associated with poor oral health. Modifiable unhealthy lifestyle behaviors, gender, age, ethnicity and health insurance are important predictors of poor oral health status in adult population. Collectively, these findings provide important insights into the relationship between multiple behavioral as well as socioeconomic factors and oral health that have considerable public health implications and can be an important measure to monitor the progress of health promotion goals set by public health programs.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

I INTRODUCTION

1.1 Background of the Problem

According to the World Health Organization (WHO) in 1946, health is defined as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.[1] The inclusion of social well-being extended the definition of health and resulted in a paradigm shift in the concept of health and health care delivery.[2]

There is a self-evident connection between health and stability of societies and governments. When diseases are coupled with poverty, lack of education and other social problems, they can destabilize nations and societies.[3] The nature and patterns of diseases have changed since 1946, when most patients suffered from acute diseases. Nowadays, chronic conditions present as the main disease burden, while chronic diseases led to early death in the 1940s. With new screening technologies, current improved public health measures and advanced medical interventions, the percentage of population living with chronic conditions for decades is increasing worldwide.[4] In a survey of elderly people affected by chronic disease in the United States, Wilson et al. reported that 87.5% of individuals had at least one chronic condition, while 32.5% of individuals were affected with three or more chronic conditions.[5]

Following the shift in the concept of health from biological to bio-psychosocial, researchers and healthcare professionals began to recognize and study the existence of health related quality of life in medicine and dentistry.[6]

It is well established that oral health is inseparable from general physical health and mental well-being.[7] Smiling, talking, eating and other routine daily activities are also determinants of a person’s well-being. Since oral health contributes to general health, understanding what constitutes oral health is very important.[2]

1.2 Statement of the Problem

Currently, there is a growing concern about the impact of oral diseases on the overall health and quality of life of an individual.[8] Good oral health is integral to general health and plays an important role in our everyday activities. However, it is often taken for granted. Oral and dental diseases such as oral cancer, periodontal (gum) disease, dental caries and tooth decay (cavities) affect millions in the United States.[9] These conditions influence the individual’s physical, psychological and social well-being, causing pain and discomfort, emotional suffering, dysfunction and even disfigurement. Oral and dental pain in children is one of the reasons for their absence from school, which affects their school performance.[10] These conditions also affect the individual’s social roles and general physical functions like eating and communication. Around one-fourth of adults in the United States aged 65 and older have lost all of their teeth, affecting chewing abilities and limiting food choice.[9, 11]

Various studies have suggested that oral infections are significantly associated with general health.[12] Teeth infections and periodontal inflammations may cause spread of infection through the blood. Additionally, oral infections have been found to be associated with several systemic diseases such as cardiovascular disease, low birth weight, preterm pregnancy, diabetes mellitus and respiratory diseases.[13] Moreover, each year oropharyngeal and oral cancers lead to the death of more than 7,600 people .[9]

1.3 Objectives

The aim of the current study was to undertake a secondary analysis of the NHANES 2011-2016 dataset in order to investigate socio-demographic, behavioral and dietary factors associated with oral health in the US adult population. Specifically, the focus was to determine any association between having health insurance and oral health. Furthermore, the study aimed to determine the association between the daily intake of the three major dietary nutrients (sugar, protein and carbohydrates) and oral health.

1.4 Research Hypotheses

Previous studies have suggested that oral health status in children is usually affected by social dimensions and circumstances, such as income and level of education of their parents.[14] Furthermore, psychosocial and psychological attributes in children were shown to be affected by childhood circumstances, such as parenting quality, family structure and home environment.[15] With socio-economic status as a major determinant of oral health and hygiene, the other causes of poor oral health include smoking, alcohol or drug usage.[16]

Smoking, which is highly prevalent among individuals dependent on alcohol, is one of major risk factors causing detrimental effects on general and oral health worldwide.[17,18] Furthermore, tobacco smoking is known to increase the risks of oral and oropharyngeal cancer and periodontal disease.[19,20]

We performed a secondary analysis of the NHANES 2011 – 2016 data to assess whether socioeconomic and behavioral factors influence the oral health of 20+ years old adults living in the US. Income to poverty ratio, education, and health insurance were used as measures of socioeconomic status. We hypothesized that higher education, higher income and having life insurance would be associated with better oral health.

The association of demographic factors (gender, age group, race, and country of origin) with oral health was evaluated for statistical significance. We hypothesized that oral health would show a statistically significant association with at least one or more of these demographic characteristics.

Behavioral factors included smoking and we hypothesized that non-smokers would have a better oral health compared to smokers. We also hypothesized that former smokers would exhibit a better oral health profile compared to the current smokers. Dietary factors included daily sugar, carbohydrate and protein intake. We hypothesized that higher sugar, carbohydrate and lower protein intake would be associated with better oral health. Research study hypotheses are summarized in Table 1.4-1.

Table1.4- 1 Research questions, hypothesis, outcomes, independent variables and statistical procedures included in the study.

Research questions	**H**	**IV**	**DV**	**Statistical procedure**
Is gender significantly associated with the overall recommendation for health?	H1	gender	overall recommendation for health	Chi-square and logistic regression
Is age significantly associated with the overall recommendation for health?	H2	age	overall recommendation for health	Chi-square and logistic regression
Is income significantly associated with the overall recommendation for health?	H3	Poverty to income	overall recommendation for health	Chi-square and logistic regression
Is education significantly associated with the overall recommendation for health?	H4	education	overall recommendation for health	Chi-square and logistic regression
Is country of birth significantly associated with the overall recommendation for health?	H5	Country of birth	overall recommendation for health	Chi-square and logistic regression
Is health insurance significantly associated with the overall recommendation for health?	H6	Health insurance	overall recommendation for health	Chi-square and logistic regression
Is smoking significantly associated with the overall recommendation for health?	H7	Smoking	overall recommendation for health	Chi-square and logistic regression
Is race significantly associated with the overall recommendation for health?	H8	Race	overall recommendation for health	Chi-square and logistic regression
Is carbohydrate intake significantly associated with the overall recommendation	H9	Standardized Carbohydrate intake	overall recommendation for health	Chi-square and logistic regression

for health?				
Is protein intake significantly associated with the overall recommendation for health?	H10	Standardized Protein intake	overall recommendation for health	Chi-square and logistic regression
Is sugar intake significantly associated with the overall recommendation for health?	H11	Standardized Sugar intake	overall recommendation for health	Chi-square and logistic regression
Is gender significantly associated with the presence of missing teeth?	H12	gender	Presence of missing teeth	Chi-square and logistic regression
Is age significantly associated with the presence of missing teeth?	H13	age	Presence of missing teeth	Chi-square and logistic regression
Is income significantly associated with the presence of missing teeth?	H14	Poverty to income	Presence of missing teeth	Chi-square and logistic regression
Is education significantly associated with the presence of missing teeth?	H15	education	Presence of missing teeth	Chi-square and logistic regression
Is country of birth significantly associated with the presence of missing teeth?	H16	Country of birth	Presence of missing teeth	Chi-square and logistic regression
Is health insurance significantly associated with the presence of missing teeth?	H17	Health insurance	Presence of missing teeth	Chi-square and logistic regression
Is smoking significantly associated with the presence of missing teeth?	H18	Smoking	Presence of missing teeth	Chi-square and logistic regression
Is race significantly associated with the presence of missing teeth?	H19	Race	Presence of missing teeth	Chi-square and logistic regression
Is carbohydrate intake significantly associated with the presence of missing teeth?	H20	Standardized Carbohydrate intake	Presence of missing teeth	Chi-square and logistic regression

Is protein intake significantly associated with the presence of missing teeth?	H21	Standardized Protein intake	Presence of missing teeth	Chi-square and logistic regression
Is sugar intake significantly associated with the presence of missing teeth?	H22	Standardized Sugar intake	Presence of missing teeth	Chi-square and logistic regression
Is gender significantly associated with the presence of decayed teeth?	H23	gender	Presence of decayed teeth	Chi-square and logistic regression
Is age significantly associated with the presence of decayed teeth?	H24	age	Presence of decayed teeth	Chi-square and logistic regression
Is income significantly associated with the presence of decayed teeth?	H25	Poverty to income	Presence of decayed teeth	Chi-square and logistic regression
Is education significantly associated with the presence of decayed teeth?	H26	education	Presence of decayed teeth	Chi-square and logistic regression
Is country of birth significantly associated with the presence of decayed teeth?	H27	Country of birth	Presence of decayed teeth	Chi-square and logistic regression
Is health insurance significantly associated with the presence of decayed teeth?	H28	Health insurance	Presence of decayed teeth	Chi-square and logistic regression
Is smoking significantly associated with the presence of decayed teeth?	H29	Smoking	Presence of decayed teeth	Chi-square and logistic regression
Is race significantly associated with the presence of decayed teeth?	H30	Race	Presence of decayed teeth	Chi-square and logistic regression
Is carbohydrate intake significantly associated with the presence of decayed teeth?	H31	Standardized Carbohydrate intake	Presence of decayed teeth	Chi-square and logistic regression
Is protein intake significantly associated with the presence of	H32	Standardized Protein	Presence of decayed teeth	Chi-square and logistic

decayed teeth?		intake		regression
Is sugar intake significantly associated with the presence of decayed teeth?	H33	Standardized Sugar intake	Presence of decayed teeth	Chi-square and logistic regression

CHAPTER II

II LITERATURE REVIEW

2.1 Oral health related quality of life

Tooth loss and Dental caries can be viewed as proxies for oral health and access to dental care. They are also important measures to monitor the progress towards health promotion goals set by Healthy People 2020.[21] Evidence shows that tooth decay and complete tooth loss have been declining since the early 1960s in the United States. However, there are still disparities between some groups such as age.[22,23] The quality of life related to oral health is inversely affected by dental caries and tooth loss.[24] Tooth decay, also known as dental caries, is a preventable disease that can result in high costs to the society, families, and individuals. These costs are attributed to pain and decreased quality of life due to caries that are left untreated, visits to the emergency room, higher risk of future caries, and missed days at school and work.[25]

2.2 Impact of socio-economic status on oral health and oral health-related quality of life

Socio-economic status are key determinants of current and future health outcomes. In the United States, approximately seven million children are suffering from poverty, and more than one million children are living in extreme poverty.[26] Several studies have reported that the socio-economic situation is negatively associated with the status of oral and dental diseases, which means the lower the socio-economic status, the lower the perception of oral health, the worse the quality of life and the higher rate of diagnosed oral and dental diseases.[27, 28]

With levels of education and income of the family and individual as the most relevant indicators for socioeconomic status, low family income and low parental educational level are proven risk factors for oral health problems and are significantly associated with poor dietary and oral hygiene habits as well as low oral health literacy. Neighborhood poverty, material and facilities deprivation, unmet dental care needs, less social support and less access to home and professional preventive healthcare services, among other factors, are associated with a greater risk poor oral health and poor oral health–related quality of life.[29-32]

According to reports of Centers for Disease Control and Prevention (CDC), half of all children with oral health and dental problems came from families with low socio-economic status. Children from lower-income families have more rates of untreated decay. For instance, approximately 40% of Mexican American children aged 6–8 were reported to have untreated dental decay, while 25% of non-Hispanic whites had dental decay.[9]

On the other hand, parental high income and high education play an important role in better children's oral health and better oral health-related quality of life.[33] Children of high-income families are more likely to have better health literacy and a higher rate of dental visits; adhere to preventive recommendations; and less likely to have untreated dental caries compared to children of low-income families.[34] Additionally, parental age, especially the mother's, has been shown to be significantly associated with better health-related quality of life in children. Younger and wealthier mothers seem to be less secure in caring for their children's health.[33, 35]

Dental visits provide are an excellent opportunity that allow for provision of preventive services, and appropriate oral health education. They also allow for the management and treatment of painful problems. Many factors affect dental care utilization. However, the cost of such service is a considerable barrier for low-income families. Presence of dental insurance coverage can help overcome this barrier and assist in improving appropriate dental care utilization.[6]

2.3 Impact of smoking behavior on oral health and oral health-related quality of life

Smoking is well-recognized as one of the major preventable risk factors that have damaging and harmful effects on general and oral health worldwide.[17] In 2010, the main three risk factors in the burden of disease worldwide were found to be high blood pressure, tobacco smoking and alcohol use.[36] The burden of smoking-related diseases on the individual, society and nation as well as the costs of treating such diseases are increasing worldwide.[37, 38]

Apart from being one of the most important determinants of cardiovascular diseases, chronic obstructive airway diseases, cancer and premature deaths, smoking is also a known threat to oral health. Several studies have reviewed the impact of smoking behavior on oral health including second-hand smoking. A positive association between tobacco smoking and increased prevalence and severity of periodontal disease and tooth loss has been reported by various studies.[39,40] According to CDC, tobacco smoking contributed to at least half of the cases of severe periodontal diseases in the United States. The rates of severe periodontal disease in smokers are three times as those in people who have never smoked.[9] In addition, smokers have an increased risk of dental caries,[41,42] precancerous lesions,[43] inflammation,[44, 45] teeth discoloration,[46] and plaque accumulation.[47] Heavy cigarette smoking has been also associated with acute necrotizing ulcerative gingivitis and oral cancer.

CHAPTER III

III METHODS

3.1 NHANES 2011 - 2016 overview

The target population for the National Health and Nutrition Examination Survey (NHANES) 2011 – 2016 was the civilian, non-institutionalized individuals living in the 50 States of USA and the District of Columbia. A stratified, multistage probability sampling design was used to select participants. The aim of such complex design is to select a sample representative of the non-institutionalized, civilian resident population of the United States. Sampling domains were defined by gender, age, race, and income state. The complex sampling design also oversamples some population subgroups so that more precise estimates can be obtained for these groups. Examples of the oversampled subgroups include Hispanics, non-Hispanic Blacks, non-Hispanic Asians, some low-income persons, and non-Hispanic white and individuals over 80 years. All data collection protocols were approved by the NCHS Research Ethics Review Board with informed consent obtained for all participants.[48]

Participants were interviewed in their homes and then provided with a complete health examination. Following household identification and the administration of a screening questionnaire by field interviewers to determine whether participants were eligible or not, an informed consent was obtained for the home interview. Home interviews were conducted to collect the socio-demographic and health-related information. Trained interviewers conducted the home interview, which included the two main sections of the household and sample participant interviews.

Following completion of the interview at home, interviewed participants were asked to participate in a health examination at a mobile examination center (MEC) and undergo a second series of informed consent procedures for the health examination. The complete health examination included collection of biological samples for laboratory testing, and a standardized physical examination. Participants also completed a dietary behavior questionnaire and a 24-hour dietary recall. The first 24-hour recall for each participant was conducted in-person dietary interviewers. The detailed information regarding NHANES data collection and methodology has been described previously.[49]

3.2 Survey weights

The final sample weight for each participant at each stage is calculated as the product of the base weight, the nonresponse adjustment, the trimming adjustment (if needed), and the post-stratification adjustment. Thus, the final screening weight is equal to the product of the base weight, the adjustment factors for nonresponse, post-stratification for screen stage, and trimming. The final weights resulting from the screening stage are equal to the base weights for the interview stage. The final interview weight was then calculated by multiplying the screen weight, adjustment factors of nonresponse, post-stratification for interview stage, and trimming. The final weights produced from the interview stage represent the base weights for the MEC examination stage while the final MEC examination weights were calculated as the product of the interview weight, adjustment factors for nonresponse, post-stratification for examine stage, and trimming.

For the combined datasets, new survey weights need to be calculated according to the NHANES recommendations.[50] For the current analysis, these weights were calculated by dividing the MEC survey weights by a factor of three. After combining the datasets for multiple survey cycles and adjusting the sample weights, the sum of combined weights should be reasonably close to an independent estimate of the USA non-institutionalized civilian population at the middle point of the combined interval. Combining multiple cycles of the NHANES data increases the sample size which provides more accurate estimates. This is particularly useful for analysis of small subgroups and rare events. However, using the combined cycles for estimation is based on the assumption of equal estimates across cycles and that the observed difference is merely due to random variation i.e. the absence of increasing or decreasing trends. As recommended, the newly calculated examination weights for the 2011 – 2016 cycles were used for the analyses of data. Examination weights (MEC) were used rather than the home interview weights as recommended by the CDC as data from the home interview and examination phases were combined to answer the needed research questions. Thus, weights from the latter stage (MEC) should be used.

3.3 Study population

We included US adults aged 20 years and older from the three NHANES cycles 2011-2012, 2013-2014, and 2015-2016. We excluded individuals less than 20 years old to ensure that only adults are included so that the sample is homogenous.

3.4 Independent variables

3.4.1 Demographic characteristics

Age, sex, ethnicity, education, income to poverty ratio (PIR) and smoking were defined using self-reported demographic data from 2011 - 2016 NHANES. Age was transformed into a categorical variable as follows: 20 - 39 years, 40 – 60 years, and greater than 60 years. Race and ethnicity were determined based on responses to questions about race and Hispanic origin. The sample participants were classified as either: Non-Hispanic white, Non-Hispanic African American (AA), Hispanic, and other. We only included individuals who reported a single racial identity as the group sample sizes were adequate for separate evaluation and estimates.[51] Level of education was categorized as less than high school, high school/equivalent, and some college education or more.

The Income to poverty ration (PIR) is a ratio of family income to the Health and Human Services (HHS) federal poverty threshold which accounts for inflation and family size. A PIR below 1 indicates that the family income is less than 130% of the poverty threshold, a PIR of 1–3 corresponds to 131% - 185% of the poverty threshold, and a PIR of greater than 3 corresponds to income greater than 185% of the poverty threshold i.e. higher PIR indicates better socioeconomic status. PIR was changed into a categorical variable as follow: < 100%, 100 – 300%, and 300% or greater. Health insurance was recoded as a yes/no variable. No insurance was used as the reference category when doing the analysis. Smoking status was determined based on the combined responses to the two questions

SMQ020 and SMQ04. Respondents were classified into non-smokers (< 100 cigarettes in life), former-smokers (smoked > 100 cigarettes in life and not smoking currently), and current smokers (smoked > 100 cigarettes in life and smoking currently). Age, gender, PIR, health insurance status, education, smoking status, and country of birth were used as independent variables for the analysis.

3.5 Diet

Four data files were produced from the information collected in the dietary interviews of the NHANES: two files contained the total nutrient intakes and two files the individual Foods. For the total nutrient intake files, each file included data for one day of food intake. These files contained information on nutrients obtained from foods, beverages, and water, including tap and bottled water. They did not include nutrient intake from dietary supplements, intake of antacids or medications. The current secondary analysis was concerned with total daily dietary intake of proteins (gm), total sugar (gm), and carbohydrates (gm). Prior to the analysis, the intake was standardized (%) for each 1000 Kcal total daily energy intake to take into account the variability in energy needs between participants and to provide a more accurate estimate of the proportion that these foods represent relative to energy consumption. Participants were categorized into tertiles (Q1, Q2, Q3) based on their self-reported intake (after standardization) for each of the three nutrients. Analysis was performed across tertiles.

3.6 Dependent variables

Three main variables were used as indicators of oral health: the overall recommendation for care for oral health (OHR), current presence of any dental caries or decayed teeth (DT), and presence of any missing teeth due to other dental reasons (MT).

3.6.1 Overall recommendation for care for oral health

We examined factors associated with the overall recommendation for care for oral health. The variable was dichotomized into "routine care needed" and "more than routine or urgent care needed". Urgent care was defined as one of the three flowing recommendations: see a dentist immediately, see a dentist within two weeks, or see a dentist at the earliest convenience. All urgent care needs were used in the analysis.

3.6.2 Presence of decayed teeth (dental caries)

We used information about the presence or absence of caries in primary or permanent teeth to create a measure for the presence of any untreated caries (decayed teeth, DT > 0). This measure provides an approximate measure of the participant's access to dental health. Participants with missing teeth were excluded from the measure of dental caries because these teeth could be missing due to natural reasons. Participants with all missing teeth (n = 28) were also excluded from the analysis. The number of decayed teeth was calculated for each participant. Dental decay (DT) was defined as the presence of at least one tooth with untreated decay or caries.

3.6.3 Presence of missing teeth

During the examination stage, the teeth for each participant was examined by trained oral health professionals. The status of each tooth was reported as follow: sound, missing due to dental disease, missing due to dental disease but replaced, missing due to other causes, tooth with surface conditions, and unerupted. The tooth was classified as missing if it was reported as missing due to dental disease, missing due to dental disease but replaced. Individuals with lost teeth as a result of trauma were excluded from the analysis. For each participant, the number of teeth missing due to dental disease was calculated. The variable was then dichotomized (yes/no) based on whether the participant lost any teeth (MT). The newly computed variable was used as the outcome for the analysis.

3.7 List of variables

All the data variables that were used in the analysis are described in Table 3.7-1.

Table 3.7- 1 Data variables included in statistical analysis.

Study parameter	**Variable name**	**Variable label**
Age	RIDAGEYR	Age in years at screening; Continuous variable
Ratio of family income to poverty	INDFMPIR	Continuous variable
Country of birth	DEBORN	1 = Born in 50 US states or Washington, DC, 2 = Others; categorical variable

Education level - Adults 20+	DEDEDUC2	1 = less than 9th grade, 2 = 9 – 11th grade (includes 12th grade with no diploma), 2 = high school graduate/GED or equivalent, 3 = some college or AA degree, 4 = some graduate or above, 7 = refused, 9 = don't know; categorical variable.
Gender	RIADENDR	1 = male, 2 = female; categorical variable.
Race	RIDRETH3	1 = Mexican American, 2 = Other Hispanic, 3 = Non-Hispanic white, 4 = Non-Hispanic black, 6 = Non-Hispanic Asian, 7 = other race - including multi-racial; categorical variable.
Smoking	SMQ020	1 = yes, 2 = no, 7 = Refused, 9 = Don't know; categorical variable.
Health insurance	HIQ011	1 = yes, 2 = no, 7 = Refused, 9 = Don't know; categorical variable.
Protein (gm)	DR1TPROT	Day 1 intake of proteins Continuous variable
Carbohydrate (gm)	DR1TCARB	Day 1 intake of carbohydrates Continuous variable
Total sugars (gm)	DR1TSUGR	Day1 intake of sugars Continuous variable
Overall recommendation for care	OHAREC	1 = see dentist immediately, 2 = see dentist within the next 2 weeks, 3 = see dentist at earliest convenience, 4 = continue routine care
Tooth count	OHX##TC	1 = primary tooth, 2 = permanent tooth present, 3 = dental implant, 4 = tooth not present, 5 = permanent dental root fragment present, 9 = could not assess
Coronal caries	OHX##CTC	A= primary tooth with restored surface condition, D = sound primary tooth, E= missing due to dental disease, F = Permanent tooth with a restored surface condition, J = Permanent root tip is present but no restorative replacement is present, K = Primary tooth with a dental carious surface condition, M = Missing due to other causes, P = Missing due to dental disease but replaced by a removable restoration, Q = Missing due to other causes but replaced by a removable restoration, R = Missing due to dental disease but replaced by a fixed

	restoration, S = Sound permanent tooth, T = Permanent root tip is present but a restorative replacement is present, U = Unerupted, X = Missing due to other causes but replaced by a fixed restoration, Y = Tooth present, condition cannot be assessed, Z = Permanent tooth with a dental carious surface condition

3.8 Statistical analysis

Statistical analysis was performed using the R 3.6.1 program. The survey package was used for the analysis to account for the complex survey design. Analyses were weighted using the newly computed six year weights for the sample of persons with examination data. Weighed percentages and standard errors were used to describe the socio-demographic, behavioral and health-related characteristics of the study sample. The un-weighted counts were also reported. Chi-square test was used to assess whether the distribution of the three dependent variables were significantly different across socio-demographic and behavioral characteristics. Pearson's Chi-square test with Rao & Scott adjustment was used instead of the conventional Chi-square test of independence to take the survey design into account.

Multivariate analysis was performed using binary logistic regression. The svyglm function in the survey package was used to account for the complex survey design. For each dependent variable, three models were constructed: The first model included insurance status in addition to socio-demographic, and behavioral characteristics (age group, sex, race, and country of birth, PIR, and smoking status). In the second model, the standardized tertile of sugar intake was added to the model. Standardized protein and carbohydrates intake was added to the third model. The models were compared using likelihood ratio test to assess whether the addition of the variables in steps 2, and 3 resulted in a statistically significant improvement in the model likelihood. Rao & Scott statistic was used for to assess the statistical significance of LRT test to take the complex survey design into account.[52] LRT was used to compare the models. The Nagelkerke R squared statistic was used to assess the predictive power of the model. Design-based estimators were used for computations as recommended.[53]

CHAPTER IV

IV RESULTS

4.1 Descriptive characteristics of the study sample

The combined data set included 29902 observation (17048 were 20+ years). Throughout the analysis, the term adult was used to describe participants who are 20+ years old. A total of 16381 participated in a health examination at a MEC. The Sampling design Characteristics for each of the cycles of NHANES 2011–2016 are shown in Table 4.1-1.

Table 4.1- 1 Sampling design characteristics for NHANES 2011 - 2016

Characteristic	**NHANES 2011 - 2012**	**NHANES 2013 - 2014**	**NHANES 2015 - 2016**	**Total**
Age	From birth	From birth	From birth	
Dental examination age	1+	1+	1+	
All ages interviewed in Home	9756	10175	9971	29902
All ages examined in MEC	9338	9813	9544	28695
20+ years MEC examined	5319	5588	5474	16381
20+ oral health examined*	4931	5204	5201	15336
20+ OHR	4857	5176	5200	15233

20+ with decayed teeth data	4557	4820	4856	14233
20+ with missing teeth data	4912	5202	5200	15314
Day 1 total dietary intake	4801	5047	5017	14865

*** Oral health examination (OHE) was marked as completed, or partial**
OHR: Oral health recommendation

The NHANES 2011 – 2016 data included the home interview results for 29902 participants. The MEC data was available for 28695 participants of which 16381 were 20+ years. OHE data was marked as completed or partial in 15336 participants. The overall OHR, missing teeth and decayed teeth data were available for 15233, 14233, and 15314 individuals, respectively. Day 1 total dietary intake (g/day) of sugar, carbohydrates, and proteins was available for 14865. After excluding participants with any missing data, 12064 complete observations were used in the final analysis.

Table 4.1-2 summarizes the characteristics of the study population. The analysis included 12064 participants without any missing data who completed the NHANES survey over the three cycles of interest. The proportions, as previously mentioned, were weighed to represent the average USA population at the midpoint for the three cycles. Males and females represented 49% and 51%, respectively. Regarding age, the three age groups included in the analysis (20 – 39, 40 – 59, and 60+ years) represented 38%, 38% and 24% of the study population, respectively. Non-Hispanic whites represented 68% of the study sample while non-Hispanic AA and Hispanics represented 11% and 14%, respectively. Regarding education, more than half of the included participants had a college degree or higher education (67%). Of the included adult population from USA, 83% (n = 9516) were with health insurance coverage, while 17% (n = 3473) did not have any insurance.

Table 4.1- 2 Weighted baseline proportions for 2011–2016 NHANES population

Variable	**% (SE)**	**Un-weighted n**
Gender:		
Male	48.749 (0.444)	5902
Female	51.251 (0.444)	6162
Age:		
20-39	38.442 (1.064)	4573
40-59	37.8 (0.741)	4157
60+	23.758 (0.772)	3334
Race		
Non-Hispanic white	67.682 (2.097)	4794
Non-Hispanic Black	10.582 (1.117)	2628
Hispanic	14.094 (1.431)	2896
Other	7.641 (0.537)	1746
Education:		
Less than high grade	12.666	2304
High school	20.603	2603
College degree or more	66.731	7157
Country:		
US	83.705	8591
Other country	16.295	3473
Insurance:		
Yes	83.146	9516
No	16.854	3473
Smoking status:		
Non	57.769	7041
Former	24.141	2727
Current	18.089	2296
PIR:		
<100%	14.575	2624
100-300%	35.307	4870
300% and more	50.118	4570
Overall OHR:		
Not-urgent (routine care needed)	56.81	5919
Urgent care needed	43.19	6145
Any decayed teeth:		
No	79.099	9006

Yes	20.901	3058
Any missing teeth:		
No	52.549	5289
Yes	47.451	6775
Daily CHO (gm/1000 Kcal):*		
Q1 (0,116 gm)	45.781	5078
Q2 (117,137 gm)	29.658	3695
Q3 (138,263 gm)	24.561	3291
Daily total Sugars (gm/1000 Kcal):*		
Q1 (0, 45 gm)	44.164	5201
Q2 (46, 66 gm)	31.071	3830
Q3 (67,250 gm)	24.766	3033
Daily protein (gm/1000 Kcal):*		
Q1 (0, 32 gm)	31.631	3730
Q2 (33, 41 gm)	32.326	3874
Q3 (42,159 gm)	36.043	4460

*** Variable was categorized into tertiles**
Results are shown as mean (SE)
PIR: Income to poverty index, Q: Tertile, OHR: Oral health recommendation

Non-smokers represented 58% of the included adult US population while former smokers and current smokers represented 24% and 18%, respectively. The PIR index was < 100% in 2624 (15%), 100 – 300% in 4870 (35%), and 300% and more in 50% of the included US adults.

Urgent care was needed in 43% (n = 6145) of adults living in USA included in this analysis while 57% (n = 6145) required only routine care. At least one decayed tooth was detected in 21% of this population during the oral examination phase and at least one tooth was missing (due to dental reasons) in 48% of these participants included in the analysis.

The standardized daily intake of carbohydrates (per 1000 Kcal) was 10 – 116 gm, 117 – 137 gm, and 138 – 263 gm in 46%, 30%, and 25% of this population included in the analysis, respectively. The standardized daily intake of total sugars (per 1000 Kcal) was 0

- 45 gm, 46 - 66 gm, and 67 - 250 gm in 44%, 31%, and 25% of the adult US population included in the analysis, respectively while the standardized daily intake of proteins was 0 – 32 gm, 33 – 41 gm, and 42 – 159 gm in 32%, 32% and 36% of the adult US population, respectively.

4.2 Unadjusted association of gender with oral health problems

Univariate statistical analysis using Chi-square test (with Rao-Scott adjustment) showed that there was a statistically significant association between gender and oral health problems (Figure 4.2-1). The proportion of adults with at least one decayed tooth was significantly higher in males compared to females (23% vs. 19%, respectively, $F = (1, 47) = 14.2$, $P < 0.001$). Urgent care was needed in 46% of adults males compared to 38% of adult females. The difference was statistically significant at the 0.1% level of significance, $F (1, 47) = 64.4$, $P < 0.001$. The proportion of adults with at least one missing tooth was not significantly different between males and females (47% vs. 47%, $F (1, 47) = 0.004$, $P = 0.953$).

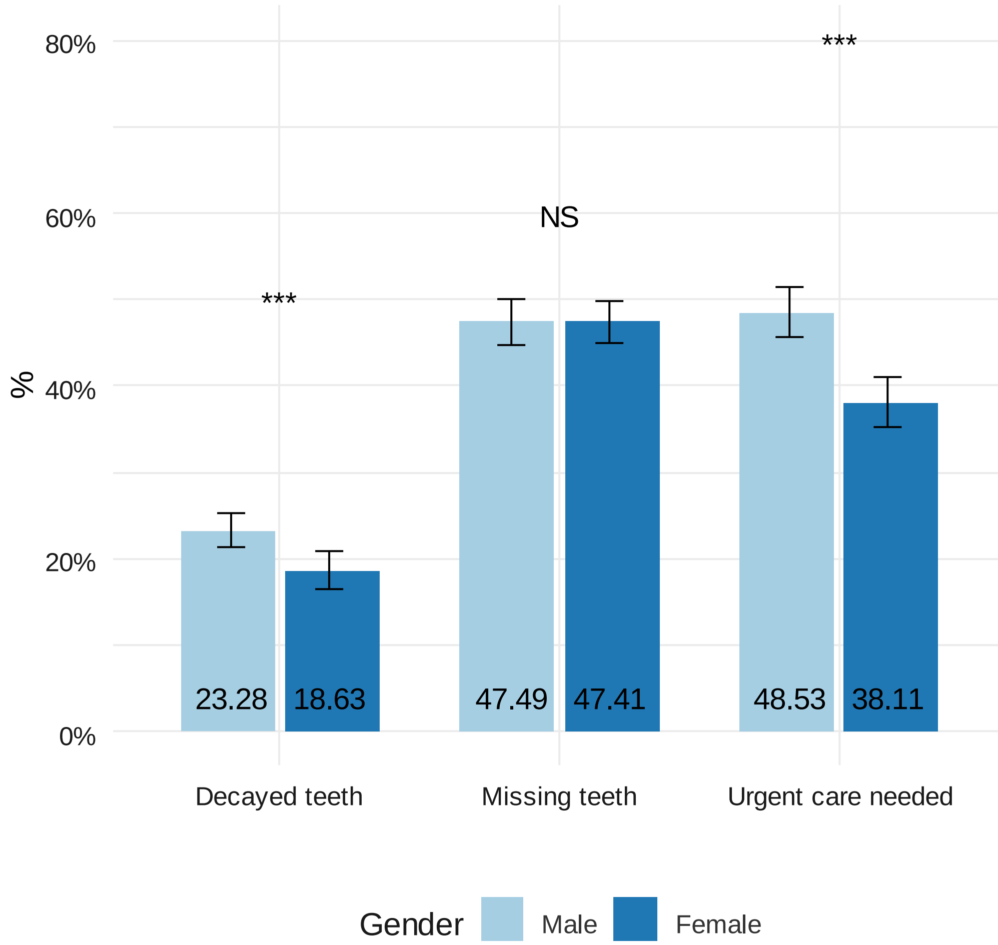

Figure 4.2- 1 Univariate association of gender with oral health problems

4.3 Unadjusted association of age category with oral health problems

Univariate statistical analysis using Chi-square test (with Rao-Scott adjustment) showed that there was a statistically significant association between age category and oral health problems (Figure 4.3-1). The proportion of adults with at least one decayed tooth decreased significantly with increasing age from 20 – 39 years to 60+ years (24% vs. 21% vs. 15%, respectively, $F = (2, 47) = 25.7$, $P < 0.001$). The proportion of adults with at least one missing tooth increased significantly with increasing age from 20 – 39 years to 60+ years (23% vs. 54% vs. 77%, $F (1, 47) = 282.3$, $P < 0.001$). Urgent care was needed in 38.3% of adults aged 20 – 39 years which was lower to the % observed in adults aged 40 – 59 years (47%) and 60+ years (46%). The difference was statistically significant at the 0.1% level of significance, $F (1, 47) = 11.48$, $P < 0.001$.

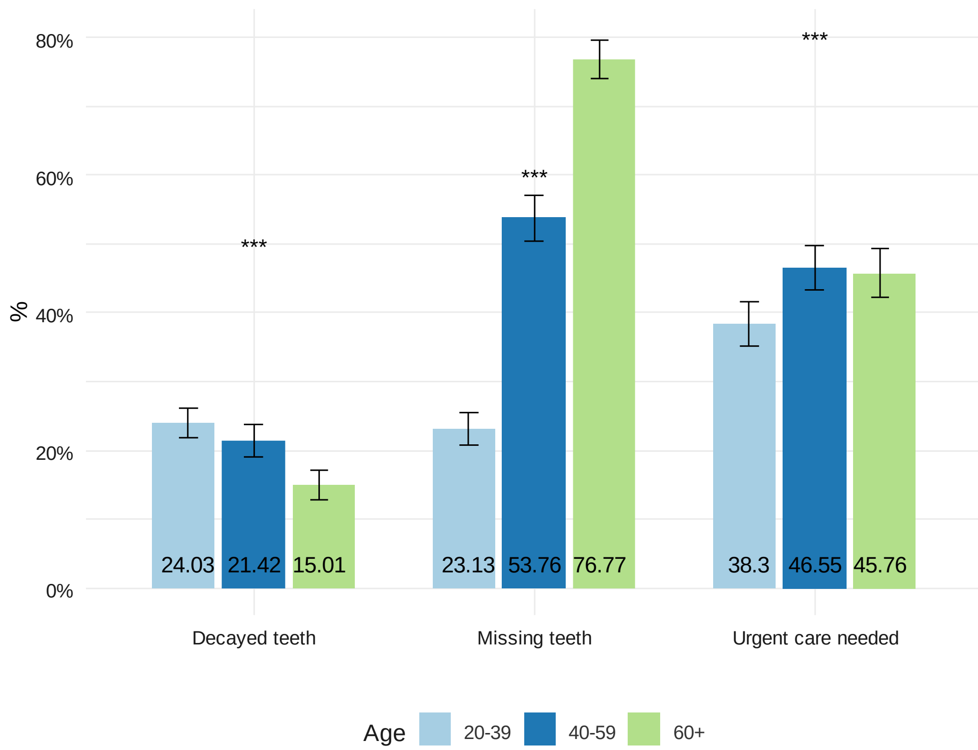

Figure 4.3- 1 Univariate association of age category with oral health problems

4.4 Unadjusted association of health insurance with oral health problems

Univariate statistical analysis using Chi-square test (with Rao-Scott adjustment) showed that there was a statistically significant difference in the distribution of participants with at least one decayed tooth across participants that had an insurance and participants that did not (Figure 4.4-1). The proportion of participants with at least one decayed tooth was higher in participants with no health insurance compared to participants with health insurance (38% vs. 17%, respectively, F = (1, 47) = 288, P < 0.001). There was also a statistically significant difference in the proportion of participants with at least one missing tooth between participants that had insurance and those that did not have (52% vs. 47%, F (1, 47) = 14.53, P < 0.001). Similarly, the overall OHR was significantly different between both groups. Urgent care was needed in 65% of individuals with no insurance compared to only 39% in individuals with insurance, F (1, 47) = 212.22, P < 0.001. These results support the association between health insurance and various metrics of oral healthcare

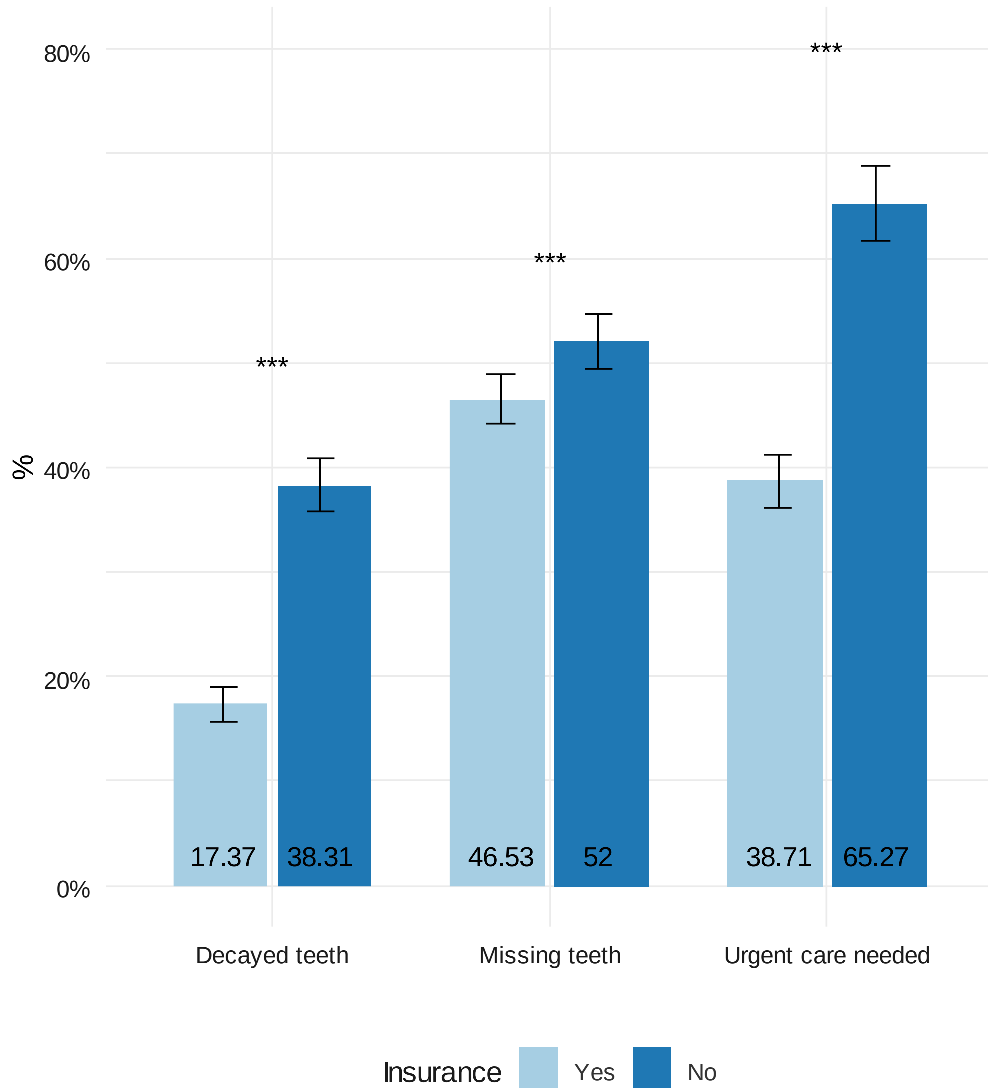

Figure 4.4- 1 Univariate association of health insurance with oral health problems

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4.5 Unadjusted association of country of birth with oral health problems

Univariate statistical analysis using Chi-square test (with Rao-Scott adjustment) showed that there was a statistically significant difference in the distribution of adults with at least one decayed tooth between the two groups (Figure 4.5-1). The proportion of participants with at least one decayed tooth was significantly higher in participants born outside the US compared to participants born in the US (23.4% vs. 20.41%, respectively, $F = (1, 47) = 6.3$, $P < 0.001$). The proportion of participants with at least one missing tooth was also higher in participants born outside the US compared to participants born in the US (54 % vs. 46%, $F (1, 47) = 25.4$, $P < 0.001$). Urgent care was needed in 50% of individuals born outside the US compared to only 42% of adults born in the US, $F (1, 47) = 16.2$, $P < 0.001$.

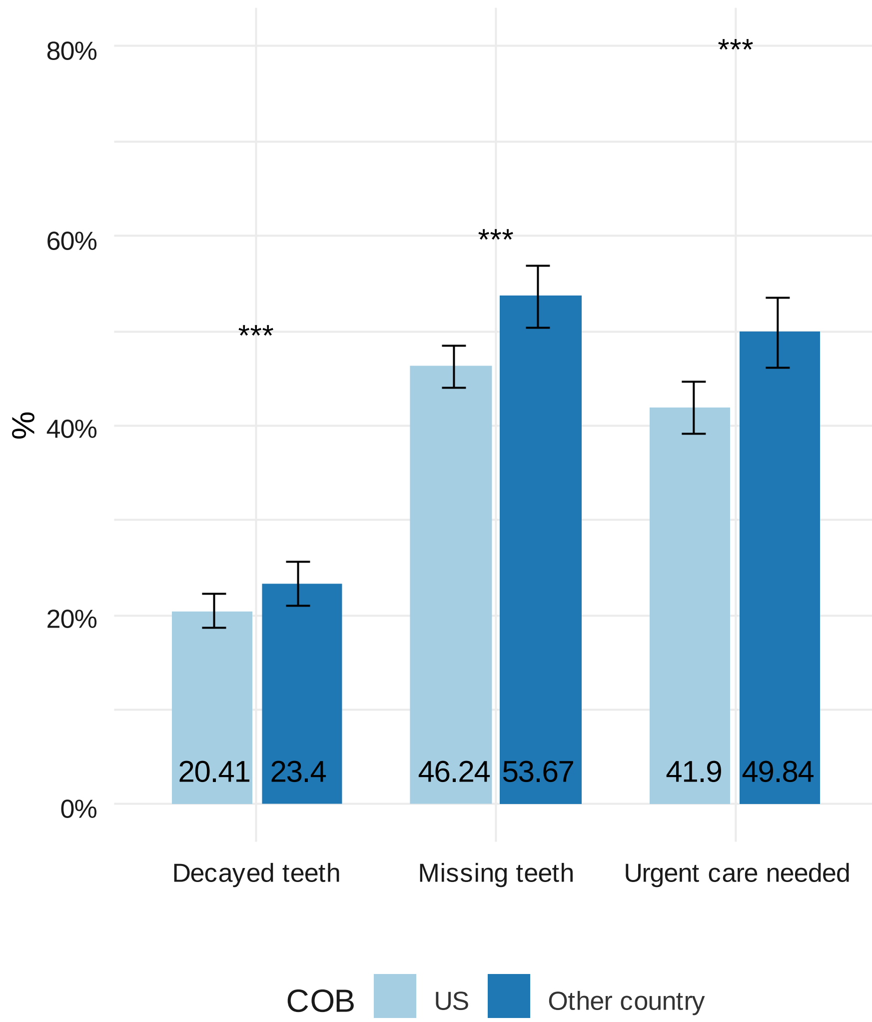

Figure 4.5- 1 Univariate association of country of birth with oral health problems

4.6 Unadjusted association of smoking status with oral health problems

A statistically significant association was observed between smoking status and oral health problems (Figure 4.6-1). The proportion of participants with at least one decayed tooth was significantly higher in current smokers compared to former and non-smokers (38% vs. 19% and 16%, respectively, F = (2, 94) = 126.9, P < 0.001). The proportion of participants with at least one missing tooth was significantly lower in non-smokers compared to former and current smokers (39 % vs. 59% and 58%, respectively, F (2, 93) = 109, P < 0.001). Urgent care was needed in 36% of non-smokers compared to 44% and 65% of former and current smokers, respectively, F (2, 94) = 143, P < 0.001.

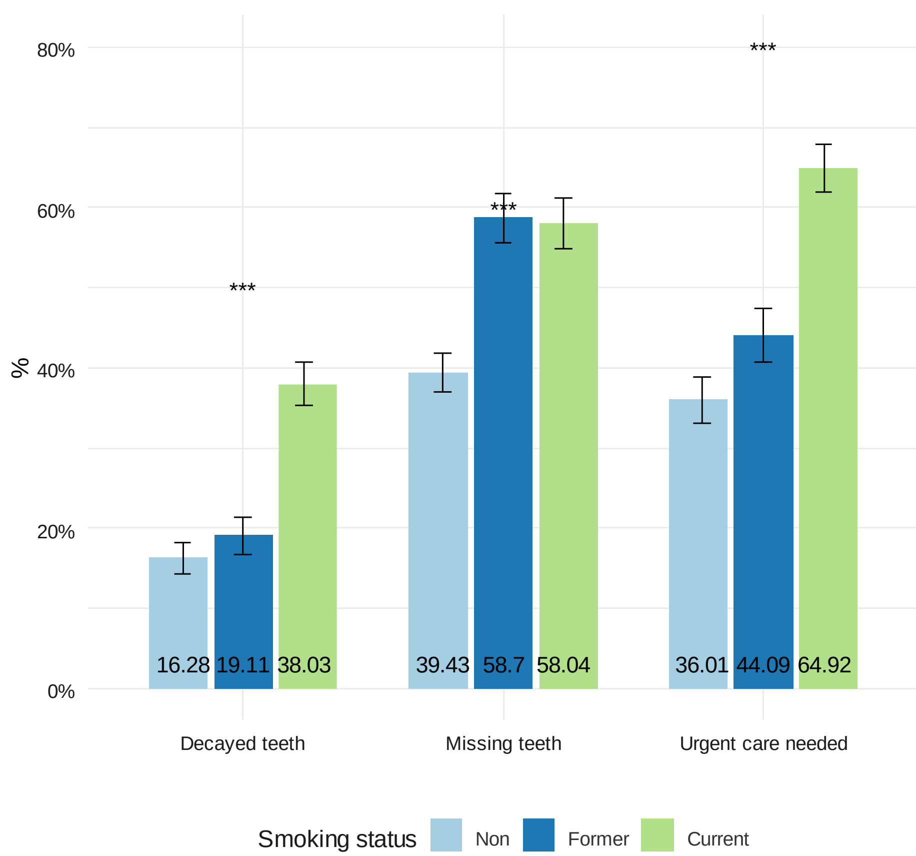

Figure 4.6- 1 Univariate association of smoking status with oral health problems

4.7 Unadjusted association of education with oral health problems

A statistically significant association was observed between education level and oral health problems (Figure 4.7.1). The proportion of adults with at least one decayed tooth decreased significantly with increasing level of education (40%, 30%, and 16%, in adults with less than high grade education, high grade education, and college degree or more, respectively, F = (2, 90) = 173, P < 0.001). A similar trend was observed for the proportion of adults with missing teeth, F (2, 94) = 94, P < 0.001, and adults who required urgent care, F (2, 94) = 109, P < 0.001.

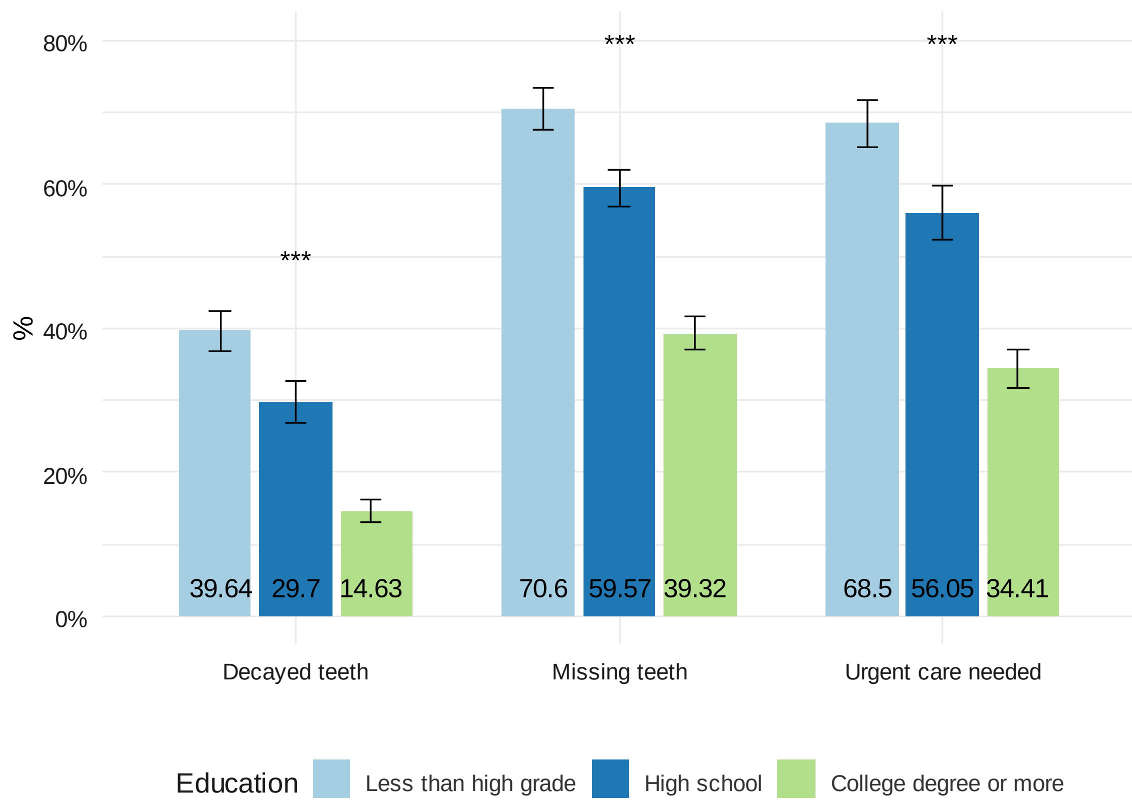

Figure 4.7- 1 Univariate association of education with oral health problems

4.8 Unadjusted association of PIR index with oral health problems

A statistically significant association was observed between PIR index and oral health problems (Figure 4.8-1). The proportion of adults with at least one decayed tooth decreased significantly with increasing PIR index (38%, 28%, and 11%, in families with PIR index < 100%, 100 – 300%, and 300% or more, respectively, $F = (2, 91) = 173$, $P < 0.001$). A similar decreasing trend was observed for the proportion of adults with missing teeth, $F (2, 80) = 94$, $P < 0.001$, and adults who required urgent care, $F (2, 83) = 109$, $P < 0.001$.

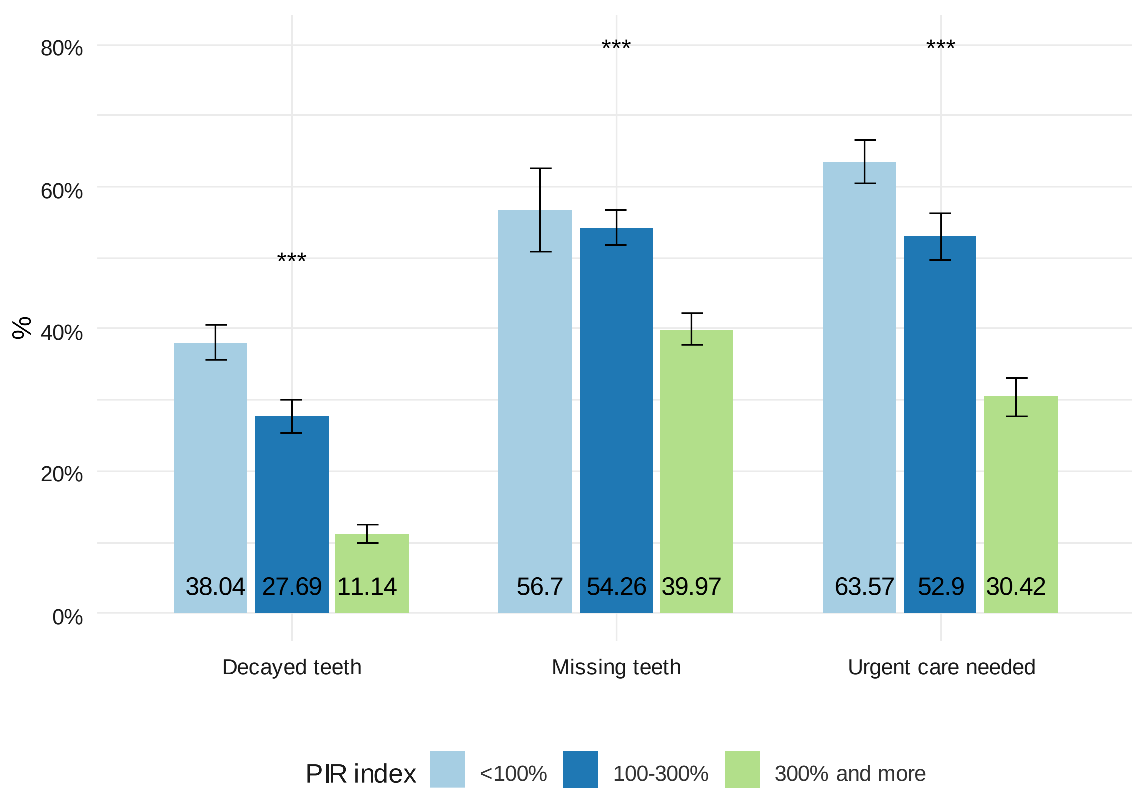

Figure 4.8- 1 Univariate association of PIR index with oral health problems

4.9 Unadjusted association of daily nutrient intake with oral health problems

Statistical analysis using Chi-square test showed that the distribution of oral health, recommendations, % of participants with decayed teeth and the % of participants with missing teeth was significantly different across tertiles of standardized carbohydrate intake (P < 0.001 for all comparisons). The distribution was also significantly different across tertiles of standardized sugar intake (P < 0.001 for all outcomes) and standardized carbohydrate intake (P < 0.001 for all outcomes). The statistics for Chi-square test are shown in Table 4.9-1.

Table 4.9- 1 Chi-square test analysis results

	F	**P**
Tertile of sugar intake		
Overall OHR	24.714	< 0.001
Prescience of decayed teeth	51.583	< 0.001
Prescience of missing teeth	10.558	< 0.001
Tertile of CHO intake		
Overall OHR	13.266	< 0.001
Prescience of decayed teeth	13.303	< 0.001
Prescience of missing teeth	8.27	< 0.001
Tertile of Protein intake		
Overall OHR	10.852	< 0.001
Prescience of decayed teeth	14.846	< 0.001
Prescience of missing teeth	5.666	< 0.001

F: Rao & Scott statistic for Chi-square test
IV: Independent variable, DV: Dependent variable,
OHR: Oral Health Recommendation

The unadjusted association between the standardized dietary intake of the three included nutrients and the three outcomes of interest is shown in Figure 4.9.1. The % of participants with DT was highest in individuals who consumed daily sugar within the third tertile compared to those in the 1st and 2nd tertile (28% vs. 18% and 20%, respectively). The % of participants with MT increased with the increase in daily sugar intake tertile (45% in the 1st tertile, 48% in the 2nd tertile and 52% in the 3rd tertile). The % of individuals that required urgent oral care increased from 39% to 50% with the increase in standardized daily sugar consumption from the 1st tertile to the 3rd tertile.

The % of participants with DT was highest in individuals who consumed daily CHO within the third tertile compared to those in the 1st and 2nd tertile (25% vs. 19% and 20%, respectively). The % of participants with MT also increased with the increase in daily CHO intake tertile (45% in the 1st tertile, 48% in the 2nd tertile and 51% in the 3rd tertile). The % of individuals that required urgent oral care increased from 39% to 50% with the increase in standardized daily CHO consumption from the 1st tertile to the 3rd tertile.

An inverse association was observed between daily consumption of protein and oral health problems. The % of participants with DT was lowest in individuals who consumed daily protein within the third tertile compared to those in the 1st and 2nd tertile (18% vs. 25% and 20%, respectively). The % of participants with MT was highest for participants with consumption in the 1st tertile compared to participants with daily intake in the 2nd and 3rd tertile, respectively (50% vs. 45%, and 47, respectively). The % of individuals that required urgent oral care decreased from 48% to 40% with the increase in standardized daily protein consumption from the 1st tertile to the 3rd tertile. These results support the association between the intake of three nutrients of interest and oral health. Binary logistic regression analysis to assess whether the association of these three nutrients would remain significant after adjusting for socio-demographic covariates.

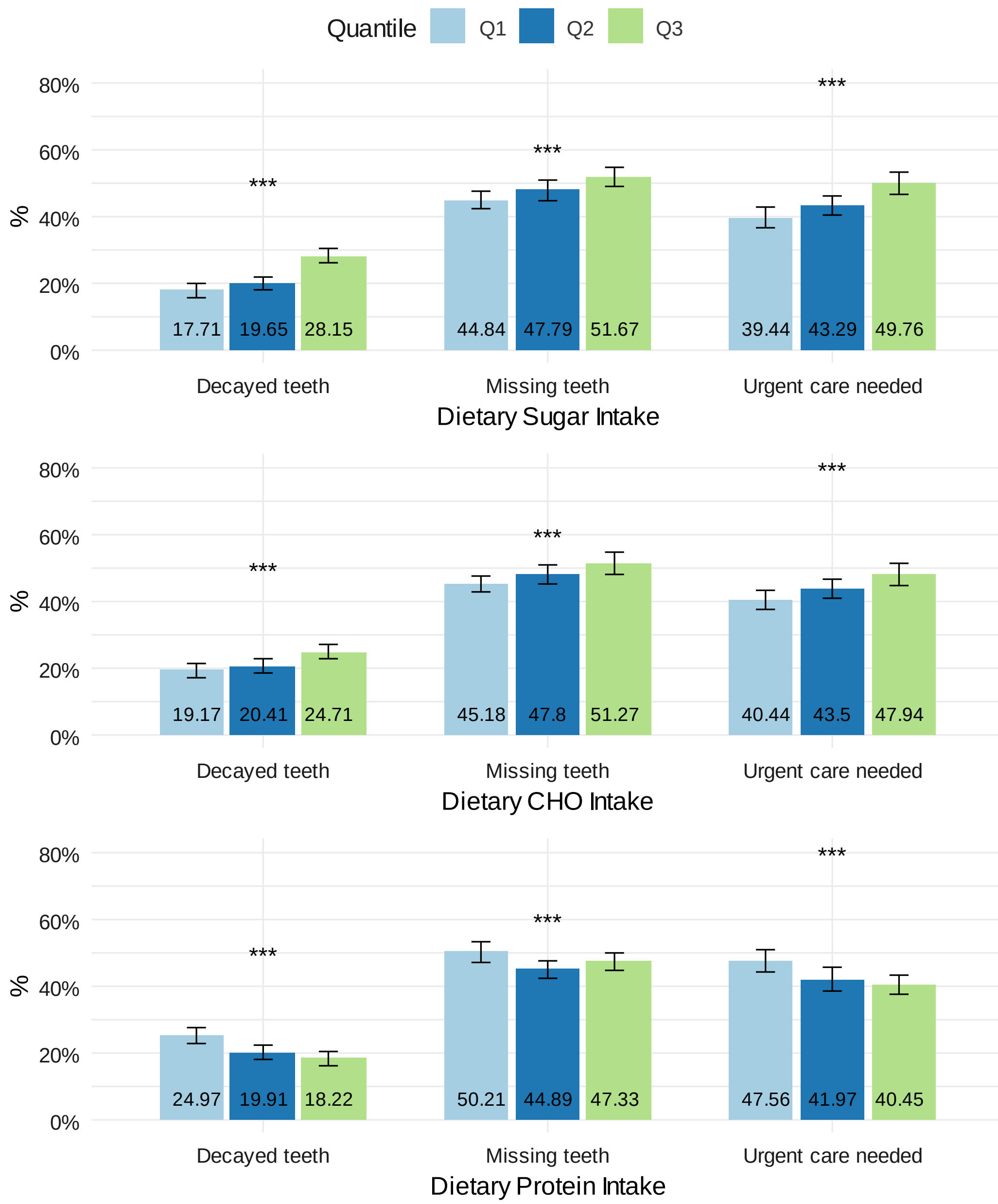

Figure 4.9- 1 Association of dietary intake of CHO, proteins, and sugar with oral health problems.

* P < 0.05, *** P < 0.001

4.9.1 Multivariate analysis of factors associated with OHR

Multivariate analysis (Table 4.9-2) showed that gender was significantly associated with the overall recommendation for oral health. The odds of an urgent recommendation were 36% lower in females compared to males (OR = 0.64, P < 0.001, Model 1). The association remained statistically significant in model 2 (OR = 0.56, P < 0.001) and model 3 (OR = 0.63, P < 0.001). This results indicate that female gender is significantly associated with better oral health and lower need for urgent dental care.

Age showed a statistically significant association with the need for urgent dental care. Participants aged 40 – 59 years were more likely to require urgent dental care compared to participants aged 20 – 39 years (OR = 1.9, P < 0.001, Model 1). Participants aged 60+ years were 2.1 times more likely to require urgent dental care compared to participants aged 20 – 39 years (OR = 2.1, P < 0.001, Mode 1). After adjusting for various daily intake of nutrients the association remained statistically significant (Models 2 and 3) and did not change significantly.

Race showed a statistically significant association with the urgent need for dental care. African-Americans were more likely to require urgent medical care compared to non-Hispanic whites (OR = 2.12, P < 0.001, Model 1). After adjusting for the remaining factors, the association of race with OHR remained statistically significant. These results indicate that the odds of requiring urgent dental care among AA are 2.1 times the odds in non-Hispanic whites.

Table 4.9- 2 Multivariate association of insurance with the overall OHR

	Model 1			*Model 2**			*Model 3*		
Predictors	***OR***	***CI***	***p***	***OR***	***CI***	***p***	***OR***	***CI***	***p***
(Intercept)	1.18	0.96 – 1.46	0.133	1.05	0.84 – 1.31	0.703	1.11	0.87 – 1.42	0.395
Gender: Female	0.64	0.57 – 0.71	<0.**001**	0.63	0.56 – 0.70	**<0.001**	0.63	0.56 – 0.70	**<0.001**
Age: 40-59	1.93	1.67 – 2.22	**<0.001**	1.93	1.67 – 2.23	**<0.001**	1.93	1.67 – 2.23	**<0.001**
Age: 60+	2.19	1.84 – 2.59	**<0.001**	2.19	1.84 – 2.60	**<0.001**	2.20	1.85 – 2.61	**<0.001**
Race: Non-Hispanic Black	2.12	1.80 – 2.50	**<0.001**	2.11	1.79 – 2.48	**<0.001**	2.11	1.79 – 2.48	**<0.001**
Race: Hispanic	1.19	0.95 – 1.49	0.130	1.20	0.96 – 1.50	0.117	1.20	0.97 – 1.50	0.109
Race: other	1.23	0.99 – 1.53	0.070	1.25	1.01 – 1.55	**0.048**	1.25	1.01 – 1.55	0.052
Education: High school	0.80	0.66 – 0.95	**0.019**	0.80	0.66 – 0.96	**0.022**	0.80	0.66 – 0.96	**0.022**
Education: College degree or higher	0.47	0.41 – 0.55	**<0.001**	0.48	0.41 – 0.56	**<0.001**	0.48	0.41 – 0.56	**<0.001**
Country: Other country	0.98	0.82 – 1.18	0.852	0.99	0.83 – 1.19	0.936	1.00	0.83 – 1.19	0.969
Insurance: No	1.95	1.66 – 2.30	**<0.001**	1.94	1.64 – 2.28	**<0.001**	1.94	1.64 – 2.28	**<0.001**
PIR: 100-300%	0.78	0.65 – 0.93	**0.009**	0.78	0.65 – 0.93	**0.009**	0.77	0.65 – 0.93	**0.010**
PIR: 300% and more	0.38	0.32 – 0.46	**<0.001**	0.39	0.32 – 0.46	**<0.001**	0.39	0.32 – 0.46	**<0.001**
Smoking status: Former	1.26	1.12 – 1.41	**0.001**	1.27	1.13 – 1.43	**<0.001**	1.27	1.13 – 1.43	**<0.001**
Smoking status: Current	2.46	2.13 – 2.86	**<0.001**	2.45	2.11 – 2.84	**<0.001**	2.43	2.09 – 2.82	**<0.001**
Total Sugars(gm): Q2				1.15	1.03 – 1.28	**0.017**	1.14	1.01 – 1.28	**0.049**
Total Sugars(gm): Q3				1.31	1.14 – 1.49	**<0.001**	1.25	1.05 – 1.50	**0.021**
Protein(gm): Q2							0.91	0.79 – 1.06	0.230
Protein(gm): Q3							0.92	0.78 – 1.08	0.303
CHO(gm): Q2							1.01	0.89 – 1.15	0.865
CHO(gm): Q3							1.02	0.84 – 1.25	0.818
*** Preferred Model**	R2 = 16.3%			R2 = 16.5% LRT P < 0.001			R2 = 16.55% LRT P > 0.05		

Increasing the level of education was positively associated with good oral health. Participants with high school education were 20% less likely to require urgent dental care compared to participants with lower than high school education (OR = 0.8, $P < 0.001$, Model 1). Participants with at least some college education were 53% less likely to require urgent dental care (OR = 0.47, $P < 0.001$, Model 1) The association did not change when sugar intake was added to the model (Model 2). The country of origin did not show a statistically significant association with the OHR.

Health insurance was significantly associated with OHR (OR = 1.95, $P < 0.001$, Model 1). Adults with no health insurance were approximately 2 times more likely to require urgent dental care compared to adults with health insurance. After adjusting for the dietary intake of sugar, protein, and carbohydrates (models 2 and 3), the association retained its statistical significance.

Income to poverty ratio showed a statistically significant positive association with OHR. Participants with PIR 100 – 300% were 24% less likely to require urgent dental care compared to adults with PIR < 100% (OR = 0.78, $P < 0.05$). Higher PIR (300% or more) was associated with an even lower likelihood of requiring urgent dental care (OR = 0.38, $P < 0.001$). The association remained statistically significant after adjusting for daily nutrient intake of sugars, carbohydrates, and protein.

Smoking status showed a statistically significant association with the OHR. Former smokers (OR = 1.26, $P < 0.001$, Model 1) and current smokers (OR = 2.46, $P < 0.001$, Model 1) were more likely to require urgent medical care compared to non-smokers. These results also suggest that current smokers were more likely to require urgent dental care compared to former smokers. The association of smoking with oral health recommendation was not altered after adjusting for the intake of the three nutrients.

Tertile of daily sugar intake was significantly associate with the OHR. The likelihood requiring urgent dental care increased by 15% in adults who consumed daily sugar within the 2nd tertile (OR = 1.15, $P < 0.05$, Model 2). The likelihood increased even further (31% more likely) in adults who consumed daily sugar within the 3rd tertile (OR = 1.31, $P < 0.001$). Model 2 was significantly better compared to model 1 as indicated by the likelihood of test results (LRT $P < 0.001$). The model explained 16.5% of the variability in the OHR.

Daily intakes of protein and carbohydrates did not show a statistically significant association with the OHR after adjusting for sugar intake (Model 3). Model 3 was not significantly better compared to model 2 (LRT $P > 0.05$) which indicates that adding daily protein and carbohydrate intake tertiles to the model did not improve the model likelihood. Thus, model 2 was statistically defined as the most probable model (Figure 4.9-2).

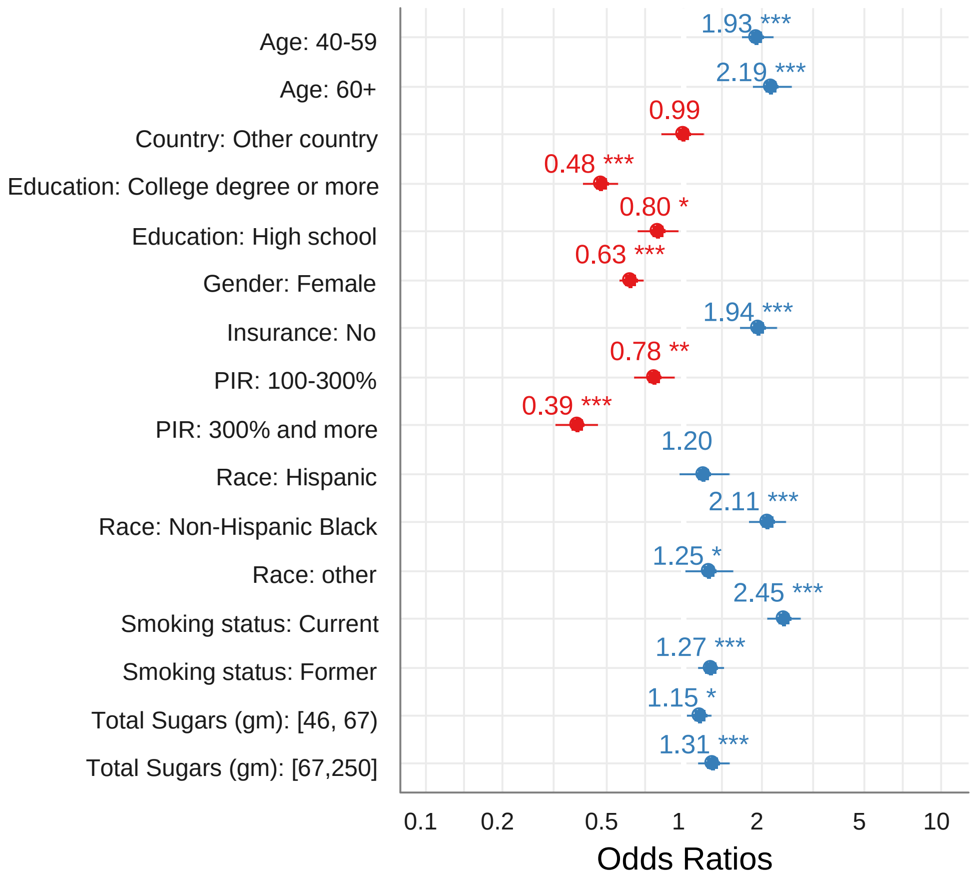

Figure 4.9- 2 Multivariate analysis of factors associated with OHR

DV: Oral Health Recommendation (OHR)

4.9.2 Multivariate analysis of factors associated with untreated caries

Multivariate analysis (Table 4.9-3) showed that gender was significantly associated with the presence of untreated dental caries. The odds of an untreated caries were 43% lower in females compared to males (OR = 0.57, P < 0.001, Model 1). The association remained statistically significant in model 2 (OR = 0.48, P < 0.001) and model 3 (OR = 0.55, P < 0.001). This results indicate that female gender is significantly associated with better oral health and lower odds of untreated dental caries.

Age showed a statistically significant association with the presence of untreated dental caries but only for the oldest group. Participants aged 60+ years were 24% less likely to have untreated dental caries compared to participants aged 20 – 39 years (OR = 0.76, P < 0.001, Mode 1). After adjusting for various daily intake of nutrients the association remained statistically significant (Models 2 and 3).

Race showed a statistically significant association with the presence of untreated dental caries. African-Americans were more likely to require urgent medical care compared to non-Hispanic whites (OR = 1.75, P < 0.001, Model 1). After adjusting for the remaining factors, the association of race with the presence of untreated dental caries remained statistically significant. These results indicate that the odds of untreated dental caries among African Americans are 1.75 times the odds in non-Hispanic whites. Hispanic race did not show a statistically significant association with untreated dental caries.

Higher level of education was positively associated with good oral health. Participants who completed high school were 19% less likely to suffer from untreated dental caries compared to participants with lower than high school education (OR = 0.81, P < 0.001, Model 1). Participants with at least some college education were 52% less likely to require urgent dental care (OR = 0.48, P < 0.001, Model 1) The association did not change when sugar intake was added to the model (Model 2). As with urgency of dental care, the country of origin did not show a statistically significant association with the OHR.

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Table 4.9- 3 Multivariate analysis of factors associated with untreated caries

	Model 1			**Model 2***			**Model 3**		
Predictors	OR	CI	p	OR	CI	p	O	CI	p
(Intercept)	0.57	0.45 – 0.71	<0.001	0.48	0.38 – 0.61	<0.001	0.55	0.44 – 0.68	<0.001
Gender: Female	0.79	0.68 – 0.93	0.006	0.78	0.67 – 0.91	0.003	0.78	0.67 – 0.91	0.004
Age: 40-59	1.04	0.88 – 1.22	0.641	1.04	0.88 – 1.23	0.624	1.04	0.88 – 1.23	0.633
Age: 60+	0.76	0.64 – 0.90	0.004	0.76	0.64 – 0.91	0.006	0.77	0.64 – 0.92	0.007
Race: Non-Hispanic Black	1.75	1.50 – 2.04	<0.001	1.75	1.50 – 2.05	<0.001	1.75	1.51 – 2.04	<0.001
Race: Hispanic	1.14	0.91 – 1.43	0.250	1.17	0.93 – 1.46	0.182	1.17	0.94 – 1.47	0.174
Race: other	1.01	0.84 – 1.21	0.947	1.03	0.86 – 1.24	0.745	1.04	0.87 – 1.25	0.663
Education: High school	0.81	0.69 – 0.94	0.009	0.81	0.69 – 0.95	0.013	0.81	0.69 – 0.94	0.011
Education: College degree or higher	0.48	0.40 – 0.57	<0.001	0.48	0.41 – 0.58	<0.001	0.48	0.41 – 0.58	<0.001
Country: Other country	0.81	0.67 – 0.99	0.050	0.83	0.68 – 1.01	0.075	0.85	0.70 – 1.03	0.117
Insurance: No	1.63	1.43 – 1.85	<0.001	1.60	1.41 – 1.82	<0.001	1.60	1.41 – 1.82	<0.001
PIR: 100-300%	0.81	0.72 – 0.92	0.002	0.82	0.72 – 0.92	0.003	0.81	0.72 – 0.92	0.003
PIR: 300%and more	0.37	0.32 – 0.43	<0.001	0.38	0.33 – 0.44	<0.001	0.38	0.32 – 0.44	<0.001
Smoking status: Former	1.27	1.10 – 1.47	0.002	1.29	1.12 – 1.48	0.001	1.28	1.12 – 1.48	0.002
Smoking status: Current	2.14	1.86 – 2.45	<0.001	2.10	1.83 – 2.41	<0.001	2.06	1.80 – 2.36	<0.001
Total Sugars(gm): Q2				1.07	0.94 – 1.22	0.285	1.13	0.97 – 1.30	0.125
Total Sugars(gm): Q3				1.51	1.31 – 1.73	<0.001	1.60	1.36 – 1.90	<0.001
Protein(gm): Q2							0.90	0.76 – 1.07	0.246
Protein(gm): Q3							0.89	0.75 – 1.05	0.181
CHO(gm): Q2							0.87	0.76 – 0.99	0.052
CHO(gm): Q3							0.86	0.73 – 1.02	0.090
***Preferred Model**	R2 = 11.3%			R2 = 11.6% LRT P < 0.001			R2 = 11.7% LRT P > 0.05		

Health insurance was significantly associated with the presence of untreated dental caries (OR = 1.63, P < 0.001, Model 1). Adults with no health insurance were 1.63 times more likely to suffer from untreated dental caries compared to adults with health insurance. After adjusting for the dietary intake of sugar, protein, and carbohydrates -(models 2 and 3), the association retained its statistical significance. Income to poverty ratio showed a statistically significant positive association with the presence of untreated dental caries. Participants with PIR 100 – 300% were 19% less likely to have untreated caries compared to adults with PIR < 100% (OR = 0.81, P < 0.05). Higher PIR (300% or more) was associated with an even lower likelihood of untreated dental caries (OR = 0.37, P < 0.001). The association remained statistically significant after adjusting for daily nutrient intake of sugars, carbohydrates, and protein.

Smoking status showed a statistically significant association with the presence of untreated dental caries. Former smokers (OR = 1.27, P < 0.001, Model 1) and current smokers (OR = 2.14, P < 0.001, Model 1) were more likely to have untreated dental caries compared to non-smokers. These results suggest that current smokers are more likely to have untreated dental caries compared to former smokers. The association of smoking with untreated dental caries was not altered after adjusting for the intake of the sugars, CHO and proteins.

Tertile of daily sugar intake was significantly associate with the presence of untreated dental caries but only for the third tertile. The likelihood of untreated dental caries were 51% higher in adults who consumed daily sugar within the 3rd tertile (OR = 1.51, P < 0.001, Model 2). Model 2 was significantly better compared to model 1 as indicated by the likelihood test results (LRT P < 0.001) and the model explained 11.6% of the variability in the dependent variable (presence of untreated caries).

Daily intakes of protein and carbohydrates did not show a statistically significant association with the presence of dental caries after adjusting for sugar intake (Model 3). Model 3 was not significantly better compared to model 2 (LRT P > 0.05) which indicates that adding daily protein and carbohydrate intake tertiles to the model did not improve the model likelihood. Similar to the OHR analysis, model 2 was statistically defined as the most probable model (Figure 4.9-3).

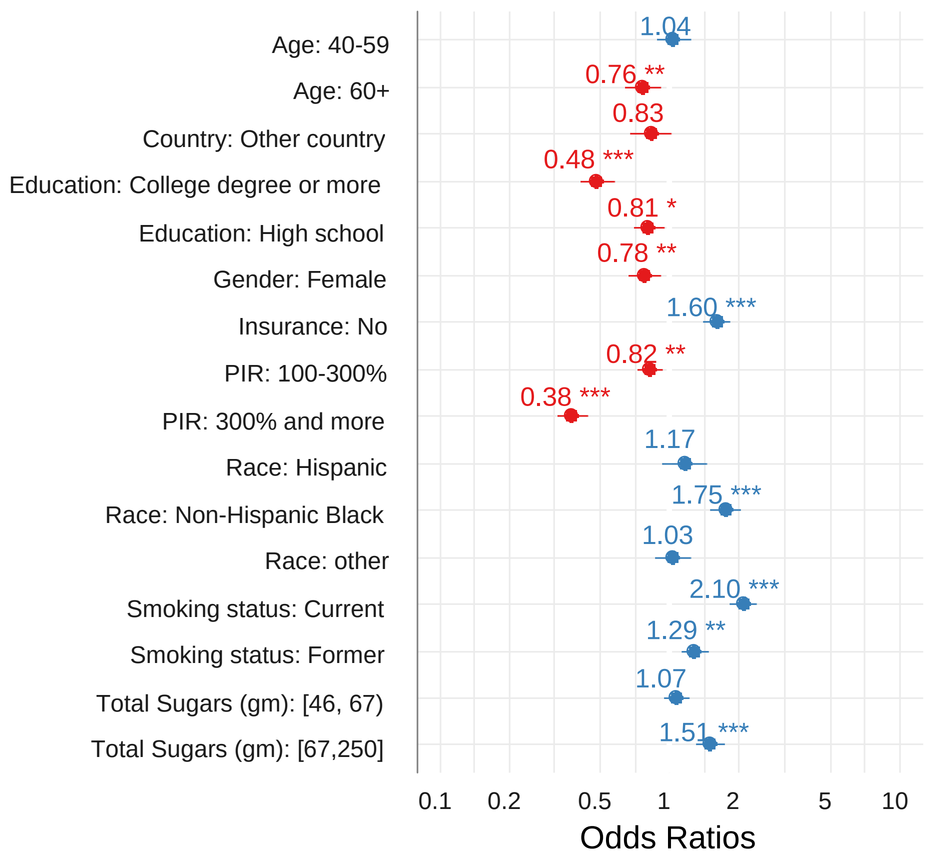

Figure 4.9- 3 Multivariate analysis of factors associated with untreated caries

DV: Untreated dental caries (Yes / No)

4.9.3 Multivariate analysis of factors associated with the presence of missing teeth

Multivariate analysis (Table 4.9-3) showed that gender was significantly associated with tooth loss. The odds of tooth loss were 55% lower in females compared to males (OR = 0.45, P < 0.001, Model 1). The association remained statistically significant in model 2 (OR = 0.4, P < 0.001) and model 3 (OR = 0.41, P < 0.001). These results indicate that females are less likely to suffer from tooth loss due to dental disease compared to males.

Age was the strongest predictor of teeth loss. Participants aged 40 – 59 years were more likely to have missing teeth due to dental diseases compared to participants aged 20 – 39 years (OR = 5.73, P < 0.001, Model 1). Participants aged 60+ years were 19.6 times more likely to have missing teeth compared to participants aged 20 – 39 years (OR = 19.6, P < 0.001, Mode 1). After adjusting for various daily intake of nutrients the association remained statistically significant (Models 2 and 3). Race showed a statistically significant association with teeth loss. African-Americans were more likely to have missing teeth due to dental disease (OR = 2.62, P < 0.001, Model 1). After adjusting for the remaining factors, the association of race with tooth loss remained statistically significant. Similar results were observed for Hispanic race (OR = 1.25, P < 0.05, Model 1).

Higher level of education was significantly associated with lower risk of tooth loss. Participants that completed high school were 30% less likely have missing teeth compared to participants with lower than high school education (OR = 0.7, P < 0.001, Model 1). Participants with at least some college education were 65% less likely to have missing teeth (OR = 0.35, P < 0.001, Model 1) compared to participants with lower than high school education. The association did not change when sugar intake was added to the model (Model 2).

Table 4.9- 4 Multivariate analysis of factors associated with tooth loss

	Model 1			Model 2*			Model 3		
Predictors	OR	CI	p	OR	CI	p	OR	CI	p
(Intercept)	0.45	0.33 – 0.60	<0.001	0.40	0.30 – 0.53	<0.001	0.41	0.30 – 0.57	<0.001
Gender: Female	1.02	0.91 – 1.14	0.754	1.01	0.90 – 1.13	0.885	1.01	0.90 – 1.13	0.904
Age: 40-59	5.73	4.95 – 6.63	<0.001	5.75	4.99 – 6.63	<0.001	5.75	4.99 – 6.63	<0.001
Age: 60+	19.64	16.30 – 23.67	<0.001	19.76	16.40 – 23.8	<0.001	19.89	16.55 – 23.9	<0.001
Race: Non-Hispanic Black	2.62	2.27 – 3.03	<0.001	2.62	2.26 – 3.02	<0.001	2.62	2.27 – 3.03	<0.001
Race: Hispanic	1.25	1.03 – 1.51	0.029	1.26	1.04 – 1.53	0.024	1.27	1.05 – 1.53	0.022
Race: other	1.39	1.13 – 1.71	0.004	1.41	1.14 – 1.74	0.003	1.40	1.13 – 1.73	0.005
Education: High school	0.70	0.57 – 0.87	0.003	0.71	0.57 – 0.87	0.003	0.71	0.57 – 0.87	0.003
Education: College degree or higher	0.35	0.29 – 0.43	<0.001	0.36	0.29 – 0.43	<0.001	0.36	0.30 – 0.44	<0.001
Country: Other country	1.36	1.14 – 1.62	0.002	1.37	1.15 – 1.63	0.001	1.36	1.14 – 1.61	0.002
Insurance: No	1.19	1.03 – 1.38	0.026	1.18	1.02 – 1.37	0.034	1.18	1.02 – 1.37	0.033
PIR: 100-300%	0.85	0.67 – 1.07	0.174	0.85	0.67 – 1.07	0.180	0.85	0.68 – 1.07	0.177
PIR: 300%and more	0.46	0.36 – 0.58	<0.001	0.46	0.37 – 0.59	<0.001	0.47	0.37 – 0.58	<0.001
Smoking status: Former	1.70	1.46 – 1.97	<0.001	1.72	1.47 – 2.00	<0.001	1.72	1.48 – 2.00	<0.001
Smoking status: Current	2.26	1.98 – 2.59	<0.001	2.25	1.96 – 2.57	<0.001	2.26	1.97 – 2.59	<0.001
Total Sugars(gm): Q2				1.12	0.97 – 1.30	0.126	1.10	0.92 – 1.30	0.299
Total Sugars(gm): Q3				1.27	1.08 – 1.50	0.007	1.19	0.93 – 1.52	0.182
Protein(gm): Q2							0.83	0.71 – 0.98	0.035
Protein(gm): Q3							0.99	0.83 – 1.17	0.903
CHO(gm): Q2							1.07	0.92 – 1.26	0.385
CHO(gm): Q3							1.09	0.88 – 1.34	0.455
*** Preferred Model**	R2 = 27.4%			R2 = 27.5% LRT P < 0.05			R2 = 27.6% LRT P > 0.05		

The country of origin showed a statistically significant association with the risk of tooth loss (OR = 1.36, $P < 0.001$) which indicates that individuals born in other countries were 36% more likely to suffer from tooth loss.

Health insurance was significantly associated with the risk of tooth loss (OR = 1.19, $P < 0.05$, Model 1). Adults with no health insurance were 19% more likely to have missing teeth due to dental disease compared to adults with health insurance. After adjusting for the dietary intake of sugar, protein, and carbohydrates (models 2 and 3), the association retained its statistical significance.

Income to poverty ratio showed a statistically significant positive association with the risk of tooth loss. Participants with PIR 100 – 300% were 15% less likely to suffer tooth loss due to dental disease compared to adults with PIR < 100% (OR = 0.85, $P < 0.05$). Higher PIR (300% or more) was associated with an even lower risk of tooth loss (OR = 0.46, $P < 0.001$). The association remained statistically significant after adjusting for daily nutrient intake of sugars, carbohydrates, and protein.

Smoking status showed a statistically significant association with the risk of tooth loss. Former smokers (OR = 1.7, $P < 0.001$, Model 1) and current smokers (OR = 2.26, $P < 0.001$, Model 1) were 1.7 and 2.26 times more likely to have missing teeth due to dental disease compared to non-smokers, respectively. These results also suggest that current smokers were more likely to have missing teeth compared to former smokers. The association of smoking with oral health recommendations was not altered after adjusting for the intake of the three major nutrients.

Tertile of daily sugar intake was significantly associate with the risk of tooth loss. The likelihood of tooth loss were 27% higher in adults who consumed sugar daily within the 3rd tertile (OR = 1.27, $P < 0.05$, Model 2). Model 2 was significantly better compared to model 1 as indicated by the likelihood of test results (LRT $P < 0.001$). The model explained 27.5% of the variability in the dependent variable (tooth loss due to dental disease).

Daily intakes of protein and carbohydrates did not show a statistically significant association with the likelihood of tooth loss after adjusting for sugar intake (Model 3). Model 3 was not significantly better compared to model 2 (LRT $P > 0.05$) which indicates that adding daily protein and carbohydrate intake tertiles to the model did not improve the model likelihood. Thus, model 2 was statistically defined as the most probable model (Figure 4.9-4).

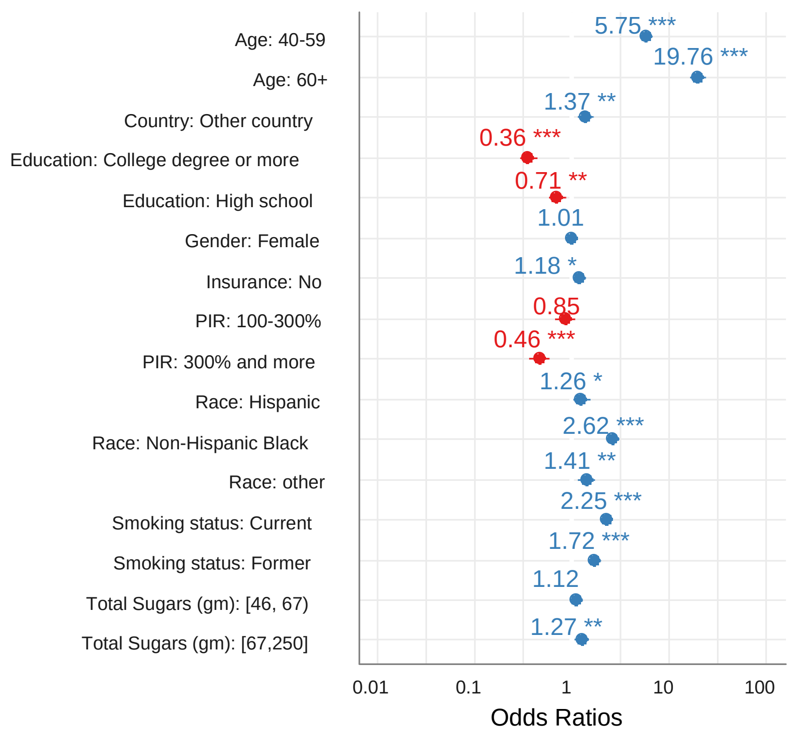

Figure 4.9- 4 Multivariate analysis of factors associated with missing teeth

DV: Presence of missing teeth (Yes / No)

CHAPTER V

V DISCUSSION

Oral health is one of the main cornerstones for physical and mental well-being that requires close attention and care since the early age of life.[54] Poor dental health is well recognized as a source of systemic inflammation, with emerging literature identifying it as a risk factor for the progression of inflammatory diseases such as cardiovascular disease (CVD). Poor oral hygiene is reportedly associated with a 70% increased CVD risk,[55] while periodontal disease is associated with a two-fold increase in mortality related to CVD risk.[56]

Tooth decay, also known as dental cavity or dental caries, is the most prevalent oral health disease worldwide with varied disparities in its incidence among different racial and ethnic groups.[57] The condition is considered an infectious disease that starts by colonization and spread of Streptococcus mutants, owing to several risk factors, followed by plaques formation, enamel demineralization, cavitation, and finally local destruction of the tooth.[58] In a considerable proportion of the children and adults tooth decay is left untreated which leads to higher risks of pain, swelling and tooth loss.[59] Therefore, tooth decay is a major public health burden that can lead to inevitable extraction of the affected teeth and impaired quality of life of the affected individuals.[59] It was also reported that tooth decay carries an economical and financial burden beyond the affected person and their families.[60]

Despite its well-recognized effects on overall health status, there is a scarcity in the published literature about the impact of various socio-economic and behavioral factors on oral health and disease among different age groups.[61] Therefore, we conducted the present NHANES-based study in order to investigate the incidences of different oral health diseases and the effects of a wide range of social and behavioral determinants on oral health among a representative population of the adults living in the USA.

In the present study, we found that the prevalence of tooth decay to be approximately 21% in adults aged 20 years and above. These findings highlight that the prevalence of dental caries remained largely unchanged among children and adolescents since 1999 in the USA; previous reports which utilized NHANES data from 1999-2002, reported that the prevalence of dental caries was 41% among children aged 2-11 years, 42% children and adolescents aged 6-19 years, and approximately 90% among adults.[62] Therefore, it is of paramount importance to identify different risk factors that contribute to the current steady trends in dental caries incidence despite major advances in access to dental health care facilities.

Personal oral hygiene and access to professional oral health facilities represent the cornerstone for treatment of early tooth decay and prevention of its progress.[63] Thus, socio-economic status and behavioral factors that hinder proper personal and professional oral care are proposed as risk factors for tooth decays.[61] The present study demonstrated that various socio-economic and behavioral factors, including education and income, were associated with a higher risk of tooth decay, and presence of missing teeth as well as the urgent need for dental care.

Based on the NHANES 2013 – 2014 data, clinical evaluation of oral healthcare need and the self-report for overall oral health self-perception had a substantial concordance at 65.4%. The authors also recommended having a minimum set of measures that can provide actionable information and capture the need for clinical dental care.[64] To minimize the bias associated with using self-reported measures, we used outcomes that are based on the clinical evaluation of oral healthcare throughout the analysis.

The logistic regression analysis showed that those without health insurance coverage were less likely to have good oral health, independent of age, gender, and ethnicity. Adjusting for individual-level SES attenuated this relationship although the association remained statistically significant. Our findings suggest that the lack of health insurance coverage may be a barrier to achieving good oral health for adults residing in USA The association between having health insurance and various health states is established in the literature. A recent secondary analysis of the NHANES 2007 - 2010 data showed that insurance coverage was associated with better cardiovascular health. Authors concluded that adults living in the USA without health insurance coverage were less likely to have an ideal cardiovascular health.[65]

Another secondary analysis showed that uninsured children had the highest rate of untreated caries (22.0%) with significantly higher odds of untreated caries relative to the privately insured children. Our findings were similar and suggest that having any type of health insurance compared to no insurance may help improve access to dental treatment and reduce untreated caries.[66] Throughout, the current analysis also provided new information about the ambiguous relationship between having health insurance and oral health.

The current analysis provided evidence to support the association between oral health and socioeconomic status. We showed that lower SES (measured by the PIR) was significantly associated with poor oral health. This is similar to what was reported in secondary analysis of the NHANES 2011 – 2014 data. Authors showed that children with low SES (low income families and less educated parents) were at greater risk of untreated caries and dental caries. The analysis included 6057 children from the NHANES 2011-2014 data.[66] In our study, the PIR index was associated with the need for urgent dental care. Indeed, the need for urgent dental care was 20% lower in adults with PIR 100 – 300% compared to adults with PIR < 100% and 60% lower in adults with PIR > 300% compared to adults with PIR < 100%. These findings are consistent with the results obtained from the analysis of the SIRS cohort where financial problems were a reason of renouncement to dental care by 10.4% of this population.[67] Results were also consistent with The Health and Social Protection Survey (ESPS) conducted among 8,000 French households. Almost half of the insured had postponed or forgone prosthetic, dental and orthodontic care for financial reasons.[68] Low income was also associated with a higher number of missing teeth.[69]

Logistic regression analysis also supported the association between race and oral health status i.e. AA race were less likely to have good oral health status compared to non-Hispanic whites. Our findings are supported by a recently published secondary analysis of the NHNES data where authors reported a significant association between race and self-reported oral health. The study found that non-Hispanic AA reported worse self-rated oral health and a higher proportion of irregular dentist visits than Non-Hispanic Whites [70] which is similar to what was reported in the current study.

A previous systematic review of 41 studies conducted by Costa and colleagues,[71] demonstrated that the annual household income, level of education in adults were associated with increased risks of tooth decay. Similarly, an ecological study on data from 48 countries reported that income inequality was strongly associated with childhood dental caries.[72] Findings from the USA study was similar as well; families with annual income below the federal poverty level were found to have higher rates of untreated childhood caries compared to those with income above the poverty level.[23]

Regarding the association of behavioral factors with oral health, our results also showed that smoking status was significantly associated with the oral health. Non-smokers were less likely to require urgent care or have any missing or decayed teeth compared to former smokers or current smokers. Former smokers were less likely to have poor oral health compared to current smokers. These results suggest that time since smoking cessation is significantly associated with oral health. These results are supported by the 2009 – 2012 data which showed that the rate of periodontitis (another measure of oral health) was highest among smokers compared with former smokers and never smokers.[73] The findings are also consistent with the prior observation that smoking is a risk factor for periodontal disease.[74] Moreover, the analysis of NHANES III data found that the strongest risk factor for periodontal loss of attachment was smoking.[73]

Research published in other countries also shows similar findings to the results of the current analysis. In Colombia, social factors and health insurance schemes were associated with teeth decay.[75] Worse decay levels were observed in uninsured individuals. The presence of missing teeth was associated with education levels with higher number of missing teeth observed among the lower educated groups. Thus, authors concluded that health insurance and education are contributors to oral health inequalities in Colombia. These results support the findings in the current study.

Infectious diseases of the gum (periodontitis) are a common oral health problems and the second most prevalent oral diseases in the USA.[59] The condition is typically initiated by gingivitis due to microbial colonization of the oral cavity, mostly due to mixed bacterial infections, which can progress to destruction of connective tissues, loss of dental attachments with eventual tooth loss in severe cases.[76] In addition to its localized effects, the current body of evidence confers that periodontitis is associated with higher risk of CVD, diabetes, chronic kidney disease, rheumatoid arthritis and preterm labor.[77] Therefore, identifying risk factors for periodontitis is critical in order to develop effective preventive strategies especially in high risk population.

A growing body of evidence has shown possible association between the risk of periodontal diseases and different demographic or behavioral characteristics. Both advanced age and male gender were found to be associated with higher risk of periodontitis.[78] Moreover, poor gingival condition and ignorance of oral hygiene are commonly linked to poverty, low socioeconomic status, and low educational level; therefore, such factors are proposed as major contributors to the increased risk of periodontal diseases.[79, 80] On the other hand, the hazardous effects of tobacco smoking on gingival condition put excessive smokers at higher risk of periodontitis.[81]

A large cross-section of 1361 subjects, Grossi and colleagues reported that male gender, race was significantly associated with higher risks of periodontal disease.[82] Alpagot and colleagues demonstrated that age, sex, smoking, and social-economic status were significant risk factors for periodontal disease.[83] The findings from the current analysis were similar to the Alpagot et al study. We demonstrated that females were less likely to have missing, or decayed teeth compared to males. They were also less likely to require urgent dental care compared to males.

Age also showed a significant association with oral health problems. Regarding the association between teeth decay and age, our results showed that older adults were less likely to suffer from untreated decay compared to younger adults. These results are consistent with the NCHS data brief for the NHANES 2011-2012 data that suggested lower risk of untreated caries in adults 65+ years compared to adults 20 – 34 and 35 – 49 years.[84] The risk of untreated caries was similar across the latter two groups which is similar to what was observed in the current analysis although we used slightly different cut-off points for age

Regarding sugar intake and oral health, our findings suggest that higher sugar intake was significantly associated with poor oral health. These findings are supported by the 1988 -1994 NHANES III data. A high consumption of added sugars was associated with a greater prevalence of periodontal disease in the middle and upper tertiles of consumption. The authors reached the conclusion that higher consumption of added sugar was significantly associated with periodontal disease even after adjusting for the conventional risk factors such as demographics. The results suggested that added sugar consumption pattern may contribute to the systemic inflammation observed in periodontal disease.[85] Although the aforementioned study was interested in the added sugar intake, these findings can be extrapolated to the total daily sugar intake.

The initial statically significant association between protein intake and oral health can be attributed to the confounding effect of sugars where higher sugar intake was associated with lower protein intake and vice versa. Indeed, the results from the current study showed that there was a statistically significant negative association between protein and total sugar intake ($r = -0.4$, $P < 0.001$). This negative correlation can explain the direct relation between protein intake and oral health. However, when the analysis was adjusted for various socio-demographic characteristics and sugar intake, the association lost its statistical significance. These results suggest that sugar intake is a more powerful predictor of oral health compared to protein intake. Similarly, the association between carbohydrate intake and oral health, initially observed, can be attributed to the positive correlation between carbohydrate intake and sugar intake ($r = 0.65$, $P < 0.001$) that was observed throughout the current analysis. This explains why the association lost its statistical significance when sugar intake was added to the model. Indeed, a review published in 2017 highlights the risk of increased consumption of dietary sugars as well as the increasing % of total sugars as a component of the diet on oral health in the USA population. The study also highlighted the importance of raising the awareness regarding public health implications among dental professionals and the importance of communicating these risks to patients.[86]

Based on data from 168 countries in 2010, the consumption of simple sugars (mono-saccharides and di-saccharides) was associated with a global dental disease burden of 4.1 million disability-adjusted life years with 2.7 million DALYs from caries and 1.4 million DALYs from periodontal disease. Dental diseases related to simple sugars were associated with a global financial burden of 172 billion US dollars. Moreover, the study attributed 26.3% of the total global oral disease burden to the consumption of simple sugars. The study also highlighted the importance of addressing the role of free sugars in oral health. They also highlighted the need for emerging economies to address such challenges through national public health policies to prevent increased chronic disease and cost burdens.

CHAPTER VI

VI CONCLUSIONS

Results from the current analysis support the association of behavioral and socio-demographic with oral health. Males were more likely to have decayed teeth and require urgent dental care than females, although the likelihood of having missing teeth was not significantly different between the two groups. Higher age groups (40 – 59 years and 60+ years) were more likely to require urgent dental care compared to the younger age group (20 – 39 years). Older age groups were more likely to suffer from tooth loss and less likely to suffer from dental decay.

Interesting trends were also observed when examining the association of smoking status with oral health problems. For example, tooth decay was more prevalent in current smokers compared to non-smokers and former smokers, while the presence of missing teeth was more likely in current and former smokers compared to non-smokers. The proportion of adults that required urgent dental care was higher in smokers compared to former smokers and higher in former smokers compared to non-smokers. This supports the beneficial role of smoking cessation on oral health. Racial disparities in oral health were also observed in the current analysis where African-Americans were more likely to suffer from dental caries, and tooth loss compared to non-Hispanic whites

Health insurance coverage was associated with a lower likelihood of requiring urgent dental care, dental caries and tooth loss. The mechanism by which health insurance coverage is believed to affect oral health is through access to dental care. Understanding the relationship between health insurance and oral health is increasingly important because of the ACA's impact on integrating health and dental insurance. The ACA essential health benefits, a health care service package that most health plans are required to cover, includes pediatric dental care, leading many health plans to cover pediatric dental care. In addition to increasing dental coverage, health plan coverage of dental benefits also provides an opportunity for greater coordination between medical and dental providers.

Regarding the association of diet with oral health problems, higher sugar intake was associated with greater oral health problems. However, no statistical significant association was found between protein or carbohydrate intake and oral health problems.

In conclusion, the analysis provides important insights regarding the relationship of socioeconomic and behavioral factors with oral health which can have important public health implications. Increasing dental visits and reducing caries are Healthy People 2020 objectives and important steps toward reducing oral health disparities.[87] Understanding the interplay of social, economic, and behavioral factors in the development of oral health problems is essential to provide timely and appropriate dental care.

Despite improvements in oral health in the adult population, these findings suggest that significant disparities still exist among the older, uninsured, less educated, and low level income populations. Individuals from lower income and education groups were more likely to have higher burdens of untreated dental decay and missing teeth. The economic interventions that aim to facilitate the access to dental care might not be sufficient to reduce the social inequalities in oral health. The findings highlight the need to improve oral health and the need to reduce inequalities across socioeconomic groups. Moreover, The WHO recommendations, related to sugar intake, must be followed by nutrition-related policies at the national level. Several strategies are required to successfully reduce the intake of free sugars and thereby guard against both dental and general problems.

6.1 Analysis strengths

We used the NHANES, a nationally representative sample of the US civilian, non-institutionalized individuals living in the USA for the analysis. In the current analysis, we used the oral health examination data to create the dependent variables for the analysis. We did not apply NHANES self-reported oral health measures (assessed using the oral health questionnaire) which can fluctuate and may be reported unreliably. Thus, the results are reliable as the outcomes of interest are based on data provided through direct dental examination which reduces bias greatly.

6.2 Study limitations

Some limitations should be highlighted in the current study. First, the NHANES is a cross-sectional study in nature which limits the confidence in the casual inferences obtained through analysis. Secondly, the lack of follow-up did not allow us to assess the prognostic impact of difference socio-economic and behavioral factors on oral health.

Another limitation was that we only classified adults according to treated or untreated caries. The association of socio-demographic and behavioral factors with the severity of dental caries was not investigated in this study. Additionally, caries management strategies vary based on risk assessment, age, and parent and practitioner preferences, and untreated caries may not always indicate lack of access to dental care. Therefore, causal conclusions from the cross-sectional NHANES data cannot be at this time reached.

6.3 Future Research

An analysis study that is focused on children and adolescent evaluating the impact of public health programs that are focused on oral health should be considered to overcome this study limitation for that age group. Future research should also be directed towards the association between socio-demographic characteristics and the severity of dental caries. Future research should be directed towards determining the optimal strategies to facilitate smoking cessation in dental patients.

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