**Association Between Oral Health and Frailty Among American Older Adults.**

Faisal F. Hakeem, MSca,b, Eduardo Bernabé, PhDa and Wael Sabbah, PhDa

a Faculty of Dentistry, Oral & Craniofacial Sciences, King’s College London, London, United Kingdom

b College of Dentistry, Department of Preventive Dental Sciences, Taibah University Dental College & Hospital, Madinah, Saudi Arabia

**Corresponding Author:**

Faisal F. Hakeem

Address: Faculty of Dentistry, Oral & Craniofacial Sciences, King’s College London, Denmark Hill Campus, Bessemer Road, London, SE5 9RS, UK

Phone: +447455504232

Email address: [Faisal.Hakeem@kcl.ac.uk](mailto:Faisal.Hakeem@kcl.ac.uk)

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**Brief Summary:** The current analysis demonstrated that having poor oral health was associated with frailty and with inadequate nutritional intake. The findings imply that maintaining natural teeth at older age could halt the progress of frailty.

***Abstract:***

**Objective:** We examined the association between tooth loss, periodontal diseases and frailty among older American adults.

**Designs, settings and participants:** Data from the National Health and Nutrition Examination Surveys (NHANES) 2011-2014 was used. We included 2,368 community-dwelling older adults aged 60 years and older. Frailty was measured with 49-item frailty index. Oral health indicators included: number of teeth and periodontal disease. A composite nutritional intake variable based on 13 micronutrients from the dietary assessment was created. Negative binomial regression was used to test the association between oral health and frailty. The first model was adjusted for age and gender, the second model was additionally adjusted for nutritional intake, and the third model was additionally adjusted for other covariates.

**Results**: For each additional tooth the rate ratio (RR) for frailty was 0.99 (95% CI 0.98, 0.99) in the fully adjusted model. Similarly, participants with moderate-severe periodontitis had 1.08 RR (95% CI 1.02, 1.14) for frailty index compared to participants with no periodontitis after adjusting for age, gender and poor nutritional intake. The association lost significance in the fully adjusted model.

**Conclusions and implications:** Oral health is associated with frailty index, and nutritional intake appears to have a modest effect on the association. Periodontal disease has a weaker association with frailty compared to number of teeth. The findings highlight the importance of maintaining good oral health at old age and incorporating oral health indicators in routine geriatric assessments. Future research should investigate the role of potential mediating factors in this association.

**Introduction:**

Frailty is characterized by decreased functional reserves which leads to greater vulnerability to stressors and adverse health outcomes including falls, increased healthcare usage, disability and mortality.[1-3](#_ENREF_1) Frailty is considered a major public health issue, since its prevalence is high in the ageing populations.[4](#_ENREF_4) It also leads to greater risk of negative health outcomes at old age.[2](#_ENREF_2) Furthermore, frailty has an impact on the society as it subjects groups of the society to higher risk of dependency and greater need for medical attention.[5](#_ENREF_5) It also impacts healthcare systems sustainability in terms of management and provision of services and expenditure.[5](#_ENREF_5), [6](#_ENREF_6) However, it was suggested that early stages of frailty could be reversible by implementation of nutritional supplementation,[7](#_ENREF_7), [8](#_ENREF_8) and physical exercise programs.[9](#_ENREF_9)

Multiple frailty models have been developed based on different conceptual definitions. The two main models are the Fried’s phenotype model and the frailty index model. The phenotype model operationalizes frailty as fulfilling three or more out of five physical criteria.[2](#_ENREF_2) The frailty index model, which was developed by Rockwood et al [10](#_ENREF_10) on the basis of a comprehensive geriatric assessment by adding up accumulated deficits, including chronic diseases, psychosocial factors, cognitive deficits, and other geriatric signs and symptoms. It provides a cumulative account of frailty as a predictor of adverse health outcomes. This index is demonstrated as the ratio of the accumulated acquired deficits to all potential deficits in the index.[10](#_ENREF_10)

Poor oral health and oral health problems are highly prevalent among older adults. [11](#_ENREF_11), [12](#_ENREF_12) Moreover, oral health conditions have links with chronic diseases [13](#_ENREF_13) and with physical functions among older adults. [14](#_ENREF_14) It was suggested that oral health conditions could be linked to frailty through different pathways, these include: nutritional pathway as dentition impact the nutritional status; biological pathway through the association with chronic inflammatory responses in the body; and psychological pathway through the impact of oral health on self-esteem and depression as proposed by Castrejón-Pérez et al.[15](#_ENREF_15)

Systematic reviews have suggested positive associations between poor oral health and frailty especially with number of teeth and oral function.[14](#_ENREF_14), [16](#_ENREF_16) However, periodontal disease as an indicator of oral health showed inconsistent results. Most of the included studies in these systematic reviews used Fried’s phenotype for defining frailty. To the best of our knowledge, only two studies assessed the association of poor oral health and frailty index. However, both studies utilized subjective oral health indicators.[17](#_ENREF_17), [18](#_ENREF_18) Moreover, the impact of nutritional intake as a potential mediator of the relationship is still not fully understood. Therefore, we set out to test the association between clinical oral health indicators and frailty index using data from the National Health and Nutrition Examination Surveys (NHANES) 2011 to 2014. The research question of this study is whether oral health indicators, namely number of teeth and periodontal disease, are associated with frailty index among older American adults?

### Materials and Methods:

The National Health and Nutrition Examination Survey data, a cross-sectional nationally representative survey of Americans, was used (NHANES 2011-2012 and 2013-2014). These two waves were chosen because data on periodontal examinations and handgrips strength are not available in the recent waves. Four years NHANES examination weights were calculated and used throughout the analysis. Only those aged 60 years and older, had a complete NHANES oral health exam, and had no missing data were included in the analysis. NHANES 2011-2014 had data on 19,931 participants among them 3,630 aged 60 years or older. After excluding participants who did not have complete oral health examination or had missing data in any other covariate, 2,368 participants were included in the analysis. In the included sample, the majority were non-Hispanic White (79.2%). Other ethnic group were Non-Hispanic Black (8.5%), other Hispanic (3.6%), Mexican American (3.3%), and other ethnic groups (5.3%)

Outcome variable:

We constructed frailty based on the standard procedure introduced by Searle and colleagues .[19](#_ENREF_19) For traits to be included in the index, they should be health deficits, their risk should increase with higher age, they should be common, they should cover multiple systems and they should be recorded for at least 80% of the participants. A value between zero and one was assigned according to the severity of the deficit, this allows continuous variables to be combined with categorical variables. The Frailty index included 49 deficits that covered multiple systems. The systems included: cognition (one question regarding confusion and memory problems), dependence (15 items related to difficulty performing activities of daily living), depression (7 items related to depressive symptoms from the Patient Health Questionnaire PHQ-9), comorbidities ( self-reported arthritis, thyroid problems, chronic bronchitis, malignancies, heart failure, chronic heart disease, angina, heart attack, stroke, hypertension, diabetes, failing kidneys, urinary leakage), hospital utilization and general health (self-rated health, health compared with 1 year ago, overnight hospitalization last year, frequency of healthcare use during last year, and number of prescribed medications) physical performance and anthropometry (handgrip strength and body mass index) and laboratory values (Glycohemoglobin, red blood cell count, haemoglobin, red cell distribution width, lymphocyte and segmented neutrophils). The frailty index value is expressed as the number of the acquired deficits by the participant divided by the total number of potential deficits. Variables of frailty index and their scores can be found in the (Table A1 in the Appendix).

### Explanatory variables

Number of teeth was obtained from the clinical oral examination performed by licenced dentists at the mobile examination centres. Periodontal disease was based on the CDC/AAP definition for periodontal disease surveillance .[20](#_ENREF_20) Periodontal examination protocol consisted of measuring clinical attachment loss (CAL) and pocket depth (PD) on six sites for each tooth. Mild periodontitis was defined as having two interproximal sites with CAL ≥ 3mm, and ≥ 2 interproximal sites with PD ≥4mm (not on the same tooth) or one site with PD ≥5mm. Moderate periodontitis was defined as ≥ 2 interproximal sites with CAL ≥ 4mm (not on the same tooth), or ≥ 2 interproximal sites with CAL ≥ 6mm (not on the same tooth) and ≥ 1 interproximal site with PD≥ 5mm were required. If participants did not fall in any of these definitions, they were defined in “no periodontitis” group. All participants with less than two teeth were excluded from the periodontal disease analysis as required in the CDC/AAP case definition of periodontitis. [20](#_ENREF_20) This definition was used in this study for its appropriateness for survey data, and due to the way in which periodontal status was assessed in NHANES. Periodontal disease in this study was categorized into two groups, “No/Mild periodontitis” and “Moderate/Severe periodontitis”.

Inadequate nutritional intake was established from micronutrients intake data from the 24 hours dietary recalls, which were obtained by both in persons and telephone interviews. To calculate the nutritional intake of the participants, the recommendations of Dietary intake and Allowances produced by the national institute of health were followed.[21](#_ENREF_21) The exact cut off points for the 13 micronutrients are presented in (Table A2 in the Appendix). We created a nutritional intake variable by summing up the 13 micronutrients variables (0 indicates adequate intake of all the nutrients, 13 indicates inadequate intake of all the nutrients).

### Covariates:

Sociodemographic factors were age and it was used as continuous variable (age in years), gender, and ethnicity which was categorized into five groups (Hispanics “Mexican American and other Hispanics,” non‐Hispanic Black, non‐Hispanic White and other races). Education was grouped into (less than 12 years, 12 years of education and more than 12 years of education). Poverty income ratio was used to indicate income and it was used as a continuous variable. Finally, smoking status was categorized into three groups (never smoker “smoked less than 100 cigarettes’’, previous smokers and current smokers).

### Statistical analysis:

Statistical analyses were performed with Stata version 16 (StataCorp, College Station, TX, USA). Stata survey command was used throughout the analysis. Descriptive statistics were carried out stratified by frailty status. A frailty index cut-off point of 0.21 was assigned based on proposed cut-off scores for use in descriptive analysis.[22](#_ENREF_22)

Negative binomial regression was used to test the association between frailty index and each of the oral health indicators, namely number of teeth (0-32) and periodontitis (No/Mild versus Moderate/Severe periodontitis). For each oral health indicator three models were constructed, the first one was adjusted for age and gender, the second was additionally adjusted for inadequate nutritional intake, and the third was additionally adjusted for poverty income ratio, education, ethnicity and smoking. To yield integer values without changing the distribution, the frailty index was multiplied by 100. To test the potential mediating role of nutritional intake and oral health,[23](#_ENREF_23) the association between inadequate nutritional intake and oral health was examined using negative binomial regression models adjusted for age and gender.

### *Results:*

Among study participants, 38.7% (95% CI 35.3 – 42.2) were frail. The mean age for frail and non-frail participants were 67.9 (95% CI 67.4 – 68.4) and 71 years (95% CI 70.3 – 71.6), respectively. Frail participants had higher percentage of current and previous smokers, and lower percentage of high education (more than 12 years) and lower poverty-income ratios. Frail individuals had a higher mean of inadequate nutritional intake 8.5 (95% CI 7.3 – 8.6). The mean number of teeth was 14.8 (95% CI 13.5 – 16.0) and 20.7 (95% CI 20.1 – 21.3) for frail and non-frail older adults, respectively. As fewer participants were included in periodontal assessment, the analysis pertaining to periodontitis only included 1,884 participants (Table 1).

The association between frailty index and number of teeth is presented in Table 2. In the first model, for each additional tooth the rate ratio (RR) for frailty decreased to 0.98 (95% CI 0.97 – 0.99). After adjusting for nutritional intake in model 2, RR was slightly attenuated. After further adjustment for socioeconomic factors and smoking, RR attenuated to 0.99 (95% CI 0.98 – 0.99).

Table 3 demonstrates the association between periodontal disease and frailty, participants who had moderate or severe periodontitis had RR 1.09 for frailty index compared to participants with mild or no periodontitis after adjusting for age and gender. The RR attenuated to 1.08 (95% CI 1.02 – 1.14) but remained significant after additionally adjusting for nutritional intake. However, the rate ratio was no longer significant in the fully adjusted model.

Inadequate nutritional intake was negatively and significantly associated with number of teeth with RR: 0.99 (95% CI 0.99 – 0.99) and positively and significantly associated with periodontitis with RR 1.08 (95 % CI 1.04 – 1.11).

### *Discussion:*

This study demonstrated that in a nationally representative sample of older American adults, oral health indicated by tooth loss and periodontal disease was associated with frailty index. The significant association between tooth loss and frailty persisted even after adjusting of important covariates. These results are in line with previous studies, as complete tooth loss,[24](#_ENREF_24) number of teeth,[25](#_ENREF_25) having more than 20 teeth,[26](#_ENREF_26) were associated with frailty. This could be attributed to the effect having fewer teeth on chewing abilities which subsequently impacts changes of food quality and quantity leading to inadequate nutritional intake. [16](#_ENREF_16)

Previous studies have found conflicting results pertaining to the association between periodontal disease and frailty. Ramsay and colleagues found that periodontal disease markers (Pocket depth and clinical attachment loss measured on six index teeth) were not associated with frailty phenotype in cross-sectional and prospective analyses of data on older British men.[24](#_ENREF_24) On the other hand, Castrejón-Pérez and colleagues found that severe periodontitis (based on pocket depth measured on six sites per tooth with the highest score recorded) was associated with three-year incidence frailty.[25](#_ENREF_25) Both of these studies used frailty phenotype for defining frailty and did not use established case definition for defining periodontal disease. In this study, we found that older adults with severe/moderate periodontitis based on CDC/AAP definition had a higher frailty index score compared with older adults with mild or no periodontitis. However, this association was only significant after adjusting for age and gender but not after further adjustments of inadequate nutritional intake and other covariates.

Previous studies have hypothesized that periodontal disease might influence frailty status through its association with the inflammatory biomarkers in the body. However, the impact of inflammation on frailty is still not fully understood [27](#_ENREF_27) and we did not test the inflammatory pathway in this study. It is also possible that periodontitis is associated with frailty through tooth loss as an ultimate consequence of periodontal disease and its impact on food selection and nutritional status. A systematic review found positive associations between lower intake of some micronutrients like vitamin C, vitamin E, B-carotene and dietary fibers and periodontitis among community dwelling older adults.28 Testing the potential nutritional pathway between periodontal diseases and frailty cannot be conducted with cross-sectional data. Future longitudinal studies are needed to confirm the association between periodontitis and frailty.

Most of the previous studies used frailty phenotype for studying the association between oral health indicators and frailty. Two recent studies have used frailty index.[17](#_ENREF_17), [18](#_ENREF_18) The first study found that older adults with fewer number of teeth had higher odds of frailty compared to those with 20 or more teeth except for older adults with 11 to 20 teeth. However, number of teeth was self-reported, the frailty index was dichotomised.[18](#_ENREF_18) In the other study that was conducted in Canada, the authors found that poor oral health (based on 24 self-reported oral health problems) was associated with frailty index. Poor diet (based on the consumption of healthy food) explained almost 1% of the association between self-reported poor oral health and frailty index.[17](#_ENREF_17) In the current analysis, while nutritional intake was associated with each of frailty index and oral health indicators, but the impact on their associations was negligible. Nevertheless, we used stronger oral health indicators which were based on clinical examination.

Nutrition has a great impact on the health of older adults. Low nutritional intake contributes to the progression of many morbidities which contribute to the complex aetiology of frailty.[29](#_ENREF_29) On the other hand, oral health conditions impact nutritional intake through changes related to chewing ability and food selection.[30](#_ENREF_30) Reduced number of teeth is linked to impaired chewing abilities.[31](#_ENREF_31) Furthermore, edentate older adults – even those who use well fitted dentures – experience more chewing problems compared to dentate older adults, implicating a higher chance for diet change and inadequate nutritional intake.[32](#_ENREF_32), [33](#_ENREF_33) Older adults tend to select processed soft food, which are usually high in fat and sugar, and low in protein, vitamins and minerals .[34](#_ENREF_34) The low intake of micronutrient exposes older adults to higher risks of malnutrition, oxidative stress, inflammation and ultimately frailty.[32](#_ENREF_32), [35](#_ENREF_35), [36](#_ENREF_36) Although nutritional intake was associated with both number of teeth and frailty in our analysis, but it did not seem to impact their association.  Other factors could explain this relationship, given the cross-sectional association it could be comorbidity related to common risk factors for oral health, nutrition and frailty. Adverse socioeconomic conditions could also lead to poor oral health and frailty simultaneously.[16](#_ENREF_16) That aside, in this cross-sectional analysis, bidirectional association between oral health and frailty cannot be dismissed, as frailty could impacts oral health through sarcopenia, loss of functions, cognitive decline which leads to difficulties performing oral hygiene and accessing dental services.[37](#_ENREF_37)

There are few limitations worth mentioning. First, due to the cross-sectional nature of the study we are unable to draw causal relationship between frailty and oral health indicators. Second, information regarding comorbidities were self-reported which might be subjected to recall bias. Nevertheless, to our knowledge, this is the first study that assessed the association between clinical indicators of oral health and frailty index which included clinical and laboratory assessments. This study showed similar results to previous studies that used frailty phenotype for assessing frailty. It should be highlighted that the phenotype model and frailty index model manifest overlap in the assessment of frailty,[3](#_ENREF_3) and should be considered as complementary rather than alternatives based on the differences of these two models.[38](#_ENREF_38) Selecting the most suitable frailty assessment tool should be based on the purpose of the investigation, the tool’s validity, the examined population, and the study setting in which the tool is used.[6](#_ENREF_6) The use of frailty index in this study allowed testing the association of oral health and frailty based on a comprehensive and informative geriatric assessment compared to assessing physical signs and symptoms in the case of the phenotype model. Using the frailty index in future longitudinal studies assessing the relationship with oral health should be considered as it is more sensitive to changes in health compared to the phenotype model. However, the consistency of the result of this study with results of previous studies that used the phenotype model indicates the importance of maintaining natural teeth and good oral health at older age.

### *Conclusions and Implications:*

This study illustrated that oral health is associated with frailty assessed by the frailty index, and nutritional intake appeared to have a modest effect on the association. It also demonstrated that periodontal disease has a weaker association with frailty index compared to number of teeth. It also highlighted the importance of maintaining good oral health at older age and incorporating indicators of oral health in routine geriatric assessments and health surveys. Future longitudinal studies assessing the association between oral health and frailty should consider using the frailty index as it reflects a comprehensive geriatric status and is more sensitive to changes in clinical and laboratory assessments. Future research should also assess the role of potential mediating factors for this association.

**Conflict of Interest:**

The authors declare no conflicts of interests.

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**List of Tables:**

Table 1: Demographic, socioeconomic and oral health characteristics of study participants stratified by frailty status (percentage/means) NHANES 2011-14 (N=2,368)

Table 2: Negative binomial regression models showing the associations between number of teeth and frailty NHANES 2011-14 (N= 2,368)

Table 3: Negative binomial regression models showing the associations between Periodontal disease and frailty index NHANES 2011-14 (N= 1,884)

**Supplementary material:**

(Table A1 in the Appendix)**.** Variables in the 49-Item Frailty Index and Their Respective Scorings

(Table A2 in the Appendix)**:** Recommended Dietary Allowances and Adequate Intakes

***Tables:***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *Table 1: Demographic, socioeconomic and oral health characteristics of study participants stratified by frailty status (percentage/means) NHANES 2011-14 (N=2,368)* | | | | |
|  | Non-frail | Frail | Total | P-value |
|  | Percentage /mean | | |  |
| *Mean Age* | 67.9 (67.4 – 68.4) | 71 (70.3 – 71.6) | 69.1 (69.6 - 69.5) | 0.0001 |
| *Education Groups* |  |  |  |  |
| *<12 years* | 12.2 (9.7 – 15.0) | 25.7 (21.8 – 29.9) | 17.4 (14.5 – 20.1) | 0.0001 |
| *=12 years* | 20.1 (15.9 – 24.9) | 25.8 (22.3 – 29.6) | 22.3 (19.6 – 25.2) |  |
| *>12 years* | 67.7 (62.3 – 72.7) | 48.4 (45.1 – 51.8) | 60.2 (56.4 – 64.0) |  |
| *Gender* |  |  |  |  |
| *Male* | 51.7 (49 – 54.4) | 41.5 (37.4 – 45.7) | 47.8 (45.4 – 50.2) | 0.0002 |
| *Female* | 48.2 (45.5 – 50.0) | 58.5 (54.3 – 62.5) | 52.2 (49.7 – 54.6) |  |
| *Ethnicity* |  |  |  |  |
| *Mexican American* | 3.1 (1.8 – 5) | 3.8 (2.2 – 6.4) | 3.3 (2 – 5.4) | 0.014 |
| *Other Hispanic* | 3.3 (2.2 – 4.8) | 4.1 (2.5 – 6.4) | 3.6 (2.4 – 5.2) |  |
| *Non-Hispanic White* | 80.5 (76.1 – 84.2) | 77.0 (72.0 – 81.0) | 79.2 (74.8 – 8) |  |
| *Non-Hispanic Black* | 7.3 (5.2 -10.0) | 10.0 (7.5 – 14.0) | 8.5 (6.2 – 1) |  |
| *Other* | 5.7 (4.1 – 7.9) | 4.6 (3.3 – 6.4) | 5.3 (4 – 7.1) |  |
| *Smoking Groups* |  |  |  |  |
| *Never* | 52.4 (48.7 – 56.1) | 42.9 (38.7 – 47.2) | 48.7 (45.6 – 51.9) | 0.006 |
| *Previous* | 36.3 (32.9 – 39.8) | 43.6 (39.6 – 47.8) | 39.1 (36.3 – 42) |  |
| *Current* | 11.2 (9.1 – 13.7) | 13.3 (10.6 – 16) | 12 (10.5 – 13.6) |  |
| *Mean poverty-income ratio* | 3.4 (3.2 – 3.5) | 2.4 (2.34 – 2.6) | 3.0 (2.9 – 3.2) | 0.0001 |
| *Mean Inadequate nutritional intake* | 7.9 (7.6 – 8.2) | 8.5 (7.3 – 8.6) | 8.1 (7.9 – 8.3) | 0.002 |
| *Mean Number of teeth* | 20.7 (20.1 – 21.3) | 14.8 (13.5 – 16.0) | 18.4 (17.6 – 19.2) | 0.0001 |
| *Self-rated Oral health* |  |  |  |  |
| *Excellent/ very good/ good* | 83.2 (80.3 - 85.8) | 68.1 (63.6 – 72.3) | 77.4 (74.6 – 8.0) | 0.0001 |
| *Fair/Poor* | 16.7 (14.1 – 19.6) | 31.8 (27.6 – 36.3) | 22.6 (20.0 – 2.0) |  |
| *Periodontal disease (N:* 1,884) |  |  |  |  |
| *No/Mild periodontal disease* | 53.5 (48.9 – 58.2) | 44 (36.1 – 52.2) | 50.2 (45.4 – 55.1) | 0.028 |
| *Moderate/Severe*  *periodontitis* | 46.4 (41.7 – 51.1) | 56 (47.7 – 64.0) | 49.7 (44.8 – 54.5) |  |

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| Table2: Negative binomial regression models showing the associations between number of teeth and frailty NHANES 2011-14 (N= 2,368) | | | | | | | |
|  |  | Model 1 | | Model 2 | | Model 3 | |
|  |  | RR | p-value | RR | p-value | RR | p-value |
| Age |  | 1.01  (1.00- 1.02) | <0.001 | 1.01  (1.00 – 1.01) | <0.001 | 1.01  (1.00 – 1.01) | <0.001 |
| Gender | Male | (Reference) |  |  |  |  |  |
|  | Female | 1.14  (1.07 – 1.22) | <0.001 | 1.16  (1.08 – 1.25) | <0.001 | 1.14  (1.06 -1.23) | <0.001 |
| Number of teeth | | 0.98  (0.97 – 0.99) | <0.001 | 0.98  (0.98 – 0.99) | <0.001 | 0.99  (0.98 – 0.99) | <0.001 |
| Inadequate nutritional intake | |  |  | 1.02  (1.01 – 1.03) | <0.001 | 1.01  (1.00 – 1.02) | 0.008 |
| Education | Less than 12 years | (Reference) |  |  |  |  |  |
|  | 12 Years |  |  |  |  | 0.95  (0.87 – 1.03) | 0.234 |
|  | More than 12 years |  |  |  |  | 0.91  (0.85 – 0.96) | 0.004 |
| Ethnicity | Mexican American | (Reference) |  |  |  |  |  |
|  | Other Hispanic |  |  |  |  | 0.92  (0.83 – 1.01) | 0.097 |
|  | Non H White |  |  |  |  | 0.95  (0.88 – 1.04) | 0.3 |
|  | Non H black |  |  |  |  | 0.97  (0.89 – 1.07) | 0.61 |
|  | Other |  |  |  |  | 0.89  (0.77 – 1.04) | 0.16 |
| Poverty-income ratio | |  |  |  |  | 0.93  (0.91 – 0.95) | <0.001 |
| Smoking | Never | (Reference) |  |  |  |  |  |
|  | Previous |  |  |  |  | 1.08  (1.01 – 1.15) | 0.01 |
|  | current |  |  |  |  | 1.04  (0.91 – 1.2) | 0.48 |
| Model 1: Adjusted for number of teeth, age, gender.  Model 2 Additionally adjusted for nutritional intake.  Model 3: Additionally, adjusted for ethnicity, education poverty income ratio and smoking.  RR: Rate ratio | | | | | | | |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Table 3: Negative binomial regression models showing the associations between Periodontal disease and frailty index NHANES 2011-14 (N= 1,884) | | | | | | | |
|  |  | Model 1 | | Model 2 | | Model 3 | |
|  |  | RR | p-value | RR | p-value | RR | p-value |
| Age |  | 1.01  (1.00- 1.01) | <0.001 | 1.01  (1.00– 1.01) | <0.001 | 1.01  (1.00 – 1.01) | <0.001 |
| Gender | Male | (Reference) |  |  |  |  |  |
|  | Female | 1.14  (1.09 – 1.20) | <0.001 | 1.16  (1.10 – 1.22) | <0.001 | 1.15  (1.09 -1.21) | <0.001 |
| Periodontitis | No/ Mild Periodontitis | (Reference) |  |  |  |  |  |
|  | Moderate/ Severe Periodontitis | 1.09  (1.04 – 1.15) | <0.001 | 1.08  (1.02 – 1.14) | 0.003 | 1.00  (0.95 – 1.05) | 0.932 |
| Inadequate nutritional intake | |  |  | 1.02  (1.01 – 1.03) | <0.001 | 1.01  (1.00 – 1.02) | 0.009 |
| Model 1: Adjusted for number of teeth, age, gender.  Model 2 Additionally adjusted for nutritional intake.  Model 3: Additionally, adjusted for ethnicity, education poverty income ratio and smoking.  RR: Rate ratio | | | | | | | |