HHS Public Access

Author manuscript

Curr Alzheimer Res. Author manuscript; available in PMC 2022 February 03.

Published in final edited form as:

Curr Alzheimer Res. 2021 ; 18(13): 1023–1031. doi:10.2174/1567205019666211223093057.

Effects of the Co-occurrence of Diabetes Mellitus and Tooth Loss on Cognitive Function

Huabin Luo[1], **Chenxin Tan**[2], **Samrachana Adhikari**[3], **Brenda Plassman**[4], **Angela Kamer**[5], **Frank Sloan**[4], **Mark Schwartz**[6], **Xiang Qi**[2], **Bei Wu**[2,*]

[1]East Carolina University, Brody School of Medicine, Greenville, USA

[2]New York University, Rory Meyers College of Nursing New York, USA

[3]New York University, Grossman School of Medicine, New York, USA

[4]Duke University School of Medicine, Durham, USA

[5]New York University College of Dentistry, New York, USA

[6]New York University Grossman School of Medicine, New York, USA

Abstract

Objective: Both diabetes mellitus (DM) and poor oral health are common chronic conditions and risk factors of Alzheimer's disease and related dementia among older adults. This study assessed the effects of DM and complete tooth loss (TL) on cognitive function, accounting for their interactions.

Methods: Longitudinal data were obtained from the 2006, 2012, and 2018 waves of the Health and Retirement Study. This cohort study included 7,805 respondents aged 65 years or older with 18,331 person-year observations. DM and complete TL were self-reported. Cognitive function was measured by the Telephone Interview for Cognitive Status. Random-effect regressions were used to test the associations, overall and stratified by sex.

[*]Address correspondence to this author at the New York University, Rory Meyers College of Nursing New York, USA; bei.wu@nyu.edu.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This current study used publicly available and non-identifiable data from HRS and is therefore exempted from Institutional Review Board review. The research project is under the ethical and safety guidelines set forth by the Institutional Review Board of New York University (IRB--FY2020-4698).

HUMAN AND ANIMAL RIGHTS

No animals were used in this study. The study on humans was conducted in accordance with the ethical rules of the Helsinki Declaration and Good Clinical Practice.

CONSENT FOR PUBLICATION

Informed consent was obtained from all participants.

AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of the article are available in this article.

STANDARDS OF REPORTING

STROBE guidelines have been followed in this study.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

Results: Compared with older adults without neither DM nor complete TL, those with both conditions (b = −1.35, 95% confidence interval [CI]: −1.68, −1.02), with complete TL alone (b = −0.67, 95% CI: −0.88, −0.45), or with DM alone (b = −0.40, 95% CI: −0.59, −0.22), had lower cognitive scores. The impact of having both conditions was significantly greater than that of having DM alone (p < .001) or complete TL alone (p = 0.001). Sex-stratified analyses showed the effects were similar in males and females, except having DM alone was not significant in males.

Conclusion: The co-occurrence of DM and complete TL poses an additive risk for cognition. Healthcare and family-care providers should pay attention to the cognitive health of patients with both DM and complete TL. Continued efforts are needed to improve older adults' access to dental care, especially for individuals with DM.

Keywords

Cognitive function; diabetes; tooth loss; effects of co-occurrence; population

1. INTRODUCTION

With the rapid aging of the U.S. population, the number of older adults with cognitive impairment, Alzheimer's disease, and related dementia (ADRD) continues to increase. Cognitive impairment has emerged as a major contributing factor to mortality in older persons [1]. Identifying risk factors for cognitive impairment and slowing its progression are essential to mitigate its adverse impact on older adults, their families, and the healthcare system [2].

Research has shown that diabetes mellitus (DM) is a risk factor for cognitive impairment and ADRD [3-7]. Emerging evidence has also shown that overall, poor oral health (*e.g.*, periodontal disease and tooth loss) is a risk factor for cognitive impairment [8-11], although the findings are inconsistent [12-15].

Both DM and poor oral health are common chronic conditions among older adults in the U.S [16, 17]. Although the prevalence of complete tooth loss (TL) has been decreasing recently [18, 19], a considerable number of older adults are edentulous. The 2009-2014 National Health and Nutrition Examination Survey in the U.S. showed that complete TL affected 17.6% of adults aged 65 years and older, and 22.5% of those aged 75 years and older [20].

Furthermore, DM and poor oral health have a reciprocal relationship: DM has an adverse effect on periodontal health, and periodontal disease affects glycemic control [21, 22]. Individuals with DM are more likely to have a higher number of missing teeth [18]. Given the interrelated mechanism (*e.g.*, chronic inflammation) between DM and poor oral health, the co-occurrence of these two factors could be expected to pose a higher risk for cognitive decline. Nevertheless, there exist limited data exploring how the co-occurrence of DM and complete TL (a measure of poor oral health) affects cognitive function compared to having either condition alone. So far, to our knowledge, only one study [23] examined the association of poor oral health and DM with dementia/cognitive decline, and found that compared to persons with 22 or more teeth, those having no teeth were at the highest risk of both dementia and cognitive decline.

To address the scarcity of empirical evidence, our study aimed to assess the association of DM and complete TL with cognitive function in a large representative sample of older adults with longitudinal data in the U.S. We hypothesized that 1) older adults with the co-occurrence of DM and complete TL would have lower cognitive function than those with either condition alone; 2) older adults with at least one of the conditions would have lower cognitive function than those with neither condition.

2. MATERIALS AND METHODS

2.1. Data and Study Sample

Data for this study were drawn from the Health and Retirement Study (HRS). The HRS is a population-based, nationally representative survey of U.S. adults aged 51 years and older. It is a biennial longitudinal survey, which began in 1992; new cohorts have been added in some waves of HRS to maintain the desired sample size. The HRS collects detailed economic and health information, including income, assets, disability, chronic conditions, and cognitive function [24]. However, some data are not collected in every wave. For example, information about complete TL, one of our primary measures, was only measured in three waves: 2006, 2012, and 2018. At the time of this study, HRS 2018 is the most recent publicly available data that include tooth loss data. As such, we included respondents aged 65 years or older from these three waves.

In this study, we excluded respondents without follow-up data on cognitive function and respondents who self-reported complete TL or DM previously in one wave of HRS survey but reported otherwise in a subsequent wave. The final analytical sample consisted of 7,805 respondents aged 65 years or older, including 2,721 respondents participating in all 3 waves (with 2006 as baseline), 3,381 in 2006 and 2012 only (2006 as baseline), 1,654 in 2012 and 2018 (2012 as baseline), and 49 in 2006 and 2018 but not in 2012 (2006 as baseline). As such, all of them had at least 2 waves of cognitive function data, and the analytical sample consisted of 18,331 person-year observations

2.2. Measures

2.2.1. Cognitive Function—Cognitive function was assessed by the HRS modified Telephone Interview for Cognitive Status (TICS-m) [25]. It is a brief cognitive status measure that includes immediate and delayed word recall (score range = 0–20), serial 7 subtraction (range = 0–5), counting backwards (range = 0–2), orientation to time (range = 0–4), object naming (range = 0–2), and president/vice president naming (range = 0–2) [26]. The total score ranges from 0 to 35 points, and a higher score indicates better cognitive function. In this analysis, cognitive function (TICS-m scores) was treated as a time-varying outcome variable.

2.2.2. DM and Complete TL—DM status (Yes/No) was based on the respondent's answer to the question, "Since the last interview, has a doctor told you that you have diabetes or high blood sugar?" Complete TL (Yes/No) was based on the response to the question, "Have you lost all of your upper and lower natural permanent teeth?"

We grouped respondents based on their self-reported DM and complete TL exposure status, *i.e.*, Group 1 with neither condition, Group 2 with DM alone, Group 3 with complete TL alone, and Group 4 with both DM and complete TL. We treated this grouping variable as a time-varying independent variable. That is, during the study period 2006-2018, if a respondent's status changed, *i.e.*, they lost all their teeth and/or were told by a doctor that they had DM after the last HRS survey, their grouping was re-classified accordingly. A total of 1,090 respondents experienced a change in status in the study period.

2.2.3. Covariates—Covariates were selected according to prior literature on factors that influence cognitive performance among older adults [27, 28]. These covariates included demographics, socioeconomic status, health status, and health behaviors. Demographic variables included age group (65-74, 75-84, and 85+), sex, race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanics, and others). Socioeconomic status variables included years of education, total annual household income, private insurance coverage, and marital status (married and unmarried). Health status was measured by the self-reported history of chronic diseases, which included high blood pressure, cancer (except non-malignant skin cancer), heart disease (heart attack, coronary heart disease, angina, congestive heart failure, or other heart problems), and stroke, all were binary variables; body mass index (BMI) (underweight [< 18.5], normal weight [18.5-24.9], overweight [25-29.9], and obese [≥ 30]), difficulty in Activities of Daily Living (ADL) (range=0-5), including bathing, dressing, transferring, toileting, and eating. Last, health behavior variables included regular physical exercise (whether doing vigorous activities at least once per week or more frequent) and being a current smoker. All covariates except for race/ethnicity, sex, and years of education were measured as time-varying variables.

2.3. Analytical Approach

First, characteristics of respondents at baseline (*i.e.*, 2006 for 6,151 respondents or 2012 for 1,654 respondents) were assessed by DM and complete TL status. Appropriate statistical tests (ANOVA test or Chi-square test) with sampling weights were used for descriptive analysis, and the complex survey design of HRS was accounted for. Second, we conducted longitudinal analyses to estimate the effects of the exposure (the grouping variable by DM and complete TL status) on cognitive function adjusting for covariates, using random-effects (RE) models with respondent level random intercept. Stratified analyses by sex were also conducted. The RE models accounted for both within- and between-individual variations, and the generalized least squares random effects estimators were estimated. Third, we conducted sensitivity analyses to assess the effects of changes in DM and/or TL status with relative changes in cognitive function using fixed effects (FE) models for the same analytical sample. The FE models only considered within-individual variation but could eliminate the effects by time-invariant unobserved factors not included in the model; thus, it provided a more robust estimation of the effects of interests. Data analyses were conducted using Stata 17 MP (S-tataCorp, College Station, TX).

3. RESULTS

3.1. Descriptive Statistics

Table 1 provides descriptive statistics of respondents by DM and complete TL status at baseline. Out of 7,805 respondents included, 67.2% (N = 5,176) had neither DM or complete TL, 16.3% (N = 1,255) had DM alone, 12.6% (N = 1,038) had complete TL alone, and 3.9% (N = 336) had both conditions. Their weighted mean cognitive scores were 23.7 (standard deviation [SD] = 0.07), 22.6 (SD = 0.15), 21.9 (SD = 0.17), and 20.4 (SD = 0.27), respectively.

Overall, non-Hispanic Blacks, Hispanics, and respondents with lower levels of income and fewer years of education were more likely to have both conditions; respondents covered by private insurance were less likely to have both conditions (all $p < .001$); respondents who needed more assistance in ADLs, had hypertension, heart disease, and stroke, and who were current smokers and obese were more likely to have both conditions (all $p < .001$).

3.2. Random-effect Model Results

The unadjusted RE model (Model 1a) results showed that in comparison with respondents without either condition, those with both conditions (b = −3.94, 95% CI: −4.31, −3.57), with complete TL alone (b = −2.41, 95% CI: −2.66, −2.16), and with DM alone (b = −1.36, 95% CI: −1.57, −1.16), had lower cognitive scores (Table 2).

The adjusted RE model (Model 1b) showed that in comparison with those without either condition, respondents with both conditions (b = −1.35, 95% CI: −1.68, −1.02), with complete TL alone (b = −0.67, 95% CI: −0.88, −0.45), and with DM alone (b = −0.40, 95% CI: −0.59, −0.22), had lower cognitive scores. In addition, comparisons between the group with both conditions and the groups with either condition alone, and the group with DM alone vs. the group with complete TL alone, showed that respondents with both conditions had lower cognitive scores than did respondents with DM alone ($p < .001$) or with complete TL alone ($p = .001$, p-values adjusted for multiple comparisons using Bonferroni correction); the difference was not significant between respondents with DM alone and with complete TL alone.

When considering the impact of specific covariates, respondents aged 75 and older had lower cognitive scores than those aged 65-74 years ($p < .001$). Respondents who were females, were racial/ethnic minorities, were married, and had better socioeconomic status (higher income, more years of education, covered by private health insurance) had higher cognitive scores than their counterparts (all $p < .001$). Respondents who were overweight or obese also had higher cognitive scores than those normal ($p < .001$), while those who were underweight had lower cognitive scores ($p < .01$). Respondents who needed more assistance in ADLs had lower cognitive scores ($p < .001$), while those who regularly exercised or worked out had higher cognitive scores ($p < .001$). Respondents with hypertension ($p < .05$) and with stroke ($p < .001$) had lower cognitive scores.

3.3. Sex Stratified Random-effects Models Results

In the sex-stratified analyses (Table 2), we also employed unadjusted (Model 2a and Model 3a) and adjusted analyses (Model 2b and Model 3b) for males and females separately. For brevity, only adjusted model results are presented here. First, in females, compared with those without either condition, female respondents with both conditions (b = −1.37, 95% CI: −1.81, −0.92), with complete TL alone (b = −0.52, 95% CI: −0.80, −0.23), and with DM alone (b = −0.58, 95% CI: −0.83, −0.32), had lower cognitive scores. In addition, female respondents with both conditions had lower cognitive scores than did respondents with DM alone (p = .006, p-values adjusted for multiple comparisons using Bonferroni correction) or with complete TL alone (p = .003); the difference in cognitive scores was not significant between female respondents with DM alone and with complete TL alone (Model 2b). Second, in males, in comparison with those without either condition, male respondents with both conditions (b = −1.29, 95% CI: −1.80, −0.79), and those with complete TL alone (b = −0.91, 95% CI: −1.23, −0.58), had lower cognitive scores. But in contrast to the results for females presented above, no significant difference in cognitive scores was found between males with diabetes alone and those without either condition (Model 3b). Having both conditions had a greater impact than having DM alone (p < .001), but not than having complete TL alone. The results of other covariates are similar in females and males overall (Table 2).

3.4. Cognitive Decline among Respondents with Changes in DM and/or Complete TL

We conducted further analyses using Fixed-effects (FE) models to examine the effects of condition changes (*e.g.*, from having neither condition to having both conditions, from one condition alone to having both conditions) using the sample analytical sample. The FE models controlling for all covariates were further used to estimate the predicted cognitive scores in 2006, 2012, and 2018. Figs. (1 and 2) present predicted cognitive scores of respondents at baseline and follow-up. In both figures, we only include two person-year observations for each respondent to ensure the same secular duration (*i.e.*, 6 years) in cognitive score change (*i.e.*, respondents participated in 2006 and 2012 or participated in 2012 and 2018). As shown in (Fig. 1), respondents who changed from Group 1 (neither condition) to Group 4 (both conditions) had the largest decline of 2.49 points (from 22.45 to 19.96, numbers not presented), followed by those who changed from Group 2 (DM alone) to Group 4 with a decline of 2.31 points (from 21.95 to 19.64), those who changed from Group 3 (complete TL alone) to Group 4 with a decline of 2.00 points (from 21.91 to 19.91), those who changed from Group 1 (neither condition) to Group 3 (complete TL alone) with a decline of 1.75 (from 22.34 to 20.59), and those who changed from Group 1 (neither condition) to Group 2 (DM alone) having a decline of 1.44 (from 22.96 to 21.52). An ANOVA test showed a significant difference in cognitive declines among these groups (p < .001).

As a comparison with (Fig. 1), we also estimated the change in predicted cognitive scores for respondents whose DM and/or tooth loss status did not change in 6 years (*e.g.*, from 2006 to 2012, or from 2012 to 2018) (Fig. 2). As shown, respondents with *neither condition* or *DM alone* had a smaller decline in cognitive scores, a decline of 1.15 points (from 22.86 to 21.71) and a decline of 1.15 points (from 22.50 to 21.35), respectively; whereas those

with *complete TL alone* or *both conditions* had a larger decline, a decline of 1.34 (from 21.66 to 20.32) and a decline of 1.36 (from 21.07 to 19.71). An ANOVA test showed a significant difference in changes in cognitive scores among them ($p < .001$).

As a comparison with (Fig. 1), we also estimated the change in predicted cognitive scores for respondents whose DM and/or tooth loss status did not change in 6 years (*e.g.,* from 2006 to 2012, or from 2012 to 2018) (Fig. 2). As shown, respondents with *neither condition* or *DM alone* had a smaller decline in cognitive scores, a decline of 1.15 points (from 22.86 to 21.71) and a decline of 1.15 points (from 22.50 to 21.35), respectively; whereas those with *complete TL alone* or *both conditions* had a larger decline, a decline of 1.34 (from 21.66 to 20.32) and a decline of 1.36 (from 21.07 to 19.71). An ANOVA test showed a significant difference in changes in cognitive scores among them ($p < 1$).

4. DISCUSSION

This cohort study investigated the effects of the co-occurrence of DM and complete TL on cognitive function using data from the HRS, a large population-based sample of adults in the US. We found that the co-occurrence of both DM and complete TL posed an additive risk for cognitive health.

Our first hypothesis was supported among females but not in males. The results showed that older female adults with both DM and complete TL had lower cognitive scores than those without either condition; they also had lower cognitive scores than those with DM alone or complete TL alone. The results obtained from the male sample were slightly different; older male adults with both DM and complete TL had lower cognitive scores than those without either condition, but they did not have lower cognitive scores than those with complete TL alone.

The second hypothesis was also fully supported in females but was partially supported in males. We found that female adults with either one condition had lower cognitive function than those without any of the two conditions. Whereas in males, compared to those with neither condition, those having complete TL alone had lower cognitive scores, but those having DM alone did not.

Overall, our study results are similar by sex. One major difference is the relationship between having diabetes alone and cognitive scores. One possible explanation is that the prevalence of heart disease (38.1% vs. 28.1%) and stroke (10.1% vs. 7.8%) was higher in males than in females in the study sample (data not shown). As such, the presence of these dementia risk factors in males may render diabetes insignificant, as we observed in this study. Given that very limited research has been conducted in this area, future research is needed to further examine the sex differences in these relationships.

Because of the small number of respondents who experienced a status change in both DM and complete TL during the study period, we did not present sex-stratified figures in assessing the changes in cognitive scores with respect to the DM and/or complete TL changes during the study period. Overall, in the whole sample, those who had no condition at baseline and developed both experienced the most cognitive decline. These findings

indicate that the adverse effects of having both conditions on cognitive function are larger than having one condition alone. Thus, our study provides evidence that having both DM and complete TL has an additive risk on cognitive function.

Our study showed edentulism to be a significant risk factor for poorer cognitive performance for both males and females. Overall, results from the whole sample show that, controlling for other covariates, older adults with complete TL alone had a 0.67-unit lower cognitive score (95% CI: −0.88, −0.45). Our findings are consistent with most existing literature that fewer teeth are a risk factor for poorer cognitive function [29-33]. For instance, data from the Atherosclerosis Risk in Communities study showed complete edentulism to be associated with lower cognitive scores in adults aged 52-75 [34].

Fewer teeth, a commonly used indicator for poor oral health, affect food choice and nutritional status [35]. Tooth loss is associated with poor masticatory function and it may affect stimulation of the central nervous system [36, 37]. Limited masticatory force and chewing capacity are associated with impaired cognitive function [38]. Prior research has found that individuals with suboptimal dentition (<20 teeth) had a 20% higher risk of developing cognitive decline and dementia than those with optimal dentition (≥20 teeth) [8]. A most recent systematic review found that each additional tooth loss was associated with a 1.41% increase in the risk of cognitive impairment. Edentulous persons faced a 1.57 times higher risk of cognitive impairment and a 1.44 times higher risk of dementia [39]. It should be noted that periodontal disease is the leading cause of tooth loss in adults, and periodontal disease signifies long-term exposure to inflammation [29]. In our sample, 17.60% of respondents were edentulous at baseline and 23.87% of them were edentulous throughout the study period. Community education to maintain good oral health is needed; restorative dental care (*e.g.*, use of denture) may potentially improve nutrition intake and mastication, which may help improve cognitive function [37, 40]. Some evidence also suggests a bi-directional relationship between oral health and cognitive health [41, 42]. Poor cognitive health may also affect oral health because persons with cognitive impairment may be less able to maintain good oral hygiene [13].

Results of other covariates are consistent with prior findings [2]. In this study, both obesity and overweight were associated with better cognitive scores in comparison with underweight. Underweight may reflect a decrease in muscle mass or a decrease in fat, and research has shown muscle loss and poor nutritional status to be associated with cognitive decline [43, 44].

While most prior research has found obesity to be associated with a greater decline of cognitive function and dementia, the association is age-related [45-48], other research has shown that obesity may be a protective factor for cognitive function while controlling for other key factors [49]; still, further research has found that cognition and BMI are not linearly correlated, and only severe obesity is associated with worse cognition [50]. The relationship between body weight and cognitive function is complex and more research is needed.

There are several limitations to this study. All the information used was based on self-report, which may be subject to reporting bias. In addition, the measure of oral health was limited. It would have been preferable to have other measurements of oral health, such as the number and condition of teeth present, as well as the exact year that the respondents lost all of their teeth, but this information was not collected in HRS. Additionally, data on whether the respondents used dentures were not available. Detailed medication data were not available in the dataset. The strengths of this study include the panel study design the large sample size, generalizability, and representation of the U.S. population. Data for all respondents (*i.e.*, cognitive scores) were obtained from at least two time points. The panel structure of HRS and a follow-up of up to 12 years could ensure a more valid estimation of the relationship between DM/TL and cognitive decline.

CONCLUSION

In our study, the co-occurrence of DM and complete TL was found to have an additive effect on cognitive function among older adults in the U.S. Clinicians and family members should pay close attention to the cognitive health of patients with both DM and tooth loss. For these patients, early screening for dementia may be necessary so care plans can be made to slow down the progression of the disease. Continuous efforts and policy changes are needed to improve older adults' access to restorative dental care and promote good dental hygiene behaviors, especially for patients with diabetes.

FUNDING

This study was supported by a grant from the National Institutes of Health and the National Institute on Aging (grant number 1R56AG067619-0).

REFERENCES

[1]. Sachs GA, Carter R, Holtz LR, et al. Cognitive impairment An independent predictor of excess mortality: A cohort study. Ann Intern Med 2011; 155(5): 300–8. 10.7326/0003-4819-155-5-201109060-00007 PMID: 21893623 [PubMed: 21893623]

[2]. Alzheimer's Association. 2020 Alzheimer's disease facts and figures. Alzheimers Dement 2020;2020. PMID: 32157811

[3]. Vagelatos NT, Eslick GD. Type 2 diabetes as a risk factor for Alzheimer's disease: the confounders, interactions, and neuropathology associated with this relationship. Epidemiol Rev 2013; 35: 152–60. 10.1093/epirev/mxs012 PMID: 23314404 [PubMed: 23314404]

[4]. Reitz C, Brayne C, Mayeux R. Epidemiology of Alzheimer disease. Nat Rev Neurol 2011; 7(3): 137–52. 10.1038/nrneurol.2011.2 PMID: 21304480 [PubMed: 21304480]

[5]. Mayeda ER, Whitmer RA, Yaffe K. Diabetes and cognition. Clin Geriatr Med 2015; 31(1): 101–115, ix. [ix.]. 10.1016/j.cger.2014.08.021 PMID: 25453304 [PubMed: 25453304]

[6]. Cheng G, Huang C, Deng H, Wang H. Diabetes as a risk factor for dementia and mild cognitive impairment: A meta-analysis of longitudinal studies. Intern Med J 2012; 42(5): 484–91. 10.1111/j.1445-5994.2012.02758.x PMID: 22372522 [PubMed: 22372522]

[7]. Gudala K, Bansal D, Schifano F, Bhansali A. Diabetes mellitus and risk of dementia: A meta-analysis of prospective observational studies. J Diabetes Investig 2013; 4(6): 640–50. 10.1111/jdi.12087 PMID: 24843720

[8]. Cerutti-Kopplin D, Feine J, Padilha DM, et al. Tooth loss increases the risk of diminished cognitive function: A systematic review and meta-analysis. JDR Clin Trans Res 2016; 1(1): 10–9. 10.1177/2380084416633102 PMID: 30931697 [PubMed: 30931697]

[9]. Holmer J, Eriksdotter M, Schultzberg M, Pussinen PJ, Buhlin K. Association between periodontitis and risk of Alzheimer's disease, mild cognitive impairment and subjective cognitive decline: A case-control study. J Clin Periodontol 2018; 45(11): 1287–98. 10.1111/jcpe.13016 PMID: 30289998 [PubMed: 30289998]

[10]. Oh B, Han DH, Han KT, et al. Association between residual teeth number in later life and incidence of dementia: A systematic review and meta-analysis. BMC Geriatr 2018; 18(1): 48. 10.1186/s12877-018-0729-z PMID: 29454307 [PubMed: 29454307]

[11]. Tonsekar PP, Jiang SS, Yue G. Periodontal disease, tooth loss and dementia: Is there a link? A systematic review. Gerodontology 2017; 34(2): 151–63. 10.1111/ger.12261 PMID: 28168759 [PubMed: 28168759]

[12]. Thomson WM, Barak Y. Tooth loss and dementia: a critical examination. J Dent Res 2021; 100(3): 226–31. 10.1177/0022034520957233 PMID: 32942945 [PubMed: 32942945]

[13]. Wu B, Fillenbaum GG, Plassman BL, Guo L. Association between oral health and cognitive status: A systematic review. J Am Geriatr Soc 2016; 64(4): 739–51. 10.1111/jgs.14036 PMID: 27037761 [PubMed: 27037761]

[14]. Stewart R, Weyant RJ, Garcia ME, et al. Adverse oral health and cognitive decline: the health, aging and body composition study. J Am Geriatr Soc 2013; 61(2): 177–84. 10.1111/jgs.12094 PMID: 23405916 [PubMed: 23405916]

[15]. Shimazaki Y, Soh I, Saito T, et al. Influence of dentition status on physical disability, mental impairment, and mortality in institutionalized elderly people. J Dent Res 2001; 80(1): 340–5. 10.1177/00220345010800010801 PMID: 11269726 [PubMed: 11269726]

[16]. Eke PI, Thornton-Evans GO, Wei L, Borgnakke WS, Dye BA, Genco RJ. Periodontitis in US adults: National health and nutrition examination survey 2009-2014. J Am Dent Assoc 2018; 149(7): 576–588.e6. 10.1016/j.adaj.2018.04.023 PMID: 29957185 [PubMed: 29957185]

[17]. Centers for Disease Control & Prevention. National Diabetes Statistic Report 2020. State and County Indicators 2020. Available from: https://www.cdc.gov/diabetes/pdfs/data/statistics/national-diabetes-statistics-report.pdf Accessed May 20,2020.

[18]. Luo H, Pan W, Sloan F, Feinglos M, Wu B. Forty-year trends in tooth loss among American adults with and without diabetes mellitus: An age-period-cohort analysis. Prev Chronic Dis 2015; 12: E211. 10.5888/pcd12.150309 PMID: 26632952 [PubMed: 26632952]

[19]. Wu B, Liang J, Landerman L, Plassman B. Trends of edentulism among middle-aged and older Asian Americans. Am J Public Health 2013; 103(9): e76–82. 10.2105/AJPH.2012.301190 PMID: 23865668 [PubMed: 23865668]

[20]. Dye BA, Weatherspoon DJ, Lopez Mitnik G. Tooth loss among older adults according to poverty status in the United States from 1999 through 2004 and 2009 through 2014. J American Dental Assoc (1939) 2019; 150(1): 9–23. 10.1016/j.adaj.2018.09.010

[21]. Borgnakke WS, Ylöstalo PV, Taylor GW, Genco RJ. Effect of periodontal disease on diabetes: systematic review of epidemiologic observational evidence. J Periodontol 2013; 84(4) (Suppl.): S135–52. PMID: 23631574 [PubMed: 23631574]

[22]. Taylor GW. Bidirectional interrelationships between diabetes and periodontal diseases: An epidemiologic perspective. Ann Periodontol 2001; 6(1): 99–112. 10.1902/annals.2001.6.1.99 PMID: 11887478 [PubMed: 11887478]

[23]. Batty GD, Li Q, Huxley R, et al. Oral disease in relation to future risk of dementia and cognitive decline: prospective cohort study based on the Action in Diabetes and Vascular Disease: Preterax and Diamicron Modified-Release Controlled Evaluation (ADVANCE) trial. Eur Psychiatry 2013; 28(1): 49–52. 10.1016/j.eurpsy.2011.07.005 PMID: 21964484 [PubMed: 21964484]

[24]. Servais M. Overview of HRS Public Data Files for Cross-sectional and Longitudinal Analysis. Ann Arbor, Michigan: Institute for Social Research, University of Michigan 2010. 10.7826/ISR-UM.06.585031.001.05.0023.2010

[25]. Brandt J, Spencer M, McSorley P, Folstein MF. Semantic activation and implicit memory in Alzheimer disease. Alzheimer Dis Assoc Disord 1988; 2(2): 112–9. 10.1097/00002093-198802020-00003 PMID: 3214579 [PubMed: 3214579]

[26]. Ofstedal M, Fisher G, AR H. Documentation of Cognitive Functioning Measures in the Health and Retirement Study. Ann Arbor, MI: University of Michigan 2005.

[27]. Wu B. Cognitive impairment and oral health in older adults. Alzheimers Dement 2011; 7(4): S368. 10.1016/j.jalz.2011.05.1060

[28]. Ge S, McConnell ES, Wu B, Pan W, Dong X, Plassman BL. Longitudinal association between hearing loss, vision loss, dual sensory loss, and cognitive decline. J Am Geriatr Soc 2021; 69(3): 644–50. 10.1111/jgs.16933 PMID: 33258497 [PubMed: 33258497]

[29]. Kaye EK. Valencia A. Baba N. Spiro A III. Dietrich T. Garcia RI. Tooth loss and periodontal disease predict poor cognitive function in older men. J Am Geriatr Soc 2010; 58(4): 713–8. 10.1111/j.1532-5415.2010.02788.x PMID: 20398152 [PubMed: 20398152]

[30]. Stein PS, Desrosiers M, Donegan SJ, Yepes JF, Kryscio RJ. Tooth loss, dementia and neuropathology in the Nun study. J Am Dent Assoc 2007; 138(10): 1314–22. 10.14219/jada.archive.2007.0046 PMID: 17908844 [PubMed: 17908844]

[31]. Stein PS, Kryscio RJ, Desrosiers M, Donegan SJ, Gibbs MB. Tooth loss, apolipoprotein E, and decline in delayed word recall. J Dent Res 2010; 89(5): 473–7. 10.1177/0022034509357881 PMID: 20139337 [PubMed: 20139337]

[32]. Okamoto N, Morikawa M, Okamoto K, et al. Relationship of tooth loss to mild memory impairment and cognitive impairment: findings from the Fujiwara-kyo study. Behav Brain Funct 2010; 6: 77.10.1186/1744-9081-6-77 PMID: 21194415 [PubMed: 21194415]

[33]. Li J, Xu H, Pan W, Wu B. Association between tooth loss and cognitive decline: A 13-year longitudinal study of Chinese older adults. PLoS One 2017; 12(2): e0171404. 10.1371/journal.pone.0171404 PMID: 28158261 [PubMed: 28158261]

[34]. Naorungroj S, Schoenbach VJ, Wruck L, et al. Tooth loss, periodontal disease, and cognitive decline in the Atherosclerosis Risk in Communities (ARIC) study. Commun Dent Oral Epidemiol 2015; 43(1): 47–57. 10.1111/cdoe.12128 PMID: 25363061

[35]. Chauncey HH, Muench ME, Kapur KK, Wayler AH. The effect of the loss of teeth on diet and nutrition. Int Dent J 1984; 34(2): 98–104. PMID: 6588038 [PubMed: 6588038]

[36]. Noble JM, Scarmeas N, Papapanou PN. Poor oral health as a chronic, potentially modifiable dementia risk factor: review of the literature. Curr Neurol Neurosci Rep 2013; 13(10): 384. 10.1007/s11910-013-0384-x PMID: 23963608 [PubMed: 23963608]

[37]. Weijenberg RA, Scherder EJ, Lobbezoo F. Mastication for the mind--the relationship between mastication and cognition in ageing and dementia. Neurosci Biobehav Rev 2011; 35(3): 483–97. 10.1016/j.neubiorev.2010.06.002 PMID: 20547177 [PubMed: 20547177]

[38]. Lexomboon D, Trulsson M, Wårdh I, Parker MG. Chewing ability and tooth loss: Association with cognitive impairment in an elderly population study. J Am Geriatr Soc 2012; 60(10): 1951–6. 10.1111/j.1532-5415.2012.04154.x PMID: 23035667 [PubMed: 23035667]

[39]. Qi X, Zhu Z, Plassman BL, Wu B. Dose-response meta-analysis on tooth loss with the risk of cognitive impairment and dementia. J Am Med Dir Assoc 2021; 22(10): 2039–45. 10.1016/j.jamda.2021.05.009 PMID: 34579934 [PubMed: 34579934]

[40]. Hasegawa Y, Ono T, Hori K, Nokubi T. Influence of human jaw movement on cerebral blood flow. J Dent Res 2007; 86(1): 64–8. 10.1177/154405910708600110 PMID: 17189465 [PubMed: 17189465]

[41]. Kang J, Wu B, Bunce D, et al. Bidirectional relations between cognitive function and oral health in ageing persons: A longitudinal cohort study. Age Ageing 2020; 49(5): 793–9. 10.1093/ageing/afaa025 PMID: 32128563 [PubMed: 32128563]

[42]. Lu N, Wu B, Pei Y. Exploring the reciprocal relationship between cognitive function and edentulism among middle-aged and older adults in China. Age Ageing 2020; 50(3): 809–14. PMID: 32931547

[43]. Sergi G, De Rui M, Coin A, Inelmen EM, Manzato E. Weight loss and Alzheimer's disease: temporal and aetiologic connections. Proc Nutr Soc 2013; 72(1): 160–5. 10.1017/S0029665112002753 PMID: 23110988 [PubMed: 23110988]

[44]. Spauwen PJ, Murphy RA, Jónsson PV, et al. Associations of fat and muscle tissue with cognitive status in older adults: the AGES-Reykjavik Study. Age Ageing 2017; 46(2): 250–7. 10.1093/ageing/afw219 PMID: 28399220 [PubMed: 28399220]

[45]. Barnes DE, Yaffe K. The projected effect of risk factor reduction on Alzheimer's disease prevalence. Lancet Neurol 2011; 10(9): 819–28. 10.1016/S1474-4422(11)70072-2 PMID: 21775213 [PubMed: 21775213]

[46]. Norton S, Matthews FE, Barnes DE, Yaffe K, Brayne C. Potential for primary prevention of Alzheimer's disease: An analysis of population-based data. Lancet Neurol 2014; 13(8): 788–94. 10.1016/S1474-4422(14)70136-X PMID: 25030513 [PubMed: 25030513]

[47]. Whitmer RA, Gunderson EP, Barrett-Connor E, Quesenberry CP Jr, Yaffe K. Obesity in middle age and future risk of dementia: A 27 year longitudinal population based study. BMJ 2005; 330(7504): 1360. 10.1136/bmj.38446.466238.E0 PMID: 15863436 [PubMed: 15863436]

[48]. Xu WL, Atti AR, Gatz M, Pedersen NL, Johansson B, Fratiglioni L. Midlife overweight and obesity increase late-life dementia risk: A population-based twin study. Neurology 2011; 76(18): 1568–74. 10.1212/WNL.0b013e3182190d09 PMID: 21536637 [PubMed: 21536637]

[49]. Qizilbash N, Gregson J, Johnson ME, et al. BMI and risk of dementia in two million people over two decades: A retrospective cohort study. Lancet Diabetes Endocrinol 2015; 3(6): 431–6. 10.1016/S2213-8587(15)00033-9 PMID: 25866264 [PubMed: 25866264]

[50]. Kuo HK, Jones RN, Milberg WP, et al. Cognitive function in normal-weight, overweight, and obese older adults: an analysis of the advanced cognitive training for independent and vital elderly cohort. J Am Geriatr Soc 2006; 54(1): 97–103. 10.1111/j.1532-5415.2005.00522.x PMID: 16420204 [PubMed: 16420204]

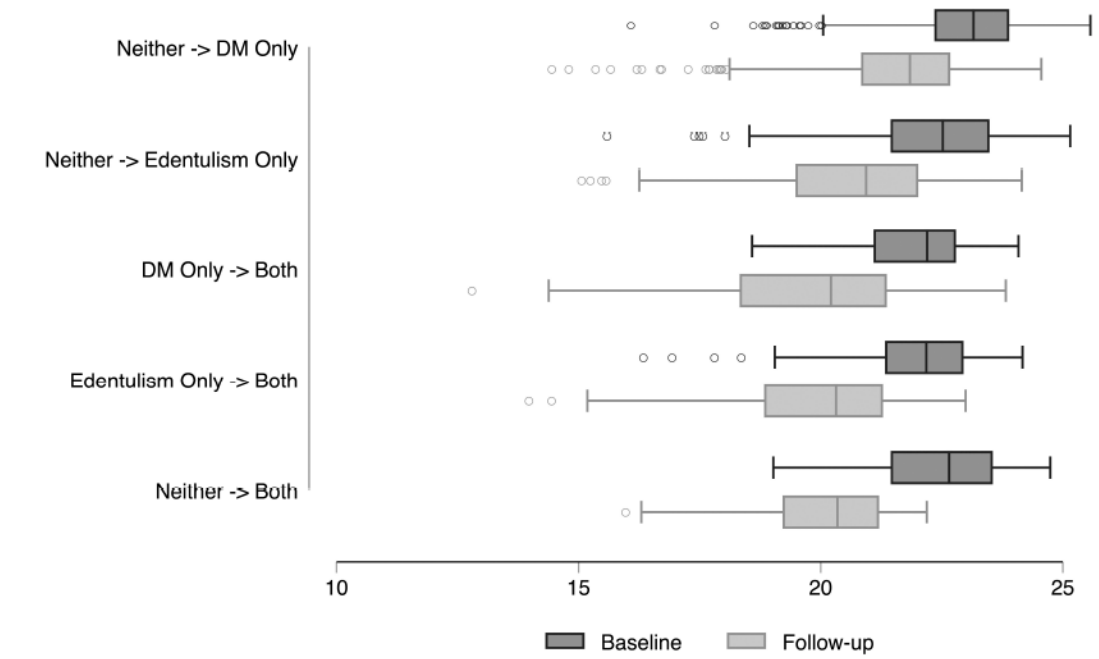

Fig. (1).

Cognitive score changes associated with status changes in DM and/or complete TL. (Number of respondents in each category, from top to bottom: 366, 266, 89, 107, and 20).

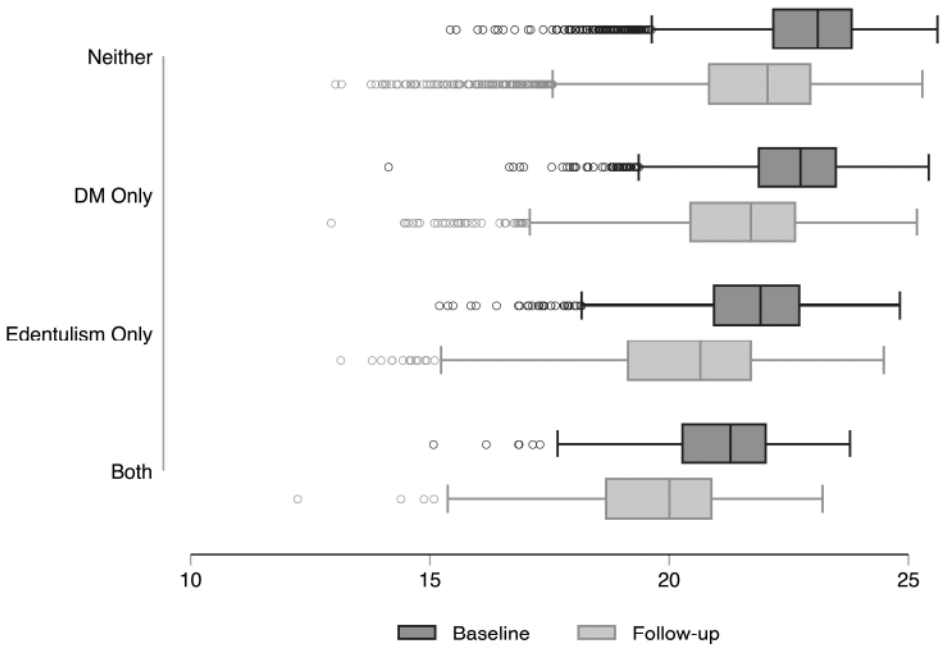

Fig. (2).

Cognitive score changes for respondents without status change in DM and/or complete TL. (Numbers of respondents in each category, from top to bottom: 4,486, 1,121, 915, and 336).

Table 1.

Descriptive statistics for respondents' baseline characteristics.

	Neither (N = 5,151)		Diabetes only (N = 1,251)		Edentulism only (N = 1,035)		Both (N = 336)		
	Mean or %	**(SD)**	**Mean or %**	**(SD)**	**Mean or %**	**(SD)**	**Mean or %**	**(SD)**	***p*-value**
Unweighted proportion	66.27%	-	16.09%	-	13.32%	-	4.32%	-	-
Weighted proportion	67.17%	-	16.35%	-	12.60%	-	3.88%	-	-
Cognitive function	23.69	(0.07)	22.63	(0.15)	21.90	(0.17)	20.36	(0.27)	< .001
Male	57.2%	-	49.6%	-	60.6%	-	60.9%	-	< .001
Age Category	-	-	-	-	-	-		-	< .001
65 - 74	72.8%	-	77.9%	-	64.1%	-	71.0%	-	-
75 - 84	23.5%	-	19.3%	-	29.6%	-	25.8%	-	-
85 & older	3.8%	-	2.8%	-	6.3%	-	3.1%	-	-
Race/ethnicity	-	-	-	-	-	-		-	< .001
White, non-Hispanic	85.7%	-	73.3%	-	81.5%	-	65.8%	-	-
Black, non-Hispanic	6.5%	-	10.6%	-	10.2%	-	20.8%	-	-
Hispanic	6.0%	-	12.7%	-	6.2%	-	11.0%	-	-
Other	1.9%	-	3.3%	-	2.2%	-	2.5%	-	-
Married	66.2%	-	65.2%	-	54.8%	-	56.2%	-	< .001
Years of schooling	13.21	(0.04)	12.49	(0.12)	11.28	(0.11)	10.94	(0.21)	< .001
Household income ($1000)	72.10	(2.71)	59.00	(2.60)	37.10	(1.50)	33.40	(2.60)	< .001
Has private insurance	60.3%	-	50.5%	-	49.0%	-	42.1%	-	< .001
BMI category	-	-	-	-		-		-	< .001
Normal weight	33.9%	-	11.9%	-	32.2%	-	16.0%	-	-
Underweight	1.3%	-	0.4%	-	0.8%	-	NA	-	-
Overweight	41.0%	-	39.0%	-	37.1%	-	30.3%	-	-
Obese	23.8%	-	48.7%	-	29.9%	-	53.6%	-	-
ADLs	0.13	(0.01)	0.27	(0.02)	0.26	(0.03)	0.35	(0.05)	< .001
Regular exercise	39.5%	-	29.5%	-	25.9%	-	16.2%	-	< .001
Problem drinker	12.4%	-	4.9%	-	7.8%	-	1.0%	-	< .001

	Neither		Diabetes only		Edentulism only		Both		
	(N = 5,151)		(N = 1,251)		(N = 1,035)		(N = 336)		
	Mean or %	(SD)	Mean or %	(SD)	Mean or %	(SD)	Mean or %	(SD)	*p*-value
Smoker	8.0%	-	6.1%	-	20.9%	-	14.0%	-	< .001
Hypertension	56.1%	-	79.5%	-	59.9%	-	83.3%	-	< .001
Cancer	16.4%	-	17.0%	-	15.8%	-	13.0%	-	0.429
Heart disease	22.9%	-	34.2%	-	29.4%	-	39.2%	-	< .001
Stroke	4.9%	-	7.8%	-	7.1%	-	10.4%	-	< .001

Notes: Results were weighted using respondents' baseline analytical weights. Abbreviations: SD, standard deviation; BMI, body mass index; ADL, activities of daily living; NA, no observations.

Table 2.

Results from random-effects models for the whole sample, females, and males.

	Males and Females				Females				Males			
	(N = 7,805, Obs = 18,331)				(N = 4,564, Obs = 10,767)				(N = 3,241, Obs = 7,456)			
	Model 1a		Model 1b		Model 2a		Model 2b		Model 3a		Model 3b	
Variable	**Coef**	**(95% CI)**	**Coef**	**(95% CI)**	**Coef**	**(95% CI)**	**Coef**	**(95% CI)**	**Coef**	**(95% CI)**	**Coef**	**(95% CI)**
DM and Edentulism	-	-	-	-	-	-	-	-	-	-	-	-
Neither (ref)	-	-	-	-	-	-	-	-	-	-	-	-
DM only	−1.35	(−1.56 - −1.15)	−0.40	(−0.59 - −0.22)	−1.75	(−2.04 - −1.45)	−0.58	(−0.83 - −0.32)	−0.84	(−1.12 - −0.55)	−0.16	(−0.42 - 0.10)
Edentulism only	−2.41	(−2.66 - −2.16)	−0.67	(−0.88 - −0.45)	−2.25	(−2.57 - −1.92)	−0.52	(−0.80 - −0.23)	−2.67	(−3.05 - −2.30)	−0.91	(−1.23 - −0.58)
Both	−3.94	(−4.30 - −3.57)	−1.35	(−1.68 - −1.02)	−4.13	(−4.61 - −3.64)	−1.37	(−1.81 - −0.92)	−3.67	(−4.23 - −3.11)	−1.29	(−1.80 - −0.79)
Female	-	-	1.16	(1.00 - 1.31)	-	-	-	-	-	-	-	-
Age Group	-	-	-		-	-	-	-	-	-	-	-
65-74 (ref)	-	-	-		-	-	-	-	-	-	-	-
75-84	-	-	−1.26	(−1.37 - −1.14)	-	-	−1.23	(−1.38 - −1.08)	-	-	−1.31	(−1.48 - −1.14)
85+	-	-	−3.39	(−3.60 - −3.18)	-	-	−3.44	(−3.72 - −3.16)	-	-	−3.34	(−3.66 - −3.01)
Race/ethnicity	-	-			-	-	-	-	-	-		
White (ref)	-	-			-	-	-	-	-	-		
Black	-	-	−2.38	(−2.63 - −2.13)	-	-	−2.36	(−2.67 - −2.05)	-	-	−2.5	(−2.91 - −2.08)
Hispanic	-	-	−0.74	(−1.06 - −0.42)	-	-	−1.25	(−1.69 - −0.82)	-	-	−0.04	(−0.50 - 0.42)
Other	-	-	−1.28	(−1.87 - −0.69)	-	-	−2.04	(−2.88 - −1.19)	-	-	−0.29	(−1.03 - 0.44)
Married	-	-	0.28	(0.13 - 0.43)	-	-	0.25	(0.06 - 0.44)	-	-	0.31	(0.06 - 0.56)
Schooling Years	-	-	0.49	(0.46 - 0.51)	-	-	0.49	(0.45 - 0.53)	-	-	0.47	(0.43 - 0.52)
Household income	-	-	0.26	(0.20 - 0.32)	-	-	0.25	(0.17 - 0.32)	-	-	0.28	(0.20 - 0.37)
Private insurance	-	-	0.67	(0.54 - 0.79)	-	-	0.75	(0.58 - 0.92)	-	-	0.54	(0.36 - 0.72)
BMI Category	-	-	-		-	-	-	-	-	-	-	-
Normal weight (ref.)	-	-	-		-	-	-	-	-	-	-	-
Underweight	-	-	−0.78	(−1.36 - −0.20)	-	-	−0.66	(−1.33 - 0.01)	-	-	−1.02	(−2.14 - 0.09)
Overweight	-	-	0.57	(0.41 - 0.72)	-	-	0.69	(0.48 - 0.90)	-	-	0.36	(0.11 - 0.60)
Obese	-	-	0.89	(0.70 - 1.07)	-	-	1.07	(0.83 - 1.30)	-	-	0.57	(0.29 - 0.86)

	Males and Females				Females				Males			
	(N = 7,805, Obs = 18,331)				(N = 4,564, Obs = 10,767)				(N = 3,241, Obs = 7,456)			
	Model 1a		Model 1b		Model 2a		Model 2b		Model 3a		Model 3b	
Variable	**Coef**	**(95% CI)**	**Coef**	**(95% CI)**	**Coef**	**(95% CI)**	**Coef**	**(95% CI)**	**Coef**	**(95% CI)**	**Coef**	**(95% CI)**
ADLs	-	-	−0.8	(−0.90 - −0.70)	-	-	−0.83	(−0.96 - −0.71)	-	-	−0.71	(−0.85 - −0.56)
Workout	-	-	0.37	(0.25 - 0.50)	-	-	0.33	(0.15 - 0.51)	-	-	0.44	(0.26 - 0.62)
Smoker	-	-	0.07	(−0.18 - 0.33)	-	-	0.06	(−0.29 - 0.41)	-	-	0.05	(−0.32 - 0.42)
Hypertension	-	-	−0.16	(−0.31 - −0.02)	-	-	−0.2	(−0.40 - −0.01)	-	-	−0.09	(−0.30 - 0.12)
Cancer	-	-	0.04	(−0.13 - 0.21)	-	-	0.04	(−0.20 - 0.28)	-	-	0.03	(−0.21 - 0.27)
Heart problem	-	-	−0.13	(−0.28 - 0.01)	-	-	−0.11	(−0.31 - 0.10)	-	-	−0.16	(−0.36 - 0.04)
Stroke	-	-	−1.23	(−1.49 - −0.97)	-	-	−1.25	(−1.62 - −0.88)	-	-	−1.23	(−1.60 - −0.87)

Notes: Robust confidence intervals in parentheses.

*
p <.05

**
p < .01

***
p<0.001

Abbreviations: Obs, observations; Coef, coefficient; CI, confidence interval; ref, reference group; BMI, body mass index; ADL, activities of daily living.