

## **Oral health, disability and physical function: results from studies of older people in the UK and USA**

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**Brief summary:** A range of oral health markers are associated with disability and physical function after full adjustment in studies of older people in the UK and USA. This finding highlights the importance of maintaining good oral health in older age.

## **Abstract**

**Objectives:** Studies examining the associations between oral health and disability have limited oral health measures. We investigated the association of a range of objectively and subjectively assessed oral health markers with disability and physical function in older age.

**Design, setting and participants:** Cross-sectional analyses were based on the British Regional Heart Study (BRHS) comprising men aged 71-92 (n=2147) from 24 British towns, and the Health, Aging and Body Composition (HABC) Study comprising men and women aged 71-80 (n=3075) from USA. Assessments included oral health (periodontal disease, tooth count, dry mouth, self-rated oral health), disability, and physical function (grip strength, gait speed, chair stand test).

**Results:** In the BRHS, dry mouth, tooth loss, and cumulative oral health problems ( $\geq 3$  problems) were associated with mobility limitations, problems with activities of daily living (ADL) and instrumental activities of daily living (IADL); these remained significant after adjustment for confounding variables (for  $\geq 3$  dry mouth symptoms, odds ratio (OR)=2.68, 95%CI=1.94-3.69; OR=1.76, 95%CI=1.15-2.69; OR=2.90, 95% CI: 2.01, 4.18, respectively). Similar results were observed in the HABC Study. Dry mouth was associated with the slowest gait speed in the BRHS, and the weakest grip strength in the HABC Study (OR=1.75, 95% CI: 1.22, 2.50; OR=2.43. 95%CI=1.47-4.01, respectively).

**Conclusions and Implications:** Markers of poor oral health, particularly dry mouth, poor self-rated oral health and the presence of more than one oral health problems were associated with disability and poor physical function in older populations. Prospective investigations of these associations and underlying pathways are needed.

## Introduction

Disability and poor physical function are common in older age and associated with poor quality of life, mortality and hospitalization.<sup>1,2,3</sup> In addition, oral health problems (periodontal disease, tooth loss, dry mouth) are very prevalent in older people and can affect chronic diseases and mortality, and adversely influence nutritional intake.<sup>4-7</sup>

Furthermore, poor oral health in older age is associated with disability and declining physical function.<sup>8-12</sup> Tooth loss was linked to problems with instrumental activities of daily living (IADL),<sup>13</sup> and activities of daily living (ADL),<sup>10,14,14, 15</sup> developing mobility limitations<sup>14</sup> and decline in physical performance.<sup>12,16, 17</sup> Moreover, periodontal disease was associated with IADL problems,<sup>13</sup> while poor self-rated oral health was linked to ADL problems.<sup>15</sup> Oral health markers are also associated with physical function. Periodontal disease was associated with a decline in handgrip strength,<sup>18</sup> while having no natural teeth (edentulism) was associated with a decline in gait speed.<sup>11</sup> In another study, the association between tooth loss and gait speed was attenuated when adjusted for inflammation.<sup>19</sup>

Although existing evidence suggests an association between oral health problems and disability and physical function in older age, studies so far have limited oral health measures (mainly periodontal disease and tooth loss). Therefore, the aim of this cross-sectional study is to examine the association of objectively and subjectively assessed measures of oral health with disability and physical function in two studies of community-dwelling older adults in the UK and USA.

## Methods

### *The British Regional Heart Study*

The British Regional Heart Study (BRHS) is a prospective cohort study where 7735 men aged 49-50 years were recruited in 1978-80 from 24 towns across the UK.<sup>20</sup> When participants were 71-92 years they were invited to a 30-year re-examination in 2010-2012.<sup>20</sup> A total of 2147 participants (68% response rate) completed the postal questionnaire and 1722 participated in the physical examination (55% response rate).<sup>20</sup> In 2010-2012, information from questionnaires and physical and oral examination was available.<sup>21</sup> Ethical approval was provided by the relevant ethical committees. Informed written consent was obtained from study subjects in order to participate in the investigations, which were conducted in accordance with the Declaration of Helsinki.

### *The Health, Aging, and Body Composition Study (Health ABC Study)*

The Health ABC (HABC) Study is a prospective cohort study where 3075 white and African-American men and women, aged 70-79 years, were recruited. White participants were randomly selected through Medicare, while African-American from neighbourhoods with a ZIP code around Memphis and Pittsburgh.<sup>22</sup> Only individuals who were able to walk 0.25 miles or climb 10 steps without any difficulty were included in the study at baseline. In Year 2 (1998-1999) participants aged 71-80 years (n=1975) underwent an oral health and physical assessment, and completed questionnaires. All of the participants provided written informed consent. Ethical approval was provided by several institutional review boards.<sup>22</sup>

## Oral Health

In both studies an oral examination comprised objective measures including a count of natural teeth, and periodontal disease measures (loss of attachment and pocket depth). Details of these measurements can be found elsewhere.<sup>21, 23</sup> Subjective measures were assessed through questionnaires and consisted of self-rated oral health, dry mouth, difficulty eating due to mouth, teeth or dentures problems, sensitivity to hot/cold/sweets, limit of food due to gum problems and dental service use. In the BRHS, dry mouth was measured based on the Xerostomia Inventory Scale;<sup>24</sup> in the HABC Study, participants were asked if they had dry mouth symptoms when eating.

Number of natural teeth was categorised as: five-level category ( $\geq 21$  teeth, 15-20, 8-14, 1-7 and 0); edentulism (no natural teeth, and  $\geq 1$ ); and having  $\geq 21$  and  $< 21$  remaining teeth.<sup>25</sup> Periodontal pocket depth was grouped as, for BRHS:  $> 20\%$  sites affected  $> 3.5$  mm, and for HABC Study:  $> 20\%$  sites affected  $> 3$  mm. Loss of attachment was grouped as, for BRHS:  $> 20\%$  sites affected  $> 5.5$  mm, and HABC Study  $> 20\%$  sites affected with  $\geq 3$  mm.<sup>21, 26</sup> Self-rated oral health was categorised as excellent/good and fair/poor in both studies. In the BRHS, dry mouth was categorised into 0, 1-2 or  $\geq 3$  dry mouth symptoms. Dental service use consisted of regular check-up, occasional check-up, only when having trouble and never go to the dentist in the BRHS, whereas in the HABC Study, included going to the dentist  $\geq 2$  times a year, once per year and less than once per year. A cumulative measure of oral problems was created. In the BRHS, it was based on having:  $\geq 3$  dry mouth symptoms,  $< 21$  natural teeth, any difficulty eating and sensitivity to hot/cold/sweets;<sup>27</sup> in the HABC Study limit of food due to gum problems was utilised instead of sensitivity to hot/cold/sweets. The cumulative oral

health problem variable was then grouped as 0, 1, 2, and  $\geq 3$  problems. Details of both studies are summarised in Figure A1 in the Appendix.

## Disability

In the BRHS, information on disability was based on questionnaires in 2010-2012. Mobility limitations was based on difficulty going up or down stairs or walking 400 yards. Having problems with ADL was based on difficulty or needing help doing any of the following tasks: (1) getting in and out of a chair, (2) dressing and undressing yourself, (3) bathing or showering, (4) feeding yourself, including cutting food or (5) getting to and using the toilet. IADL problems was based on any difficulty or needing help in: shopping for personal items, preparing your own meals, using telephone by yourself, managing money or using public transport. In the HABC Study, data from Year 2 (1998-1999) questionnaires were used to ascertain disability. Mobility limitations was based on any difficulty in walking one quarter of a mile or climbing 1 flight. ADL problems included any problem or needing help in dressing, getting in and out of bed or bathing on your own. Information on IADL was not available.

## Physical Function

Physical function measures were obtained through physical examinations in both studies. In the BRHS, gait speed was assessed as the time (in seconds) required to walk 3 meters at normal pace.<sup>28</sup> Grip strength (Jamar Hydraulic Hand Dynamometer Model J00105) was measured 3 times for each hand and the highest reading was used.<sup>20</sup> Chair stand test was assessed as time taken (in seconds) for participants to sit and stand from a chair five times. In the HABC Study, grip strength and gait speed were measured. Gait speed was measured as

the time (seconds) taken to walk 400 m at a steady rate (long distance corridor walk).<sup>29</sup> Grip strength (isometric Jamar Hydraulic Hand Dynamometer) was measured twice for each hand and the highest reading in either hand was used.<sup>30</sup>

### Covariates

In both studies, information on socioeconomic position, smoking, physical activity, and history of doctor-diagnosed cardiovascular disease (CVD) and diabetes were obtained from questionnaires.<sup>20, 23</sup> In the BRHS, socioeconomic position was based on occupational social class which was derived from longest-held occupation when participants entered the study.<sup>21</sup> Smoking history was based on combined set of questions from previous questionnaires, while physical activity was based on self-report of usual physical activity levels.<sup>31</sup> In the HABC Study, socioeconomic position was based on the highest level of education accomplished.<sup>23</sup> Physical activity was a composite measure of the total calories consumed per kilogram per week from a number of activities.<sup>32</sup> For both studies, measures of self-rated general health and regular use of prescribed medications causing dry mouth (xerostomia) were included.<sup>33</sup>

### Statistical Analysis

Due to differences in the populations of the BRHS and HABC Study and in the assessment of oral health measures and covariates, we conducted separate analyses for the two studies. Logistic regression was performed to calculate odds ratios (95%CI) for the associations of poor oral health with disability and poor physical function. For physical function outcome measures included the slowest gait speed (top quintile), slowest chair stand speed (top quintile) and weakest grip strength (bottom quintile). In the BRHS, fully-adjusted models included age



(continuous), social class (2 levels), smoking (4 levels), physical activity (5 levels), history of CVD and diabetes. In the HABC Study, adjustment for age (continuous), gender, race, education (3 levels), smoking (3 levels), physical activity (continuous), and history of CVD and diabetes was performed. In both studies, we further adjusted the models for self-rated general health (continuous), and analyses with dry mouth were also adjusted for use of medications (3 levels). Covariates were tested for correlation before they were entered in the models. All analyses were performed using SAS, version 9.4 software (SAS Institute, Inc., Cary, North Carolina).

## **Results**

The baseline characteristics and prevalence of oral health measures in the BRHS and HABC Study populations are presented in Table 1. The mean age of BRHS participants was 78.8 years, 48% were in manual social class, 20% were edentulous, 35% reported poor self-rated oral health, 62% had at least 1 dry mouth symptom, and 36%  $\geq 2$  cumulative oral health problems. In the HABC Study, mean age was 74.7 years, 48% were males and 52% females, 58% White and 42% African-American, and 42% completed postsecondary education. Additionally, 11% had no natural teeth, 31% reported poor self-rated oral health, and 4% dry mouth and 22% had at least 2 cumulative oral health problems.

Table 2 presents odds ratios and 95% CIs for the associations of objective and subjective markers of oral health with measures of disability in the BRHS. Tooth loss was associated with ADL (OR=1.65, 95% CI 1.05-2.57) after full adjustment for covariates (age, social class, smoking, physical activity, history of CVD and diabetes). Edentulism was associated with IADL problems (OR=1.51, 95%CI 1.03-2.22). Fair/poor self-rated oral health was associated with

mobility limitations, and IADL problems (OR=1.44, 95% CI 1.12-1.85; OR=1.66, 95% CI 1.24-2.22, respectively). Similarly, having  $\geq 3$  dry mouth symptoms and  $\geq 2$  oral health problems were associated with mobility limitations, ADL and IADL problems. Dental service use was associated with mobility limitations and IADL problems.

The associations between oral health and physical function are presented in Table 3. Periodontal pocket depth greater  $>3.5$  mm was associated with having the weakest grip strength (OR=1.59, 95%CI: 1.14-2.20). Additionally,  $\geq 3$  dry mouth symptoms and limited dental service use were associated with the slowest gait speed (OR= 1.75, 95% CI 1.22-2.50; OR=1.69, 95% CI: 1.08-2.62, respectively).

Table 4 presents the associations between oral health markers and disability in the HABC Study. In the fully-adjusted model, tooth loss was associated with mobility limitations and ADL problems. Associations with mobility limitations and ADL problems were observed in fully-adjusted models for fair/poor self-rated oral health (OR=1.19, 95%CI 1.10-1.30; OR=1.27, 95% CI 1.15-1.41, respectively), dry mouth (OR=2.26, 95%CI 1.50-3.39; OR=2.23, 95%CI 1.46-3.41, respectively), and difficulty eating (OR=1.51, 95% CI: 1.22-1.86; OR=1.90, 95%CI: 1.50, 2.40). Presence of  $\geq 3$  oral health problems was associated with mobility limitations and ADL problems.

Odds ratios for oral health markers and physical function in the HABC Study are presented in Table 5. Periodontal disease and tooth loss were not associated with grip strength and gait speed. Poor self-rated oral health was associated with the slowest gait speed (OR=1.16, 95%CI: 1.03-1.30). Dry mouth was associated with the weakest grip strength in the fully-adjusted model. Associations of dry mouth with disability and physical function did not materially change after adjusting for medications use (results not presented).

Adjustment for self-rated general health attenuated some of the associations reported above, including tooth loss, self-rated oral health and dental service with disability measures, and dry mouth and dental service with slow walking speed in the BRHS, and self-rated oral health and dental service with mobility limitations and self-rated oral health with slow walking speed in the HABC Study (results not presented).

## **Discussion**

Our study comprising two samples of community-dwelling older people from the UK and USA found that tooth loss, dry mouth, poor self-rated oral health and cumulative oral health problems were associated with mobility limitations, ADL, and IADL problems. Dry mouth and poor self-rated oral health were also associated with poor physical function. This study provides new evidence on the associations of objective and subjective oral health markers with disability and physical function in older age.

After adjustment for self-rated general health, the associations of partial tooth loss, edentulism and self-rated oral health with disability (mobility limitations, ADL, IADL) were abolished in the BRHS, showing that these associations could be influenced by poor underlying health status. Nevertheless, associations between tooth loss and disability remained significant in the HABC Study, in accordance with previous studies.<sup>8, 9, 14-17</sup> Our findings support the hypothesis that poor oral health and disability coexist in older age. However our cross-sectional findings are unable to demonstrate if poor oral health leads to the development of disability and whether these associations are causal. Furthermore, we found that dry mouth was associated with a greater risk of disability in both studies, even after adjustment for medications causing xerostomia. Dry mouth is highly prevalent in older people and is linked to co-morbidities because of the number of medications commonly

prescribed to older people.<sup>24</sup> The positive association of dry mouth with disability adds to the existing literature and suggests that dry mouth is an important oral health condition that may be independently linked to the physical condition of individuals. These results also highlight that subjective measures such as dry mouth and self-rated oral health, are important markers of poor oral health in older age.

In the BRHS, periodontal pocket depth, a marker of acute periodontal disease, was associated with weak grip strength.<sup>18</sup> A previous study did not report any association between periodontal disease and grip strength cross-sectionally, but found that periodontal disease led to a decrease in grip strength over time.<sup>18</sup> Although, tooth loss has been linked to gait stability and speed,<sup>11, 34</sup> in our study tooth loss was not associated with physical function, either grip strength or gait or chair stand speed. However, subjective oral health markers, such as dry mouth, were associated with poor physical function in both our study populations. A previous study reported that dry mouth was associated with poor oral health related quality of life, but did not examine the relations with physical function.<sup>35</sup> However, our previous study on frailty, which is closely linked to physical function since grip strength and gait speed are two components of frailty, reported an association between dry mouth and frailty, thus emphasizing the importance of dry mouth in functional capacity of older people.<sup>27</sup> Moreover, the observed association of poor dental service use and physical function, shows that limited access to oral health services may influence physical condition of older people. Most of these associations with physical function remained significant and were independent of pre-existing CVD, diabetes and poor self-rated general health.

Possible pathways underlying the associations between tooth loss and disability could be inflammation and poor nutrition. Tooth loss is linked to previous periodontal disease.<sup>36</sup>

Periodontal disease is characterised by chronic oral inflammation which may be associated with increased levels of systemic inflammation (i.e. C-reactive protein, IL-6)<sup>37</sup> and therefore could contribute to disability.<sup>19</sup> Furthermore, individuals with poor oral health, particularly tooth loss tend to have poor nutritional status, as a result of decreased consumption of specific food groups and impaired mastication,<sup>38</sup> which can in turn affect muscle strength and consequently contribute to disability (ADL, IADL and mobility limitations) and decreased physical function.<sup>39, 40</sup> Likewise, dry mouth in older people often leads to ulceration and inflammation of oral mucosa, which can create difficulties in eating and swallowing; this can also significantly impact dietary intake and poor nutritional status, and increase the risk of disability.<sup>39, 41</sup>

In this study the associations of a range of both objective and subjective markers of oral health with disability and physical function were examined. Few studies have examined subjective oral health measures such as self-rated oral health and dry mouth; studies so far have mostly focused on tooth loss and periodontal disease. Furthermore, we created a composite measure of oral health problems as an indicator of the burden of oral health problems in older people. Also, the lack of correlation and the observed differences in the associations of objective and subjective measures indicate the importance of utilising both of these measures separately since we cannot use objective measures as indicators of subjective oral problems or vice versa. This study has some limitations. Our findings are based on cross-sectional analyses, and the results cannot establish a causal relationship between oral health and disability or poor physical function. Nevertheless, the findings are supported by longitudinal analyses in the BRHS, where tooth loss and dry mouth were associated with higher risks of developing frailty.<sup>27</sup> Additionally, both cohorts may not be representative of the general populations of the UK and USA. Furthermore, whilst the studies were comparable in terms of

having community-dwelling older people, there were differences in the populations (BRHS comprised men only), and in assessments of oral health measures (i.e. periodontal disease, dry mouth). Nevertheless, we observed similar associations between poor oral health and disability in the two studies. Moreover, while we were able to adjust for a range of covariates in both studies, but the possibility of residual confounding remains because of possible confounders which were not available in the studies or due to measurement error and underreporting of confounders. Furthermore, poor oral health may be a proxy of poor socioeconomic or physical status throughout the life-course. It is also likely in both studies that individuals who participated were healthier with better oral health and physical function status than those who did not attend.<sup>27</sup> Therefore, the potential for under-adjustment remains in our findings.

### **Conclusions and Implications**

We found that oral health problems, particularly, tooth loss, poor self-rated oral health, and dry mouth, were associated with disability and impaired physical function in older populations. These findings merit further research in longitudinal studies, examining the possible mediating roles of nutrition and inflammation to establish the influence of oral health markers on development of disability. Nonetheless, our findings suggest that health care professionals responsible for the care of older people should take into consideration the oral health status of older people including the individual's perception of their oral problems. Moreover, screening tools of dental health,<sup>42</sup> could be useful in identifying and preventing oral health problems and maintaining a good quality of life in older people.

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Table 1. Population characteristics and prevalence of oral health problems in the British Regional Heart Study (BRHS) and the Health ABC (HABC) Study

	<b>BRHS (n=2147)</b>
<b>Age (years), mean ± standard deviation</b>	78.8 ± 4.8
<b>Social class, n (%)</b>	
Nonmanual	1081 (52%)
Manual	1003 (48%)
<b>Smoking, n (%)</b>	
Never	768 (36%)
Long-term exsmoker (gave up before 1983)	1153 (54%)
Recent exsmoker	122 (6%)
Current smoker	91 (4%)
<b>Physical activity, n (%)</b>	
Inactive	405 (20%)
Occasional	475 (24%)
Light	447 (22%)
Moderate	278 (14%)
Moderate vigorous	232 (12%)
Vigorous	165 (8%)
<b>History of cardiovascular disease, n (%)</b>	500 (24%)
<b>History of diabetes, n (%)</b>	321 (16%)
<b>Oral health measures</b>	
Edentulism (no natural teeth)	338 (20%)
<21 teeth	1066 (64%)
>20 % sites with loss of attachment >3.5mm	303 (24%)
>20% sites with pocket depth >5.5mm	365 (29%)
Fair/poor self-rated oral health	719 (35%)
≥ 1 dry mouth symptoms	1272 (62%)
≥ 2 Cumulative oral health problems	766 (36%)
Never been to the dentist	307 (15%)
<b>Mobility limitations, n (%)</b>	564 (27%)
<b>ADL problems, n (%)</b>	412 (20%)
<b>IADL problems, n (%)</b>	367 (17%)
	<b>HABC Study (n=3075)</b>
<b>Age (years), mean ± standard deviation</b>	74.7 ± 2.9
<b>Gender, n (%)</b>	
Male	1491 (48%)
Female	1584 (52%)
<b>Race, n (%)</b>	
White	1794 (58%)
African-American	1281 (42%)
<b>Education, n (%)</b>	
Less than high school	775 (26%)
High school graduate	1000 (33%)
Postsecondary	1292 (42%)
<b>Smoking, n (%)</b>	
Never	1348 (44%)
Current smoker	318 (10%)
Former	1404 (46%)
<b>Physical activity (kcal/kg/week)*, †, mean ± standard deviation</b>	82.9 ± 69.3
History of cardiovascular disease, n (%)	106 (4%)
History of diabetes, n (%)	142 (5%)
<b>Oral health measures</b>	
Edentulism (no natural teeth)	207 (11%)
<21 teeth	1031 (52.2%)
>20 % sites with loss of attachment >3mm	721 (64%)
>20% sites with pocket depth >3mm	627 (55%)
Poor self-rated oral health	829 (31%)
Dry mouth	107 (4%)
≥2 Cumulative oral health problems	617 (22%)
Visiting dentist less than once per year	993 (37%)
<b>Mobility limitations, n (%)</b>	882 (29%)
<b>ADL problems, n (%)</b>	467 (17%)

ADL: Activities of Daily Living; IADL: Instrumental Activities of Daily Living

\* Total kcal/kg/week from household chores, walking and stairs, exercise or recreation activities and work or volunteering or caregiving

†Baseline data (Year 1)

Table 2. Odds ratios (95%CI) for the association of oral health markers with mobility limitations, ADL and IADL problems in 2147 older men aged 71-92 years in the British Regional Heart Study

Oral Health Markers	Mobility limitations (n=564; 27%)			ADL problems (n=412; 20%)			IADL problems (n=367; 17%)		
	N (%)	Age-adjusted OR (95% CI)	Fully-adjusted* OR (95% CI)	N (%)	Age-adjusted OR (95% CI)	Fully-adjusted* OR (95% CI)	N (%)	Age-adjusted OR (95% CI)	Fully-adjusted* OR (95% CI)
<b>Objective</b>									
<b>Tooth Loss</b>									
≥21teeth	106 (18%)	1.00	1.00	70 (12%)	1.00	1.00	56 (10%)	1.00	1.00
15-20 teeth	68 (20%)	1.10 (0.78, 1.56)	0.93 (0.62, 1.38)	44 (13%)	1.07 (0.71, 1.60)	0.97 (0.62, 1.53)	45 (14%)	1.40 (0.92, 2.14)	<b>1.31 (1.12, 2.95)</b>
8-14 teeth	79 (30%)	<b>1.85 (1.31, 2.60)</b>	1.48 (0.98, 2.22)	57 (22%)	<b>1.90 (1.29, 2.81)</b>	<b>1.65 (1.05, 2.57)</b>	44 (17%)	<b>1.75 (1.13, 2.69)</b>	1.54 (0.92, 2.58)
1-7 teeth	38 (32%)	<b>1.90 (1.22, 2.98)</b>	1.23 (0.73, 2.07)	22 (18%)	1.39 (0.81, 2.36)	1.02 (0.56, 1.86)	20 (17%)	1.54 (0.88, 2.70)	1.00 (0.51, 1.95)
0 teeth	103 (31%)	<b>1.73 (1.26, 2.39)</b>	1.14 (0.76, 1.69)	76 (23%)	<b>1.80 (1.24, 2.60)</b>	1.28 (0.82, 1.99)	74 (22%)	<b>2.16 (1.46, 3.19)</b>	<b>1.82 (1.12, 2.95)</b>
<b>Edentulism</b>									
≥1 teeth	291 (22%)	1.00	1.00	193 (15%)	1.00	1.00	165 (13%)	1.00	1.00
0 teeth	103 (31%)	<b>1.36 (1.04, 1.79)</b>	1.01 (0.72, 1.42)	76 (23%)	<b>1.45 (1.07, 1.98)</b>	1.12 (0.78, 1.62)	74 (22%)	<b>1.65 (1.20, 2.26)</b>	<b>1.51 (1.03, 2.22)</b>
<b>Tooth loss</b>									
≥21teeth	106 (18%)	1.00	1.00	70 (12%)	1.00	1.00	56 (10%)	1.00	1.00
<21 teeth	288 (27%)	<b>1.56 (1.21, 2.01)</b>	1.15 (0.85, 1.56)	199 (19%)	<b>1.53 (1.13, 2.06)</b>	1.22 (0.87, 1.73)	183 (18%)	<b>1.74 (1.26, 2.40)</b>	1.46 (0.98, 2.17)
<b>Subjective</b>									
<b>Self-rated oral health</b>									
Good or excellent	290 (22%)	1.00	1.00	217 (17%)	1.00	1.00	182 (14%)	1.00	1.00
Fair or poor	241 (34%)	<b>1.78 (1.45, 2.18)</b>	<b>1.44 (1.12, 1.85)</b>	170 (24%)	<b>1.53 (1.21, 1.92)</b>	1.23 (0.94, 1.60)	171 (24%)	<b>1.90 (1.50, 2.41)</b>	<b>1.66 (1.24, 2.22)</b>
<b>Dry mouth symptoms</b>									
0	135 (18%)	1.00	1.00	92 (12%)	1.00	1.00	77 (10%)	1.00	1.00
1-2	153 (23%)	<b>1.40 (1.08, 1.82)</b>	1.26 (0.92, 1.72)	108 (16%)	<b>1.43 (1.06, 1.94)</b>	1.24 (0.88, 1.75)	109 (17%)	<b>1.80 (1.31, 2.48)</b>	<b>1.67 (1.15, 2.47)</b>
≥3	245 (41%)	<b>3.05 (2.37, 3.92)</b>	<b>2.89 (2.14, 3.91)</b>	188 (31%)	<b>3.12 (2.35, 4.13)</b>	<b>2.68 (1.94, 3.69)</b>	164 (27%)	<b>3.11 (2.30, 4.21)</b>	<b>2.90 (2.01, 4.18)</b>
<b>Difficulty eating</b>									
No	373 (27%)	1.00	1.00	261 (19%)	1.00	1.00	232 (17%)	1.00	1.00
Yes	51 (40%)	<b>1.80 (1.23, 2.63)</b>	1.28 (0.81, 2.04)	44 (34%)	<b>2.22 (1.50, 3.30)</b>	<b>1.67 (1.05, 2.65)</b>	47 (37%)	<b>2.90 (1.95, 4.32)</b>	<b>2.39 (1.46, 3.89)</b>
<b>Number of cumulative oral health problems†</b>									
0	43 (13%)	1.00	1.00	24 (7%)	1.00	1.00	20 (6%)	1.00	1.00
1	232 (23%)	<b>1.82 (1.27, 2.59)</b>	1.27 (0.83, 1.93)	161 (16%)	<b>2.20 (1.40, 3.45)</b>	1.64 (0.98, 2.72)	146 (14%)	<b>2.02 (1.17, 3.48)</b>	1.77 (0.98, 3.19)
2	191 (36%)	<b>3.44 (2.38, 4.99)</b>	<b>2.25 (1.45, 3.48)</b>	146 (27%)	<b>4.36 (2.75, 6.91)</b>	<b>3.29 (1.96, 5.52)</b>	128 (24%)	<b>3.84 (2.23, 6.62)</b>	<b>3.01 (1.65, 5.49)</b>
≥3	98 (44%)	<b>4.62 (3.04, 7.03)</b>	<b>2.83 (1.71, 4.67)</b>	81 (36%)	<b>6.36 (3.85, 10.51)</b>	<b>4.19 (2.36, 7.43)</b>	82 (36%)	<b>7.67 (4.34, 13.57)</b>	<b>5.94 (3.10, 11.37)</b>
<b>Dental service use</b>									
Regular check-up	286 (21%)	1.00	1.00	214 (16%)	1.00	1.00	174 (13%)	1.00	1.00
Occasional check-up	48 (32%)	<b>1.62 (1.11, 2.35)</b>	1.33 (0.84, 2.11)	42 (27%)	<b>1.85 (1.25, 2.73)</b>	1.42 (0.88, 2.29)	42 (28%)	<b>2.35 (1.57, 3.50)</b>	<b>2.01 (1.21, 3.34)</b>
Only when having trouble	88 (38%)	<b>2.07 (1.53, 2.79)</b>	<b>1.51 (1.04, 2.19)</b>	62 (27%)	<b>1.69 (1.21, 2.36)</b>	1.29 (0.87, 1.91)	68 (29%)	<b>2.44 (1.75, 3.40)</b>	<b>1.93 (1.27, 2.91)</b>
Never go to the dentist	116 (38%)	<b>2.06 (1.57, 2.69)</b>	1.25 (0.88, 1.76)	74 (25%)	<b>1.50 (1.10, 2.04)</b>	1.05 (0.72, 1.53)	76 (25%)	<b>1.95 (1.43, 2.67)</b>	1.33 (0.90, 1.98)

ADL: Activities of Daily Living; IADL: Instrumental Activities of Daily Living

Bold indicates p<.05

\*adjusted for age, social class, smoking, physical activity, history of CVD and diabetes

†≥3 dry mouth symptoms, <21 remaining teeth, difficulty eating due to mouth or teeth or dentures problems, sensitivity to hot and cold

Table 3. Odds ratios (95%CI) for the association of oral health markers with grip strength, gait and chair stand speed in 1722 older men aged 71-92 years in the British Regional Heart Study

Oral Health Markers	Weakest grip strength (n=347; 21%)			Slowest gait speed (n=337; 21%)			Slowest chair stand speed (n=390; 24%)		
	N (%)	Age-adjusted OR (95% CI)	Fully-adjusted* OR (95% CI)	N (%)	Age-adjusted OR (95% CI)	Fully-adjusted* OR (95% CI)	N (%)	Age-adjusted OR (95% CI)	Fully-adjusted* OR (95% CI)
<b>Objective</b>									
<b>Tooth loss</b>									
≥21teeth	111 (19%)	1.00	1.00	91 (16%)	1.00	1.00	112 (20%)	1.00	1.00
15-20 teeth	59 (18%)	0.87 (0.61, 1.23)	0.89 (0.61, 1.29)	49 (15%)	0.89 (0.60, 1.30)	1.16 (0.77, 1.74)	62 (20%)	0.94 (0.66, 1.34)	1.19 (0.81, 1.75)
8-14 teeth	58 (23%)	1.13 (0.78, 1.63)	1.11 (0.74, 1.66)	60 (25%)	<b>1.51 (1.03, 2.20)</b>	0.93 (0.53, 1.62)	71 (29%)	<b>1.49 (1.05, 2.12)</b>	1.23 (0.73, 2.06)
1-7 teeth	26 (22%)	0.98 (0.60, 1.60)	1.00 (0.59, 1.72)	29 (26%)	1.44 (0.88, 2.36)	1.00 (0.64, 1.56)	34 (31%)	1.48 (0.93, 2.36)	1.22 (0.82, 1.83)
0 teeth	79 (24%)	1.10 (0.78, 1.54)	1.20 (0.82, 1.76)	96 (31%)	<b>1.82 (1.29, 2.57)</b>	<b>0.63 (0.41, 0.98)</b>	99 (32%)	<b>1.53 (1.11, 2.12)</b>	0.83 (0.56, 1.22)
<b>Edentulism</b>									
≥1 teeth	254 (20%)	1.00	1.00	229 (18%)	1.00	1.00	279 (23%)	1.00	1.00
0 teeth	79 (24%)	1.11 (0.83, 1.49)	0.83 (0.60, 1.16)	96 (31%)	<b>1.64 (1.22, 2.19)</b>	1.30 (0.92, 1.84)	99 (32%)	<b>1.36 (1.02, 1.80)</b>	1.15 (0.83, 1.61)
<b>Tooth loss</b>									
≥21teeth	111 (19%)	1.00	1.00	91 (16%)	1.00	1.00	112 (20%)	1.00	1.00
<21 teeth	222 (22%)	1.01 (0.78, 1.32)	0.97 (0.72, 1.29)	234 (24%)	<b>1.38 (1.04, 1.81)</b>	0.90 (0.65, 1.24)	266 (27%)	<b>1.31 (1.02, 1.70)</b>	0.94 (0.70, 1.26)
<b>Subjective</b>									
<b>Self-rated oral health</b>									
Good or excellent	224 (21%)	1.00	1.00	185 (18%)	1.00	1.00	226 (22%)	1.00	1.00
Fair or poor	105 (19%)	0.83 (0.64, 1.08)	0.83 (0.62, 1.10)	128 (25%)	<b>1.44 (1.10, 1.87)</b>	1.00 (0.73, 1.35)	141 (27%)	1.28 (0.99, 1.64)	1.01 (0.76, 1.35)
<b>Dry mouth symptoms</b>									
0	107 (18%)	1.00	1.00	91 (15%)	1.00	1.00	123 (21%)	1.00	1.00
1-2	118 (22%)	1.34 (1.00, 1.80)	1.25 (0.91, 1.72)	106 (21%)	<b>1.51 (1.10, 2.08)</b>	1.34 (0.93, 1.91)	116 (23%)	1.14 (0.85, 1.53)	0.96 (0.70, 1.33)
≥3	102 (22%)	1.20 (0.88, 1.63)	1.15 (0.83, 1.61)	120 (28%)	<b>1.98 (1.44, 2.72)</b>	<b>1.75 (1.22, 2.50)</b>	131 (30%)	<b>1.56 (1.17, 2.09)</b>	1.33 (0.96, 1.84)
<b>Difficulty eating</b>									
No	225 (20%)	1.00	1.00	216 (20%)	1.00	1.00	266 (25%)	1.00	1.00
Yes	24 (23%)	1.11 (0.68, 1.81)	1.22 (0.72, 2.06)	34 (34%)	<b>1.90 (1.20, 3.01)</b>	1.49 (0.88, 2.50)	36 (36%)	<b>1.58 (1.02, 2.45)</b>	1.23 (0.75, 2.04)
<b>Number of cumulative oral health problems†</b>									
0	63 (19%)	1.00	1.00	51 (16%)	1.00	1.00	53 (16%)	1.00	1.00
1	169 (22%)	1.09 (0.79, 1.52)	1.16 (0.81, 1.66)	146 (19%)	1.18 (0.83, 1.68)	0.84 (0.56, 1.26)	184 (24%)	<b>1.56 (1.11, 2.20)</b>	1.23 (0.84, 1.81)
2	81 (21%)	0.98 (0.67, 1.42)	1.03 (0.68, 1.56)	85 (23%)	1.39 (0.94, 2.07)	0.92 (0.58, 1.44)	101 (27%)	<b>1.75 (1.20, 2.55)</b>	1.38 (0.90, 2.10)
≥3	34 (20%)	0.93 (0.58, 1.49)	1.03 (0.61, 1.74)	55 (35%)	<b>2.49 (1.57, 3.93)</b>	1.52 (0.90, 2.57)	52 (33%)	<b>2.24 (1.43, 3.52)</b>	1.58 (0.95, 2.63)
<b>Dental service use</b>									
Regular check-up	228 (20%)	1.00	1.00	185 (17%)	1.00	1.00	226 (21%)	1.00	1.00
Occasional check-up	19 (17%)	0.73 (0.43, 1.23)	0.83 (0.48, 1.46)	25 (24%)	1.40 (0.86, 2.30)	1.06 (0.60, 1.88)	28 (27%)	1.29 (0.81, 2.07)	1.30 (0.77, 2.19)
Only when having trouble	35 (22%)	0.93 (0.61, 1.39)	0.87 (0.56, 1.37)	50 (33%)	<b>2.04 (1.39, 3.01)</b>	<b>1.69 (1.08, 2.62)</b>	45 (29%)	1.36 (0.92, 2.00)	1.07 (0.69, 1.65)
Never go to the dentist	52 (24%)	1.08 (0.75, 1.53)	1.10 (0.74, 1.64)	61 (29%)	<b>1.67 (1.17, 2.38)</b>	0.98 (0.65, 1.50)	72 (35%)	<b>1.74 (1.25, 2.42)</b>	1.43 (0.97, 2.11)

Bold indicates p<.05

\*adjusted for age, social class, smoking, physical activity, history of CVD and diabetes

†≥3 dry mouth symptoms, <21 remaining teeth, difficulty eating due to mouth or teeth or dentures problems, sensitivity to hot and cold

Table 4. Odds ratios (95%CI) for the association of oral health markers with mobility limitations and ADL problems in 3075 older men and women aged 71-80 years in the Health ABC Study

Oral Health Markers	N (%)	Mobility limitations (n=882; 29%)		N (%)	ADL problems (n=467; 17%)	
		Age-adjusted OR (95% CI)	Fully-adjusted* OR (95% CI)		Age-adjusted OR (95% CI)	Fully-adjusted* OR (95% CI)
Objective						
Tooth loss						
≥21teeth	212 (23%)	1.00	1.00	138 (15%)	1.00	1.00
15-20 teeth	90 (25%)	1.16 (0.87, 1.54)	0.95 (0.70, 1.29)	61 (17%)	1.19 (0.85, 1.65)	1.15 (0.82, 1.62)
8-14 teeth	96 (34%)	<b>1.78 (1.33, 2.37)</b>	<b>1.44 (1.06, 1.98)</b>	68 (25%)	<b>1.86 (1.34, 2.58)</b>	<b>1.74 (1.23, 2.47)</b>
1-7 teeth	55 (30%)	<b>1.49 (1.05, 2.11)</b>	1.12 (0.77, 1.65)	33 (18%)	1.30 (0.86, 1.98)	1.24 (0.79, 1.93)
0 teeth	70 (34%)	<b>1.72 (1.24, 2.38)</b>	1.02 (0.70, 1.49)	30 (15%)	1.01 (0.66, 1.55)	0.91 (0.57, 1.44)
Edentulism						
≥1 teeth	453 (26%)	1.00	1.00	300 (17%)	1.00	1.00
0 teeth	70 (34%)	<b>1.46 (1.07, 1.98)</b>	0.94 (0.66, 1.33)	30 (15%)	0.85 (0.57, 1.28)	0.74 (0.48, 1.15)
Tooth loss						
≥21teeth	212 (23%)	1.00	1.00	138 (15%)	1.00	1.00
<21 teeth	311 (30%)	<b>1.49 (1.21, 1.82)</b>	1.12 (0.89, 1.41)	192 (19%)	<b>1.34 (1.06, 1.71)</b>	1.28 (0.98, 1.66)
Subjective						
Self-rated oral health						
Good or excellent	435 (23%)	1.00	1.00	278 (15%)	1.00	1.00
Fair or poor	300 (36%)	<b>1.31 (1.21, 1.41)</b>	<b>1.19 (1.10, 1.30)</b>	185 (22%)	<b>1.30 (1.18, 1.43)</b>	<b>1.27 (1.15, 1.41)</b>
Dry mouth symptoms						
No	689 (26%)	1.00	1.00	428 (16%)	1.00	1.00
Yes	52 (49%)	<b>2.66 (1.80, 3.92)</b>	<b>2.26 (1.50, 3.39)</b>	35 (33%)	<b>2.49 (1.64, 3.78)</b>	<b>2.23 (1.46, 3.41)</b>
Difficulty eating						
No	546 (25%)	1.00	1.00	328 (15%)	1.00	1.00
Yes	196 (37%)	<b>1.76 (1.44, 2.15)</b>	<b>1.51 (1.22, 1.86)</b>	138 (26%)	<b>1.99 (1.58, 2.49)</b>	<b>1.90 (1.50, 2.40)</b>
Number of cumulative oral health problems†						
0	173 (22%)	1.00	1.00	108 (14%)	1.00	1.00
1	355 (26%)	1.23 (1.00, 1.52)	0.98 (0.78, 1.22)	202 (15%)	1.08 (0.84, 1.39)	1.07 (0.82, 1.39)
2	120 (31%)	<b>1.53 (1.16, 2.01)</b>	1.14 (0.85, 1.53)	86 (22%)	<b>1.70 (1.24, 2.33)</b>	<b>1.61 (1.16, 2.24)</b>
≥3	107 (48%)	<b>3.28 (2.40, 4.49)</b>	<b>2.19 (1.56, 3.07)</b>	71 (32%)	<b>2.88 (2.03, 4.08)</b>	<b>2.63 (1.81, 3.81)</b>
Dental service use						
2 times or more per year	276 (22%)	1.00	1.00	205 (16%)	1.00	1.00
Once per year	119 (27%)	<b>1.33 (1.04, 1.71)</b>	1.11 (0.85, 1.45)	62 (14%)	0.85 (0.62, 1.15)	0.79 (0.57, 1.08)
Less than once per year	331 (33%)	<b>1.78 (1.48, 2.15)</b>	<b>1.30 (1.04, 1.62)</b>	188 (19%)	1.20 (0.96, 1.49)	1.08 (0.84, 1.40)

ADL: Activities of daily living

Bold indicates p<.05

\*adjusted for age, gender, race, education, smoking, physical activity, history of CVD and diabetes

†dry mouth when eating, <21 remaining teeth, any difficulty eating or chewing, limit of food due to gum problems

Table 5. Odds ratios (95%CI) for the association of oral health markers with grip strength and gait speed in 3075 older men and women aged 71-80 years in the Health ABC Study

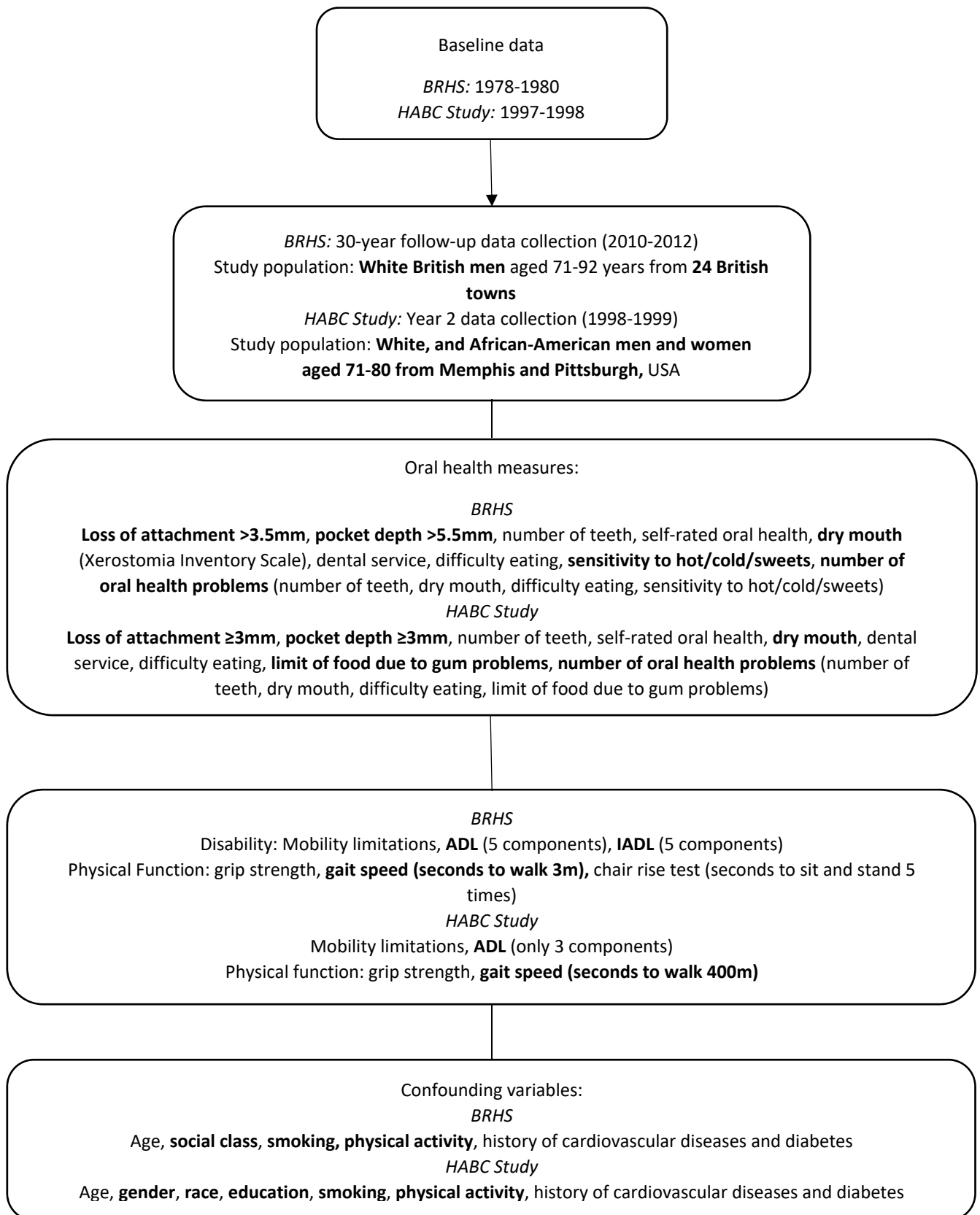
Oral Health Markers	Weakest grip strength (n=469; 20%)			Slowest gait speed (n=375; 20%)		
	N (%)	Age-adjusted OR (95% CI)	Fully-adjusted* OR (95% CI)	N (%)	Age-adjusted OR (95% CI)	Fully-adjusted* OR (95% CI)
Objective						
Tooth loss						
≥21teeth	159 (20%)	1.00	1.00	49 (7%)	1.00	1.00
15-20 teeth	59 (19%)	0.94 (0.68, 1.32)	0.85 (0.59, 1.24)	20 (8%)	1.44 (0.99, 2.09)	1.08 (0.73, 1.62)
8-14 teeth	36 (16%)	0.75 (0.50, 1.11)	0.66 (0.42, 1.03)	19 (12%)	1.52 (0.99, 2.32)	1.08 (0.68, 1.71)
1-7 teeth	24 (15%)	0.76 (0.48, 1.22)	0.71 (0.42, 1.21)	11 (10%)	1.55 (0.94, 2.56)	1.08 (0.63, 1.85)
0 teeth	30 (18%)	0.90 (0.58, 1.38)	0.72 (0.43, 1.21)	15 (11%)	<b>2.02 (1.30, 3.12)</b>	1.15 (0.70, 1.89)
Edentulism						
≥1 teeth	278 (18%)	1.00	1.00	99 (8%)	1.00	1.00
0 teeth	30 (18%)	0.98 (0.64, 1.49)	0.86 (0.53, 1.40)	15 (11%)	<b>1.63 (1.08, 2.47)</b>	1.06 (0.67, 1.68)
Subjective						
Self-rated oral health						
Good or excellent	317 (19%)	1.00	1.00	101 (7%)	1.00	1.00
Fair or poor	148 (21%)	1.07 (0.98, 1.17)	1.06 (0.96, 1.18)	74 (15%)	<b>1.31 (1.18, 1.46)</b>	<b>1.16 (1.03, 1.30)</b>
Dry mouth symptoms						
No	430 (19%)	1.00	1.00	167 (9%)	1.00	1.00
Yes	33 (37%)	<b>2.58 (1.65, 4.03)</b>	<b>2.43 (1.47, 4.01)</b>	8 (14%)	1.78 (0.98, 3.25)	1.54 (0.82, 2.89)
Difficulty eating						
No	389 (20%)	1.00	1.00	129 (8%)	1.00	1.00
Yes	79 (18%)	0.85 (0.65, 1.11)	0.84 (0.62, 1.14)	47 (14%)	<b>1.57 (1.19, 2.08)</b>	1.29 (0.96, 1.75)
Number of cumulative oral health problems†						
0	130 (19%)	1.00	1.00	35 (6%)	1.00	1.00
1	235 (20%)	1.06 (0.84, 1.35)	1.01 (0.77, 1.32)	91 (10%)	<b>1.86 (1.40, 2.48)</b>	<b>1.40 (1.03, 1.91)</b>
2	63 (19%)	1.00 (0.72, 1.40)	0.92 (0.63, 1.34)	28 (11%)	<b>1.97 (1.35, 2.87)</b>	1.31 (0.88, 1.97)
≥3	41 (22%)	1.23 (0.82, 1.83)	1.06 (0.67, 1.67)	22 (18%)	<b>2.35 (1.47, 3.76)</b>	1.40 (0.84, 2.33)
Dental service use						
2 times or more per year	226 (21%)	1.00	1.00	62 (7%)	1.00	1.00
Once per year	68 (18%)	0.87 (0.65, 1.18)	0.88 (0.63, 1.24)	31 (11%)	<b>1.79 (1.27, 2.50)</b>	<b>1.56 (1.09, 2.23)</b>
Less than once per year	171 (20%)	1.00 (0.80, 1.25)	0.99 (0.74, 1.32)	80 (13%)	<b>2.35 (1.81, 3.04)</b>	<b>1.64 (1.21, 2.23)</b>

Bold indicates p<.05

\*adjusted for age, gender, race, education, smoking, physical activity, history of CVD and diabetes

† dry mouth when eating, <21 remaining teeth, any difficulty eating or chewing, limit of food due to gum problems

Supplemental Figure A1. Flowchart of the study characteristics of the British Regional Heart Study (BRHS) and the Health ABC (HABC) Study



Bold indicates difference between the two studies

ADL: Activities of daily living; IADL: Instrumental Activities of Daily Living