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Predicting cognitive function changes from oral health status: a longitudinal cohort study

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Recent studies indicate a potential link between oral health and cognitive function; however, long-term associations remain unclear. This study aimed to identify oral health factors that predict changes in cognitive function among older adults over time. The study included 583 independent older adults (201 male, 382 female) with a mean age of 72.7 years. Cognitive function was assessed using Mini-Mental State Examination (MMSE) at baseline and follow-up over two years, with relative change in MMSE (rMMSE) calculated. Baseline oral health variables included number of remaining teeth, masticatory performance, occlusal force, oral diadochokinesis and tongue pressure. Physical performance and confounding factors were also considered. The relationship between rMMSE and the variables was analyzed using Pearson's correlation, Mann-Whitney U test, and multiple linear regression analysis. Cognitive function declined in 196 subjects, with rMMSE significantly correlated with oral diadochokinesis. Regression analysis revealed significant associations between cognitive changes and oral diadochokinesis ($p = 0.020$) and knee extension strength as a physical performance ($p = 0.047$). Our findings suggest that cognitive decline may be indicated by declines in both physical and oral motor performance. Incorporating oral diadochokinesis testing into health screenings could aid early detection of cognitive decline, improving outcomes and reducing healthcare burdens.

Keywords Cognitive function, MMSE, Oral health, Oral diadochokinesis

Currently, more than 55 million individuals worldwide suffer from dementia, with approximately 10 million new cases diagnosed annually[1]. In Japan, the number of people with dementia was 4.62 million in 2012, accounting for 1 out of 7 older people aged 65 and over, and it is projected to account for 1 out of 5 people in 2025[2]. However, currently, there is no established treatment for dementia[3].

Several studies have identified various risk factors for cognitive decline, including family history, genetics, smoking, alcohol intake, physical activity, drug use, and depressive symptoms[4]. Age is the most significant and consistent risk factor for dementia globally[5], and cognitive decline may be associated with several diseases including diabetes, cardiovascular disease, stroke, hypertension, and dyslipidemia[6]. A recent systematic review revealed findings that periodontal disease is associated with cognitive impairment and a higher risk of incident dementia[7]. Several reports revealed that having fewer teeth is associated with an increased risk of incident dementia, but this association is primarily observed in individuals who do not use dentures[8]. Tooth loss is also a risk factor for the development of all-cause dementia and Alzheimer's disease in an older Japanese population[9], as indicated by cross-sectional studies revealing that significant relationships were found between the number of remaining teeth, the length of the edentulous period, and cognitive function[10]. Namely, tooth loss is reliably associated with cognitive dysfunction and increased risk of dementia[8–10].

Other studies on the relationship between oral health and cognitive function, other than the number of teeth, have suggested that decreased occlusal force may be associated with decreased cognitive function[11–13]. Older adults with poor mastication had significantly lower cognitive function[14]. Furthermore, diminished tongue

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pressure and oral diadochokinesis may lead to cognitive decline[15]. Moreover, the psychological health, physical health, environment, and total quality of life domains were positively correlated with cognitive function[16].

Thus, the relationship between cognitive function decline and several oral health factors has been clarified in reports from several cross-sectional studies; however, the causal relationship is unclear due to the cross-sectional nature of the studies, and the long-term effects of poor oral health on cognitive function are still unclear. It is also unclear which oral health factors are more strongly related to cognitive function.

Therefore, the purpose of this longitudinal cohort study was to identify various factors of oral health status that can predict changes in cognitive function among older adults over time.

Materials and methods

This prospective longitudinal study protocol was approved by the Institutional Review Board (IRB) of Hyogo Medical University (approval no. Rinhi 0342) and the Ethics Committee of the Faculty of Dentistry, Niigata University (G2021-0027). All participants provided written informed consent. All study methods were performed in accordance with relevant guidelines and regulations. This study was part of the Frail Elderly in the Sasayama-Tamba Area (FESTA) study, which was a medical-dental joint academic survey. From April 2016 to December 2022, the survey included independent, healthy older adults who volunteered and resided in the Sasayama-Tamba area of Hyogo Prefecture. The older adults participated in the survey every two years except from 2019 to September 2021 when the FESTA study was suspended due to the COVID-19 pandemic.

Study participants

Participants were recruited through advertisements in local publications and poster announcements from Hyogo Medical University, Sasayama Medical Centre. The inclusion criteria were as follows: (i) individuals aged 65 years and older living in the Sasayama-Tamba area, Hyogo Prefecture, (ii) independent older adults requiring less than level 1 care under the long-term care insurance system in Japan[17] and (iii) participants who had taken part in the survey at least twice. Exclusion criteria were: (i) cognitive impairment (Mini-Mental State Examination [MMSE] score < 20), (ii) a history of cerebrovascular or neuromuscular disease, (iii) missing data, and (iv) participants who did not consent to undergo oral function examination. Before participating, all participants were provided with an explanation of the purpose and methodology of the assessment and were requested to provide a written agreement.

Survey items

Participants completed a self-administered questionnaire that aimed to gather information on their age, sex, and medical history. Additionally, participants were interviewed to gather details on their educational level, history of smoking, hypertension, stroke, and diabetes mellitus, as well as their instrumental activities of daily living, and quality of life. We assessed education level based on the number of years required for completion within the Japanese education system (≤ 12 years or > 12 years of education). To assess instrumental activities of daily living status, we utilized the 13-item Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC), categorized into self-maintenance, intellectual activity, and social role[18]. A higher score indicates higher levels of competence.

For quality of life assessment, we used the World Health Organization Quality of Life Brief Version (WHOQOL-BREF) questionnaire, a 26-item self-report questionnaire that generates four domain scores[19]. This questionnaire asked respondents to rate their overall quality of life and their satisfaction with their health, as well as 24 additional items from four domains: physical health, psychological health, social relationships, and environmental health. Overall, quality of life was rated on a five-point scale (very poor, poor, neither poor nor good, good, or very good). The other items were rated on a five-point scale, either as type A (not at all, a little, moderately, mostly, and completely) or type B (very dissatisfied, dissatisfied, neither satisfied nor dissatisfied, satisfied, and very satisfied). Each domain score was calculated, with higher scores indicating a better quality of life.

Assessment of cognitive function

The Japanese version of the Mini-Mental State Examination (MMSE) was used to assess cognitive function. The MMSE score ranges from 0 to 30, with higher scores indicating better performance[20]. A qualified examiner administered the MMSE at both baseline and follow-up assessments, allowing sufficient time for each. For participants with more than two follow-ups, we selected the follow-up MMSE score that was the furthest from the baseline. To calculate the relative change in the MMSE (rMMSE), we used the following formula: the difference between the follow-up MMSE and baseline MMSE divided by the baseline MMSE.

$$rMMSE = \frac{Follow\text{-}up\ MMSE\ - Baseline\ MMSE}{Baseline\ MMSE}$$

Assessment of oral health status

Oral health assessments were conducted by trained and calibrated dental examiners. The participants were seated in reclinable nursing chairs and underwent oral examinations under well-lit conditions. Various factors, such as the number of remaining teeth, occlusal force, masticatory performance, tongue pressure, and oral diadochokinesis, were evaluated.

The term “remaining teeth” refers to the total number of teeth, including both residual teeth and wisdom teeth.

To assess masticatory performance, we adopted a scoring method (ranging from 0 to 9). The participants were given a test gummy jelly (UHA Mikakuto Co., Ltd., Osaka, Japan) and instructed to chew it freely. After 30 chews, they were asked to spit it out into a paper cup covered with gauze[21].

We measured the maximum occlusal force of the first left and right molars using an occlusal force meter (Occlusal Force-Meter GM10, NAGANO KEIKI) and calculated the sum of these measurements[22]. In cases in which the first molar was missing, we measured the maximum occlusal force of the immediately adjacent tooth. For participants wearing removable dentures, measurements were taken while wearing the removable dentures.

Using a tongue pressure measuring device (JMS Co. Ltd., Hiroshima, Japan), we conducted two assessments of maximum tongue pressure[23]. We recorded the highest value obtained, as low tongue pressure reflects dysphagia[24].

To evaluate tongue motor function (oral diadochokinesis), we used oral function measurement equipment (KENKOU-KUN handy; Takei Scientific Instruments Co., Ltd., Niigata, Japan) to measure the articulatory velocity of /ta/[25].

Assessment of physical function

The physical function of each participant was assessed by measuring their normal walking speed, knee extension strength, retention time of standing on one leg, and hand grip strength.

During the walking speed test, participants were instructed to walk at their normal speed. We recorded the normal walking speed (m/sec) (referred to as the "walking speed" hereafter) and analysed the data. We also evaluated any changes in walking speed from the start to the end of the walking range, which was a total of 12 m (10 m measurement range with 1 m from the front and 1 m from the end).

To measure knee extension strength, we used a manual muscle strength meter (Mobie, SAKAI Medical). The subjects were asked to sit upright with their knee joints bent at a 90-degree angle to prevent their gluteal region from rising. We measured the dominant leg twice and recorded the maximum torque (N) from the two measurements[26].

For the retention time of standing on one leg with eyes open (referred to as "one-leg standing"), we began measuring when the subjects' dominant leg left the floor and their hands touched their waist. The time (in seconds) until the patient's hands moved away from their waist, the position of their foot changed, or any part of their body outside from the supporting foot touched the floor was measured[27]. The duration of the one-leg standing test was limited to a maximum of 60 seconds, and the test was terminated once this time was achieved.

We measured the participants' hand grip strength using a digital grip strength meter (Takei Kikai Kogyo Co., Ltd., Niigata, Japan). Measurements were taken while the participants were standing, and the maximum grip strength of the dominant hand was recorded after two trials using the highest value as the grip strength measurement[28].

Statistical analysis

The data were checked for normality using the Shapiro-Wilk method. The Student's t-test was used to compare data that followed a normal distribution. For non-parametric data, the Mann-Whitney U test was used. To assess the relationships between the rMMSE and various explanatory variables, including oral health factors and factors related to cognitive function, Pearson's correlation analysis was performed. Additionally, to assess the factors associated with changes in cognitive function, multiple linear regression analysis was conducted, using the rMMSE as the dependent variable and considering confounding variables such as physical function and medical history. Explanatory variables with a p-value < 0.1 in the univariate correlation coefficient were included in the multiple linear regression analysis after adjusting for age, sex, and follow-up duration. Statistical analysis was performed using SPSS (version 24, IBM, Tokyo, Japan), and the significance level was set at 5%.

Results

Characteristics of participants

Table 1 provides an overview of the participants. A total of 583 older adults with an average age of 72.7 ± 0.2 years participated. The average follow-up duration for the study was 3.8 years, ranging from 1.5 to 6.5 years. The majority of participants were female (65.6%). These female participants were found to be significantly younger than male participants, and they also had higher MMSE scores, higher oral diadochokinesis scores, and higher instrumental activities of daily living scores. However, female participants had a significantly lower occlusal force, grip strength, and knee extension strength. Additionally, they had lower rate of smoking, hypertension, and diabetes mellitus.

Relationship between changes in cognitive function and oral health/physical performance

Details and features of changes in cognitive function

The distribution of relative change in MMSE (rMMSE) scores among the study participants is illustrated in Fig. 1. Overall, 33.6% of the subjects declined in cognition, and the average rate of change in the MMSE score was 0.003. The mean rMMSE value was 0.31%, suggesting that the majority of individuals in this study did not undergo significant changes in their MMSE score over the given period. Moreover, there was no gender difference observed in rMMSE in this study.

Table 2 shows the correlations between oral health factors and changes in cognitive function. A positive correlation was observed between oral diadochokinesis ($r = 0.111$) and rMMSE score. The positive correlations of the other assessed items with the MMSE score were as follows: walking speed ($r = 0.120$), one-leg standing ($r = 0.090$), and knee extension strength ($r = 0.094$).

Measurement variables	Overall (*n* = 583)	Male (*n* = 201)	Female (*n* = 382)	*p* Value
Age (years)*	72.7 ± 0.2	73.8 ± 0.4	72.2 ± 0.3	0.003[a]
Cognitive function				
MMSE score*	28.4 ± 0.1	28.1 ± 0.1	28.5 ± 0.1	0.008[a]
Oral function				
Remaining teeth (teeth)	21.1 ± 0.3	20.9 ± 0.6	21.2 ± 0.4	0.96[a]
Masticatory performance (score)	4.2 ± 0.1	4.3 ± 0.2	4.2 ± 0.1	0.44[a]
Occlusal force (kgf)*	61.3 ± 1.5	68.2 ± 3	57.6 ± 1.7	0.016[a]
Oral diadochokinesis "ta" (times/5 s)*	30.5 ± 0.2	29.3 ± 0.5	31 ± 0.3	0.014[a]
Tongue pressure (kPa)	33.5 ± 0.3	34.1 ± 0.6	33.2 ± 0.4	0.24[b]
Physical performance				
Walking speed (m/s)	1.5 ± 0	1.5 ± 0	1.5 ± 0	0.17[b]
One-leg standing (s)	34.4 ± 0.9	34.9 ± 1.6	34.2 ± 1.1	0.64[a]
Grip strength (kg)*	27.7 ± 0.3	35.5 ± 0.5	23.6 ± 0.2	< 0.001[a]
Knee extension strength (N)*	362.7 ± 4.8	463.1 ± 7.9	310.2 ± 4	< 0.001[a]
TMIG-IC*	12.6 ± 0.5	12.4 ± 0.1	12.7 ± 0.0	0.002[a]
QOL				
Physical health domain	3.7 (1.9-5)	3.7 (1.9-5)	3.7 (2.3–4.9)	0.56[a]
Psychological health domain	3.5 (1.5-5)	3.5 (1.7-5)	3.5 (1.5–4.7)	0.23[b]
Social relations domain*	3.7 (2-4.7)	3.7 (2-4.7)	3.7 (2-4.7)	0.009[a]
Environmental health domain	3.5 (2.1–4.6)	3.5 (2.3–4.6)	3.5 (2.1–4.6)	0.10[b]
Overall QOL rating	3.5 (1.5-5)	3.5 (2–5)	3.5 (1.5-5)	0.66[a]
Social history				
Educational year (≤ 12 years)*	353 (60.5)	109 (54.2)	244 (63.9)	< 0.001[c]
Smoking habit (current or past)*	164 (28.1)	143 (71.1)	21 (5.5)	< 0.001[c]
Medical history				
Hypertension	216 (37.0)	87 (43.3)	129 (33.8)	0.06[c]
Diabetes mellitus*	53 (9.1)	29 (14.4)	24 (6.3)	0.002[c]
Stroke	5 (0.9)	3 (1.5)	2 (0.5)	0.25[c]
Follow-up duration (years)	3.8 ± 0.1	3.9 ± 0.1	3.8 ± 0.1	0.41[b]

Table 1. Characteristics of participants. Data at baseline are shown and presented as the mean ± standard error or number of participants (%) or median (max-min). *MMSE* Mini-Mental State Examination, *QOL* quality of life, *TMIG-IC* Tokyo Metropolitan Institute of Gerontology Index of Competence. [a]Comparison between males and females using Mann-Whitney's U test. [b]Comparison between males and females using Student's t-test. [c]Comparison between males and females using the Chi-square test. The significance level was set at $p < 0.05$. *There is a significant difference between males and females.

Relationship between changes in cognitive function and social/medical factors

Table 3 shows the relationships between the rMMSE score and social/medical factors. Participants with a history of diabetes had a significantly higher rMMSE score ($p = 0.037$). There was no difference in the rMMSE score among the other social and medical factors, such as education level, smoking habits, history of hypertension, and stroke.

Oral health factors associated with cognitive function

The results of multiple linear regression analysis are presented in Table 4. We found a significant association between oral diadochokinesis and the rMMSE score, even after accounting for factors that are known to be linked to dementia and cognitive function.

Discussion

Oral frailty encompasses a decline in oral functions such as chewing, swallowing, and articulatory skills, and is often linked to cognitive and physical decline[29]. Our study focused on the relationship between various factors of oral health status which are components of oral frailty and changes in cognitive function. We found a significant correlation between oral diadochokinesis and rMMSE. While the exact mechanism linking changes in cognitive function to oral diadochokinesis remains unclear, this study contributes to the understanding of oral frailty, a concept increasingly recognized in gerodontology, particularly in Japan[30].

There are possible mechanisms by which poor oral diadochokinesis leads to a change in cognitive function. One potential explanation is that a decrease in oral diadochokinesis, particularly in the /ta/ sound, often indicates reduced function of the tip of the tongue[31]. This is crucial because the tongue tip plays a vital role in bolus formation during the oral preparatory phase of swallowing[32]. Impaired tongue tip function can

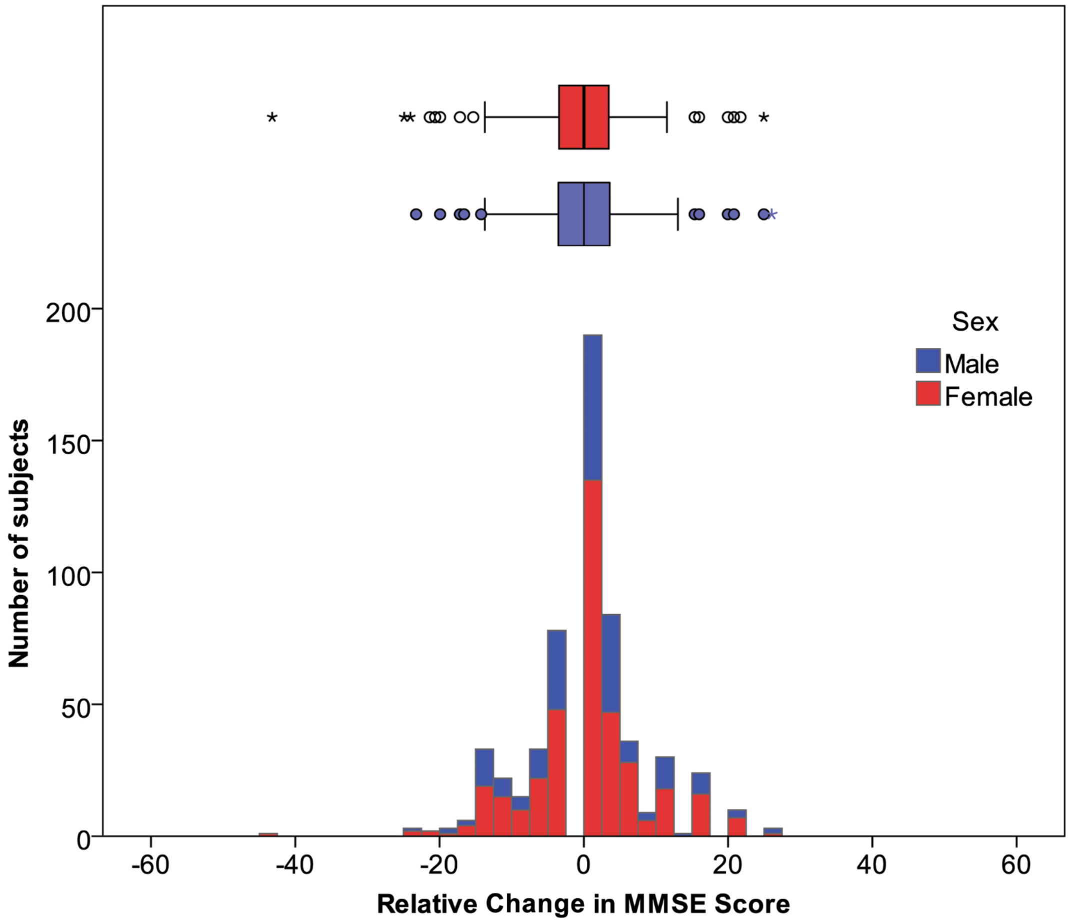

Fig. 1. Distribution of changes in cognitive function. The changes in cognitive function are evaluated by the relative change in the Mini-Mental State Examination (rMMSE), which is calculated using this formula: rMMSE = (Follow-up MMSE - Baseline MMSE) / (Baseline MMSE).

compromise efficient food manipulation and swallowing, potentially leading to nutritional deficiencies[33]. Given the importance of adequate nutrition for cognitive health, these deficiencies may contribute to cognitive decline over time[34]. Another possible explanation is that in a previous study, oral diadochokinesis for the 'ta' syllable was significantly related to anteflexion, suggesting that elevation of the anterior tongue correlates with the flexibility of the lower body and tongue and lip movements and is related to physical fitness[35]. In another study of older people, Chen, Honda, et al. reported that physical frailty is associated with a longitudinal decline in global cognitive function in nondemented older adults over two years[36]. These findings revealed that oral diadochokinesis and changes in cognitive function were related to physical fitness. It was also found that communication impairment is a significant independent predictor of key aspects of the social function of older adults and demonstrates two distinct pathways to loneliness and depression[37]. Hasegawa et al. demonstrated that, in addition to decreased physical function, oral hypofunction is related to greater social withdrawal in older persons[38]. In addition, Kelly et al. reported that larger social networks and greater levels of social support were associated with improved global cognition[39]. These findings suggested that social participation may contribute to decreased oral diadochokinesis and negative changes in cognitive function.

In this study, we discovered a positive association between oral diadochokinesis and changes in cognitive function. This finding is consistent with a previous study that examined the relationship between oral motor function and cognitive function[15]. Participants with a lower rate of oral diadochokinesis are more likely to experience a decline in cognitive function[40]. Moreover, a 3-month program of home-based oral exercises significantly enhanced participants' tongue strength and tongue-lip motor function[41].

Previous studies have shown that the number of remaining teeth is associated with cognitive impairment[8–10]. However, our study did not find any significant relationship between the number of remaining teeth and relative change in MMSE score. One possible explanation is that most of the participants in our study wore removable prostheses, allowing them to maintain better nutrition through improved mastication despite having fewer remaining natural teeth. This is supported by a previous study that found cognitive impairment to be worse in individuals with fewer remaining teeth who do not use dentures compared to those who do[42]. Our study did not find any significant relationships between masticatory performance, occlusal force, or tongue pressure and the relative change in MMSE score.

Variables	r	p Value
Age	− 0.078	0.06
Oral function		
Remaining teeth	0.006	0.89
Masticatory performance	0.022	0.60
Occlusal force	− 0.013	0.75
Oral diadochokinesis “ta”*	0.111	0.039
Tongue pressure	0.077	0.06
Physical performance		
Walking speed**	0.120	0.004
One-leg standing*	0.09	0.031
Grip strength	0.057	0.2
Knee extension strength*	0.094	0.024
TMIG-IC	0.021	0.68
QOL		
Physical health domain	0.016	0.69
Psychological health domain	0.040	0.34
Social relations domain	0.048	0.24
Environmental health domain	0.019	0.65
Overall QOL rating	− 0.010	0.81

Table 2. Correlations between changes in cognitive function and oral function/physical performance. r: Pearson correlation coefficient with rMMSE. Variable explanations are the same as in Table 1. *$p < 0.05$, **$p < 0.01$.

Variables	Number of subjects	rMMSE	p Value
Social history			
Educational level			
≤ 12 years	353	0.2 ± 0.5	0.66
> 12 years	164	-0.1 ± 0.6	
Smoking habit			
Past or current smoker	164	0.5 ± 0.6	0.48
Never smoker	357	-0.1 ± 0.4	
Medical history			
Hypertension			
Yes	216	0.3 ± 0.6	0.28
No	305	0.0 ± 0.5	
Diabetes mellitus*			
Yes	53	1.8 ± 1.1	0.037
No	465	-0.1 ± 0.4	
Stroke			
Yes	5	4.3 ± 1.3	0.07
No	516	0.1 ± 0.4	

Table 3. Relationship between changes in cognitive function and social/medical factors. Data are shown and presented as the mean ± standard error. rMMSE Score: Relative change in Mini-Mental State Examination score. *$p < 0.05$. Variables are analysed by the Mann–Whitney’s U test. The education level, smoking habit, hypertension, diabetes mellitus, and stroke history variables are baseline data.

In our study, we found a positive correlation between knee extension strength and changes in cognitive function. These findings suggest that knee extension strength plays an important role in changes in cognitive function in older adults. This conclusion is consistent with a previous study that investigated the relationship between knee extensor muscle strength and overall cognitive performance[43]. Similarly, Chen et al. reported a significant relationship between knee extension strength and cognitive function, even after adjusting for potential confounding variables[44]. Moreover, Furthermore, a study on subjective cognitive decline (SCD) in older Japanese adults found that knee extension strength was significantly worse in the SCD group, indicating a potential link between reduced physical function and cognitive decline[45].

Variables	B	Standard error	β	t value	95% CI Lower	95% CI Upper	*p* value
Model 1							
Age	-0.018	0.101	-0.012	-0.174	-0.216	0.181	0.86
Sex	-0.003	1.707	0.000	-0.002	-3.363	3.357	0.99
Oral Diadochokinesis "ta"*	0.258	0.111	0.144	2.327	0.040	0.477	0.021
Tongue pressure	0.053	0.057	0.058	0.933	-0.059	0.166	0.35
Walking speed	1.503	2.167	0.043	0.694	-2.763	5.769	0.49
Standing on one leg	0.001	0.024	0.004	0.062	-0.046	0.049	0.95
Knee extension strength*	0.011	0.006	0.167	2.016	0.000	0.022	0.045
Education level	0.915	0.991	0.055	0.923	-1.036	2.867	0.36
Smoking habit	0.184	1.499	0.011	0.123	-2.768	3.136	0.90
Hypertension	1.160	0.992	0.072	1.170	-0.793	3.113	0.24
Diabetes mellitus	2.682	1.694	0.096	1.583	-0.653	6.017	0.12
Stroke	4.079	5.607	0.043	0.727	-6.960	15.117	0.47
Model 2							
Age	-0.014	0.101	-0.010	-0.139	-0.212	0.184	0.89
Sex	0.318	1.715	0.019	0.185	-3.060	3.695	0.85
Oral Diadochokinesis "ta"*	0.260	0.111	0.145	2.349	0.042	0.478	0.020
Tongue pressure	0.060	0.057	0.066	1.051	-0.053	0.173	0.29
Walking speed	1.929	2.180	0.055	0.885	-2.362	6.220	0.38
Standing on one leg	-0.001	0.024	-0.002	-0.028	-0.048	0.047	0.98
Knee extension strength*	0.011	0.006	0.165	1.995	0.000	0.022	0.047
Education level	0.806	0.992	0.049	0.813	-1.146	2.758	0.42
Smoking habit	0.401	1.502	0.023	0.267	-2.557	3.359	0.79
Hypertension	0.951	0.999	0.059	0.952	-1.015	2.918	0.34
Diabetes mellitus	2.921	1.697	0.105	1.721	-0.421	6.263	0.09
Stroke	4.633	5.605	0.049	0.827	-6.402	15.668	0.41
Follow-up duration	0.603	0.397	0.091	1.521	-0.178	1.384	0.13

Table 4. Factors associated with changes in cognitive function. B: Unstandardized coefficient, β: Standardized coefficient, CI: 95% confidence interval for unstandardized coefficient. The multiple regression analysis was performed as follows: Dependent variable: Relative Change in MMSE Score. Explanatory variables: Respective oral/physical performance/medical history. The adjusted R^2 values for Model 1 and Model 2 were 0.054 and 0.059, respectively. $*p < 0.05$.

Study limitations

This study has several limitations. First, there might have been participant selection bias because we relied on older individuals who voluntarily underwent medical checkups. We recruited participants through community newspaper advertisements or oral announcements, which could introduce bias since those who responded tended to be health-conscious and relatively healthy. As a result, the study included a low proportion of participants with cognitive impairment. Second, we assessed cognitive function using only the MMSE and defined changes in cognitive function based solely on the MMSE score, without using other assessment tools. Therefore, future studies should include a more comprehensive evaluation of cognitive functions. Third, the follow-up rate was low (57%). One reason for this is that our study included individuals who could physically travel to the location where the survey was conducted, using any form of transportation. Consequently, many participants were unable to complete the follow-up survey due to limited public transportation in the Tamba-Sasayama area. It is important to note that individuals who have experienced a decline in physical function and cognitive function may have dropped out of the follow-up survey, and the impact on rMMSE deterioration should be carefully assessed.

Clinical implications

This study revealed that the decline /ta/ sound in oral diadochokinesis may be a potential risk factor for cognitive decline. Additionally, oral diadochokinesis is currently a significant subject in the medical field because of its non-invasive nature and the fact that it does not necessitate the use of devices or intraoral examinations. This suggests that oral diadochokinesis may serve as a valuable tool for assessing cognitive impairment. Our findings can contribute to the prevention of cognitive decline by identifying patients with decreased oral diadochokinesis counts. For these patients, referral to medical doctors for comprehensive cognitive function assessment should be considered. This approach enables early detection and intervention, potentially delaying or preventing cognitive decline. Integrating oral diadochokinesis testing into national health screening programs for older adults could facilitate early identification of individuals at risk, potentially improving outcomes and reducing the healthcare burden.

Conclusion

This study revealed that poor oral health has long-term effects on cognitive function in older adults. Oral diadochokinesis "ta" is associated with changes in cognitive function over time, implying that improving oral motor function may be essential for maintaining cognitive function in older adults.

Data availability

The data for this study can be requested from the corresponding author. They are not publicly accessible due to privacy restrictions, as they include information that could compromise the confidentiality of the research participants.

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Author contributions
All authors were involved in data collection and data analysis. M.T.Y. and Y.H. were involved in the study design and data interpretation. M.T.Y., M.T.S.M., and Y.H. were involved in data analysis and critical review. Y.H., M.T.S.M., K.N., and K.S. critically revised the manuscript, commented on drafts of the manuscript, approved the manuscript to be published, and agreed to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors reviewed the manuscript.

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Declarations

Competing interests
The authors declare no competing interests.

Ethical approval
This prospective longitudinal study protocol was approved by the Institutional Review Board (IRB) of Hyogo Medical University (approval no. Rinhi 0342) and the Ethics Committee of the Faculty of Dentistry, Niigata University (G2021-0027). All participants provided written informed consent. All study methods were performed in accordance with relevant guidelines and regulations.

Additional information
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