

Association of Oral Hypofunction with Reduced Hand Dexterity in Community-Dwelling Older Adults: A Cross-Sectional Study

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Purpose: Oral function and hand dexterity are related to cognitive function; however, no previous studies have explored their direct relationship. Considering the increasing prevalence of dementia and mild cognitive impairment (MCI), elucidating the relationship between these motor functions may contribute to early screening strategies. Thus, this study aimed to investigate the association between oral function and hand dexterity, and to examine whether this association is independent of sarcopenia-related factors.

Patients and Methods: From the 1044 participants from the 2017 Iwaki Health Promotion Project, we obtained 419 individuals aged ≥ 60 years (170 men, 249 women) after excluding participants with missing values. Oral function was assessed based on remaining teeth, tongue pressure, and oral diadochokinesis, and an oral hypofunction score (0–3 points) established. Hand dexterity was evaluated using the Purdue Pegboard Test (PPT) across the following four items: right hand, left hand, both hands, and assembly. The relationship between oral function and hand dexterity was analyzed using multiple regression.

Results: Kruskal–Wallis tests revealed that higher oral hypofunction scores were associated with fewer pegs placed (all $p < 0.001$). Multiple regression (Model 1, $n = 419$) revealed significant associations between oral hypofunction score and all PPT items (unstandardized $B = -0.49$ to -0.23 , all $p \leq 0.011$). After adjusting for sarcopenia-related factors (Model 2, $n = 294$), associations remained significant for simple tasks (right hand $B = -0.45$, $p = 0.002$; left hand $B = -0.33$, $p = 0.010$) but not for complex tasks (both hands $p = 0.080$; assembly $p = 0.161$).

Conclusion: This cross-sectional study demonstrated that decline in oral function is partially independent of sarcopenia-related factors and associated with reduced hand dexterity, specifically in simple motor tasks.

Keywords: aging, oral hypofunction, hand dexterity

Introduction

In Japan, the proportion of residents over 65 years of age (hereafter, “aging rate”) exceeded 21% in 2007, marking Japan’s transition to a super-aged society. This proportion reached 29.1% in 2024 and is expected to keep rising. Aging is a domestic and global issue, with the global aging rate projected to reach 18.7% by 2060.¹ As a large elderly population contributes to enormous healthcare and welfare costs, extending healthy life expectancy is an urgent issue, with prevention and care of dementia being one of the major global healthcare and welfare challenges.²

For dementia prevention, intervention at the precursor stage of mild cognitive impairment (MCI) is crucial.² MCI can either progress to dementia (convert) or recover to normal (revert). The conversion rate averages 10% annually,³ whereas the reversion rate is 14%–44%.⁴

Oral function is essential for nutrition intake, communication through voice and articulation, and aesthetics at all life stages. To conceptually represent oral function decline in older adults, Tanaka et al proposed “oral frailty”,⁵ defined as a series of phenomena where age-related changes in oral conditions combined with decreased interest in oral health lead to decline in other physical and mental functions.⁶ The relationship between oral function and cognitive function has been extensively investigated. Traditionally, a unidirectional causal relationship has been assumed, where cognitive decline impairs the ability to perform adequate oral self-care, such as toothbrushing and denture maintenance, thus increasing the risk of dental caries, periodontal disease, and subsequent oral function decline.^{7–9} However, there is increasing evidence that suggests a bidirectional relationship. Tooth loss has been associated with increased risk of cognitive impairment,¹⁰ decreased occlusal force and tongue pressure are significantly associated with MCI,^{11,12} and in community-dwelling elderly with physical frailty, oral frailty increases the hazard ratio for new-onset MCI.¹³ Moreover, longitudinal cohort studies show that fewer remaining teeth without denture use increase dementia risk.^{14,15}

Hand dexterity is an essential physical function directly related to activities of daily living, including grasping objects, holding, writing, and cooking. Generally, it is crucial for maintaining healthy and independent daily life. Hand dexterity is known to decline with aging,^{16–18} however, elderly individuals with MCI or Alzheimer’s disease show greater decline compared to cognitively normal elderly,¹⁹ suggesting an association with cognitive function.

Oral function and hand dexterity are associated with cognitive function, but they may also share common pathophysiological pathways. One possible pathway is through sarcopenia. Oral dysfunction impairs nutritional intake, accelerating muscle loss, and ultimately affecting orofacial muscles and hand function. Kumar et al comprehensively reviewed the links between oral health components (chewing ability, tongue pressure) and sarcopenia parameters (muscle mass, grip strength, nutritional status) in older adults,²⁰ suggesting that sarcopenia may represent a shared mechanism linking oral dysfunction and reduced hand dexterity. Furthermore, reduced hand dexterity may impair oral hygiene, leading to periodontal disease and tooth loss. These potential pathways suggest that adjustment for sarcopenia-related factors is necessary when examining the association between oral function and hand dexterity.

Although oral function and hand dexterity are known to be associated with cognitive function, previous studies examining the direct relationship between oral function and hand dexterity are lacking. Understanding this relationship may provide insights into shared pathophysiological mechanisms and inform early screening strategies, as both functions are easily assessable in clinical settings and may decline before overt cognitive impairment becomes apparent. Thus, this study aimed to investigate the relationship between oral function and hand dexterity in older adults, specifically examining whether this association is independent of sarcopenia-related factors such as muscle mass, grip strength, and nutritional status.

Materials and Methods

Participants

We first considered 1044 participants (435 men, 609 women) who participated in the 2017 Iwaki Health Promotion Project/Project Health Examination. After excluding individuals with missing data, a cross-sectional study was conducted on 419 individuals aged ≥ 60 years (170 men, 249 women). Individuals with a history of cancer, stroke, ischemic heart disease, or Parkinson’s disease were excluded to minimize confounding effects on oral function and hand dexterity, as these conditions directly impair motor skills and cognitive function. The Iwaki Health Promotion Project/Project Health Examination is an initiative aimed at clarifying the current health status and issues of residents in the Iwaki district of Hirosaki City (Aomori Prefecture, Japan) and promoting health-boosting activities for community residents.²¹ This study was approved by the Hirosaki University Ethics Committee (Research Ethics Approval No. 2016–028) and conducted in compliance with the Declaration of Helsinki. All participants received sufficient explanation regarding research content and study purpose, and informed consent was obtained.

Figure 1 illustrates the participant selection process, including the number of exclusions based on age, missing data, and predefined criteria.

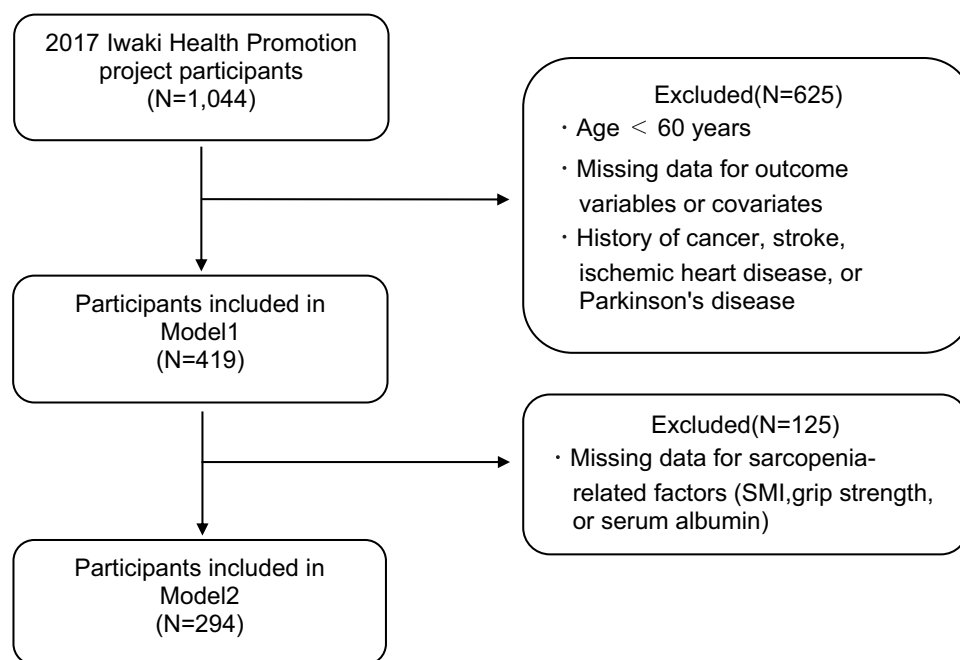


Figure 1 The flowcharts showing the selection of research participants.

Oral Function

Oral function was evaluated using three items: the number of remaining teeth, tongue pressure, and tongue–lip motor function. The number of remaining teeth reflected the total count of all teeth present, excluding residual roots and third molars. Fewer than 20 remaining teeth indicated decreased occlusal force.²² Tongue pressure was measured as maximum pressure using a tongue pressure measuring device (JMS Tongue Pressure Measuring Device, TPM-02E). The measurement method involved participants pressing a balloon on the tongue pressure probe between the tongue and palate with maximum force for several seconds. Measurements were taken three times, and the maximum value was adopted. Low tongue pressure was defined as maximum tongue pressure below 30 kPa.²³ Tongue–lip motor function was assessed by having participants repeat the syllables /pa/, /ta/, and /ka/ as quickly as possible for 5 seconds each, with an automatic measuring device counting the number of pronunciations per second (oral diadochokinesis [ODK]). Notably, /pa/ evaluates lip motor function, /ta/ evaluates anterior tongue motor function, and /ka/ evaluates posterior tongue motor function. Syllables repeated fewer than 6.0 times/second indicated decreased oral function.²⁴ For each of the remaining teeth, tongue pressure, and ODK values, 1 point was added if diagnostic criteria were not met, establishing an oral hypofunction score with a maximum of 3. This study defined an oral hypofunction score of 3 as the oral hypofunction group. Finally, all examinations were conducted by dentists. All dentist examiners underwent standardized training in oral function assessment protocols before data collection. Training included instruction on measurement techniques for remaining teeth counts tongue pressure assessment, and ODK evaluation to ensure consistency across examiners. Inter-examiner calibration sessions were conducted to verify measurement reliability and minimize variability.

Hand Dexterity Assessment

Hand dexterity was evaluated using the Purdue Pegboard Test (PPT). PPT uses pins, collars, washers, and a board. The following four items were tested individually: right hand, left hand, both hands, and assembly. Participants sat facing the pegboard and inserted pegs with the right hand in the right column, with the left hand in the left column, and with both hands on both sides. The number of pins inserted in 30 seconds was measured. For both hands, participants assembled multi-component objects in the order of pin, washer, collar, and washer, and the number completed in 1 minute was scored.²⁵ Practice time was provided after explanation before each test, and understanding of the test method was confirmed.

Other Recorded Variables

Age, sex, smoking habit (pack years), years of education, presence of exercise habits, presence of diabetes, and presence of hypertension were investigated. Body mass index (BMI) was calculated as weight (kg)/height (m²). The Mini-Mental State Examination (MMSE) was conducted as a cognitive function test. These variables have been reported to be associated with oral function, hand dexterity, and cognitive function, and it has been particularly confirmed that these factors interact with each other in older adults. By considering these variables, we can ensure a more accurate and reliable interpretation of the results.

For Model 2 analyses, sarcopenia-related measurements were added. Skeletal muscle index (SMI) was calculated by dividing appendicular skeletal muscle mass measured by bioelectrical impedance analysis by height squared. Maximum grip strength was measured twice for each hand using a hand dynamometer, with the maximum of all measurements adopted. Moreover, serum albumin concentration was measured using standard laboratory methods. Complete data for these variables were available for 294 participants.

Statistical Analyses

All statistical analyses were performed using IBM SPSS Statistics version 29 (IBM Japan, Tokyo, Japan). Participants were classified into a robust group and the oral hypofunction group, with between-group comparisons examined using Mann–Whitney *U*-tests and χ^2 -tests. Additionally, participants were divided into four groups based on oral hypofunction score, and the relationship with PPT was examined using a Kruskal–Wallis test.

Furthermore, to adjust for potential confounders, the relationship between oral hypofunction score and PPT was examined using multiple regression analysis. PPT scores (right hand, left hand, both hands, assembly) were used as dependent variables, oral function score as the primary independent variable, and sex, age, years of education, MMSE, pack years, BMI, presence of diabetes, presence of hypertension, and presence of exercise habits as covariates. This analysis is referred to as Model 1 (*n* = 419).

Furthermore, to examine whether the association between oral function and hand dexterity was independent of sarcopenia-related factors, Model 2 (*n* = 294) was constructed including all variables in Model 1 plus SMI, maximum grip strength, and serum albumin concentration. Moreover, attenuation rates of standardized β coefficients from Model 1 to Model 2 were calculated as $[(\beta_1 - \beta_2) / \beta_1] \times 100\%$, where β_1 is the coefficient in Model 1 and β_2 is the coefficient in Model 2. Smaller attenuation rates suggest that the association is less dependent on sarcopenia-related factors. The significance level was set at $p < 0.05$.

Results

Characteristics of Participants Classified by Oral Function

This study included 419 community-dwelling individuals aged ≥ 60 years (170 men, 249 women), after excluding participants with missing data from 1044 participants in the 2017 Iwaki Health Promotion Project/Project Health Examination. The mean age (SD) of participants was 68.9 ± 6.2 years, and 60 individuals (14.3%) were classified in the oral hypofunction group (score = 3). Table 1 summarizes the baseline characteristics of the normal oral function group and the oral hypofunction group. The oral hypofunction group exhibited significantly higher age ($p < 0.001$), lower years of education ($p < 0.001$), lower MMSE scores ($p < 0.001$), fewer remaining teeth ($p < 0.001$), lower tongue pressure ($p < 0.001$), and reduced pegboard test performance in right hand, left hand, both hands, and assembly (all $p < 0.001$). Higher prevalence of hypertension ($p = 0.049$) was also observed. Furthermore, there was no significant difference in sex distribution ($p = 0.638$), BMI ($p = 0.337$), exercise habits ($p = 0.387$), pack years ($p = 0.847$), or diabetes ($p = 0.184$) between the two groups.

For Model 2, a total of 294 participants with available data on SMI, albumin, and grip strength were analyzed. Among these, 35 individuals (11.9%) were classified as having oral hypofunction. Table 2 shows the baseline characteristics of Model 2 participants by oral functional status. The oral hypofunction group was significantly older ($p < 0.001$), had fewer years of education ($p = 0.005$), lower MMSE scores ($p = 0.008$), fewer remaining teeth ($p < 0.001$), lower tongue pressure ($p < 0.001$), and poorer pegboard test performance in right hand, left hand, and both hands (all $p < 0.001$), and

Table 1 Baseline Characteristics of the Study (Model 1)

	All	Robust	Oral Hypofunction	P-value
Number of participants	419	359	60	
Age, y	68.9 (±6.2)	68.1 (±5.9)	73.8 (±6.0)	<0.001 ^a
Sex, man	170	144	26	0.638 ^b
Sex, women	249	215	34	
Hypertension				
No	203	181	22	0.049 ^b
Yes	216	178	38	
Diabetes				
No	382	330	52	0.184 ^b
Yes	37	29	8	
Exercise				
No	244	206	38	0.387 ^b
Yes	175	153	22	
Years of education	11.6 (±2.0)	11.7 (±1.9)	10.8 (±1.9)	<0.001 ^a
MMSE	29.0 (±1.6)	29.2 (±1.3)	27.9 (±2.7)	<0.001 ^a
BMI	23.4 (±3.3)	23.4 (±3.2)	23.1 (±3.8)	0.337 ^a
Smoking (pack years)	8.3 (±22.1)	7.4 (±16.5)	13.5 (±42.3)	0.847 ^a
Oral examination				
Number of remaining teeth	18.2 (±9.1)	19.9 (±8.3)	8.1 (±6.6)	<0.001 ^a
Tongue pressure	31.1 (±6.9)	32.7 (±6.4)	23.5 (±5.2)	<0.001 ^a
ODK				
/pa/	6.4 (±0.7)	6.5 (±0.6)	5.8 (±0.8)	<0.001 ^a
/ta/	6.2 (±0.7)	6.4 (±0.7)	5.6 (±0.7)	<0.001 ^a
/ka/	5.8 (±0.8)	5.9 (±0.7)	5.1 (±0.8)	<0.001 ^a
PPT				
Right hand	13.2 (±2.4)	13.4 (±2.4)	11.7 (±2.2)	<0.001 ^a
Left hand	12.3 (±2.2)	12.6 (±2.0)	10.9 (±2.6)	<0.001 ^a
Both hands	10.0 (±2.0)	10.2 (±1.9)	8.7 (±2.1)	<0.001 ^a
Assembly	5.7 (±1.8)	5.8 (±1.7)	4.7 (±1.6)	<0.001 ^a

Notes: ^amann–Whitney test. ^bchi-squared test. Data are presented as mean±standard deviation or n(%). pack-years, (number of cigarettes smoked per day/20) × number of years smoked.

Abbreviations: MMSE, Mini-mental state examination; BMI, body mass index; ODK, oral diadochokinesis; PPT, purdue pegboard test.

Table 2 Baseline Characteristics of the Study (Model 2)

	All	Robust	Oral Hypofunction	P-Value
Number of participants	294	259	35	
Age, y	68.4 (±5.9)	67.7 (±5.5)	73.8 (±5.7)	<0.001 ^a
Sex, man	123	106	17	0.389 ^b
Sex, women	171	153	18	
Hypertension				
No	149	137	12	0.039 ^b
Yes	145	122	23	
Diabetes				
No	263	233	30	0.443 ^b
Yes	31	26	5	
Exercise				
No	160	141	19	0.986 ^b
Yes	134	118	16	
Years of education	11.6 (±2.0)	11.7 (±2.0)	10.7 (±1.9)	0.005 ^a
MMSE	29.1 (±1.5)	29.2 (±1.2)	27.9 (±2.8)	0.008 ^a
BMI	23.3 (±3.1)	23.5 (±3.1)	22.3 (±2.6)	0.038 ^a
Smoking (pack years)	7.8 (±16.5)	7.5 (±15.7)	9.8 (±21.6)	0.860 ^a
Maximum handgrip strength	24.6 (±3.9)	24.8 (±3.9)	23.3 (±3.6)	0.131 ^a
Serum albumin	4.4 (±0.3)	4.4 (±0.2)	4.4 (±0.4)	0.881 ^a
SMI	6.7 (±0.9)	6.7 (±1.0)	6.7 (±0.9)	0.031 ^a
Oral examination				
Number of remaining teeth	18.6 (±8.8)	19.9 (±8.2)	9.4 (±6.8)	<0.001 ^a
Tongue pressure	31.8 (±6.7)	32.9 (±6.1)	23.5 (±5.2)	<0.001 ^a
ODK				
/pa/	6.4 (±0.7)	6.5 (±0.6)	5.8 (±0.7)	<0.001 ^a
/ta/	6.3 (±0.7)	6.4 (±0.6)	5.6 (±0.7)	<0.001 ^a
/ka/	5.9 (±0.7)	6.0 (±0.6)	5.1 (±0.8)	<0.001 ^a
PPT				
Right hand	13.4 (±2.4)	13.6 (±2.3)	11.8 (±2.1)	<0.001 ^a
Left hand	12.5 (±2.1)	12.7 (±1.9)	11.1 (±3.0)	<0.001 ^a
Both hands	10.2 (±2.0)	10.3 (±1.9)	8.8 (±2.5)	<0.001 ^a
Assembly	5.9 (±1.7)	6.0 (±1.7)	5.0 (±1.9)	0.004 ^a

(Continued)

Table 2 (Continued).

	All	Robust	Oral Hypofunction	P-Value
Right grip strength	24.0 (±3.9)	24.1 (±4.0)	22.7 (±3.5)	0.104 ^a
Left grip strength	23.3 (±4.0)	23.4 (±4.1)	22.7 (±3.6)	0.308 ^a

Notes: ^amann–Whitney test. ^bchi-squared test. Data are presented as means±standard deviation or n(%). pack-years, (number of cigarettes smoked per day/20) × number of years smoked.

Abbreviations: MMSE, Mini-mental state examination; BMI, body mass index; ODK, oral diadochokinesis; PPT, purdue pegboard test; SMI, Skeletal muscle index.

assembly ($p = 0.004$). Additionally, higher prevalence of hypertension ($p = 0.039$), lower BMI ($p = 0.038$), lower SMI ($p = 0.031$) were noted in individuals with oral hypofunction. Moreover, there were no significant differences in sex ($p = 0.389$), diabetes ($p = 0.443$), pack years ($p = 0.860$), albumin level ($p = 0.881$), exercise habits ($p = 0.986$), right grip strength ($p = 0.104$), and left grip strength ($p = 0.308$) between groups.

Relationship Between Oral Function and Hand Dexterity

Next, the relationship between oral hypofunction score and PPT (right hand, left hand, both hands, assembly) was examined using a Kruskal–Wallis test, revealing significant differences among the four groups for all items (all $p < 0.001$) (Figure 2a–d). For each item, no significant difference in the number of pegs was observed between scores 0 and 1, while significant differences were observed in comparisons of 0 vs 2, 0 vs 3, 1 vs 2, and 1 vs 3. Additionally, for both hands, a significant difference was found between scores 2 and 3.

Model 1 ($n = 419$) multiple regression analysis revealed that oral hypofunction score was significantly associated with all four items: right hand ($B = -0.49$, $SE = 0.12$, $p < 0.001$), left hand ($B = -0.43$, $SE = 0.10$, $p < 0.001$), both hands ($B =$

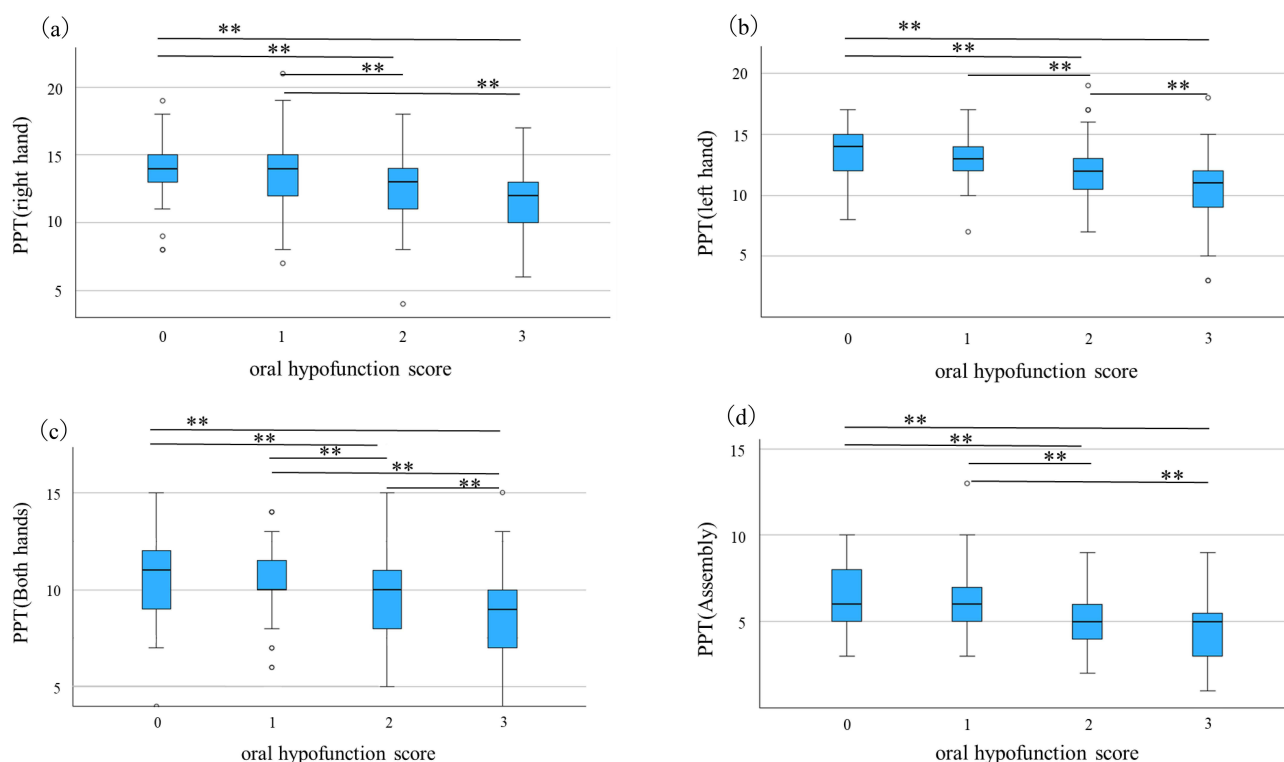


Figure 2 (a) The relationship between oral hypofunction and PPT (right hand). (b) The relationship between oral hypofunction and PPT (Left hand). (c) The relationship between oral hypofunction and PPT (both hands). (d) The relationship between oral hypofunction and PPT (assembly).

Note: ** $p < 0.05$.

Abbreviation: PPT, purdue pegboard test.

−0.23, SE = 0.09, $p = 0.011$), and assembly ($B = -0.23$, SE = 0.08, $p = 0.007$) (Tables 3–6). R^2 values ranged 0.332–0.368.

In Model 2 ($n = 294$), which additionally adjusted for sarcopenia-related factors (SMI, grip strength, serum albumin), the association remained significant for simple tasks: right hand ($B = -0.45$, SE = 0.15, $p = 0.002$) and left hand ($B = -0.33$, SE = 0.13, $p = 0.010$). However, for both hands ($B = -0.21$, SE = 0.12, $p = 0.080$) and assembly ($B = -0.15$, SE = 0.11, $p = 0.161$), the association became non-significant (Tables 7–10). R^2 values ranged 0.270–0.334.

Attenuation rates of standardized β coefficients from Model 1 to Model 2 were 9.2% for right hand, 22.0% for left hand, 12.5% for both hands, and 33.1% for assembly (Table 11). The relatively small attenuation rates for simple tasks suggest that the association between oral function and hand dexterity is largely independent of sarcopenia-related factors. Clinically, the unstandardized coefficients (eg,

Table 3 Multiple Regression Analysis for PPT (Right hand) (Model 1)

Predictor	Unstandardized Coefficient (B)	SE	Standardized Coefficient (β)	P-Value	95% CI
Oral function score	−0.49	0.12	−0.20	<0.001	− 0.72, − 0.26
Sex	1.15	0.22	0.23	<0.001	0.71, 1.58
Age	−0.12	0.02	−0.30	<0.001	− 0.15, − 0.08
BMI	−0.08	0.03	−0.10	0.018	− 0.14, − 0.01
Years of education	−0.06	0.06	−0.05	0.292	− 0.17, 0.05
MMSE	0.18	0.07	0.12	0.009	0.04, 0.31
Exercise habits	0.68	0.21	0.14	0.001	0.27, 1.09
Hypertension	0.01	0.21	0.001	0.946	− 0.40, 0.43
Diabetes	−0.06	0.35	−0.01	0.856	− 0.76, 0.63
Pack years	−0.005	0.005	−0.05	0.264	− 0.015, 0.004

Notes: Dependent variable: PPT (Right hand). Explanatory variable: Oral function score. Covariate: Sex, Age, BMI, Years of education, MMSE, Exercise habits, Hypertension, Diabetes, Pack years. Adjusted R^2 : 0.307.

Table 4 Multiple Regression Analysis for PPT (Left hand) (Model 1)

Predictor	Unstandardized Coefficient (B)	SE	Standardized Coefficient (β)	P-Value	95% CI
Oral function score	−0.43	0.10	−0.19	<0.001	− 0.63, − 0.23
Sex	0.85	0.19	0.19	<0.001	0.46, 1.23
Age	−0.12	0.02	−0.36	<0.001	− 0.16, − 0.09
BMI	−0.06	0.03	−0.09	0.037	− 0.11, − 0.003
Years of education	−0.09	0.05	−0.09	0.052	− 0.19, 0.001
MMSE	0.23	0.06	0.17	<0.001	0.11, 0.34
Exercise habits	0.30	0.18	0.07	0.101	− 0.06, 0.66
Hypertension	0.05	0.19	0.01	0.792	− 0.31, 0.41
Diabetes	−0.29	0.31	−0.04	0.356	− 0.90, 0.32
Pack years	−0.001	0.004	−0.01	0.773	− 0.009, 0.007

Notes: Dependent variable: PPT (Left hand). Explanatory variable: Oral function score. Covariate: Sex, Age, BMI, Years of education, MMSE, Exercise habits, Hypertension, Diabetes, Pack years. Adjusted R^2 : 0.336.

Table 5 Multiple Regression Analysis for PPT (Both hands) (Model 1)

Predictor	Unstandardized Coefficient (B)	SE	Standardized Coefficient (β)	P-Value	95% CI
Oral function score	-0.23	0.09	-0.11	0.011	- 0.41,- 0.05
Sex	0.80	0.17	0.20	<0.001	0.46,1.14
Age	-0.14	0.02	-0.45	<0.001	- 0.17,- 0.11
BMI	-0.06	0.03	-0.09	0.025	- 0.10,- 0.007
Years of education	-0.16	0.04	-0.15	<0.001	- 0.24,- 0.07
MMSE	0.20	0.05	0.17	<0.001	0.10,0.30
Exercise habits	0.64	0.16	0.16	<0.001	0.32,0.96
Hypertension	0.12	0.17	0.03	0.475	- 0.21,0.44
Diabetes	0.23	0.28	0.03	0.416	- 0.32,0.77
Pack years	-0.01	0.004	-0.07	0.112	- 0.013,0.001

Notes: Dependent variable: PPT (Both hands). Explanatory variable: Oral function score. Covariate: Sex, Age, BMI, Years of education, MMSE, Exercise habits, Hypertension, Diabetes, Pack years. Adjusted R²: 0.368.

Table 6 Multiple Regression Analysis for PPT (Assembly) (Model 1)

Predictor	Unstandardized Coefficient (B)	SE	Standardized Coefficient (β)	P-Value	95% CI
Oral function score	-0.23	0.08	-0.13	0.007	- 0.39,- 0.06
Sex	0.70	0.16	0.19	<0.001	0.39,1.01
Age	-0.11	0.01	-0.38	<0.001	- 0.14,- 0.08
BMI	-0.05	0.02	-0.09	0.027	- 0.09,- 0.01
Years of education	0.002	0.04	0.002	0.968	- 0.08,0.08
MMSE	0.14	0.05	0.13	0.004	0.04,0.23
Exercise habits	0.61	0.15	0.17	<0.001	0.32,0.91
Hypertension	0.06	0.15	0.02	0.677	- 0.23,0.36
Diabetes	-0.09	0.25	-0.02	0.71	- 0.59,0.40
Pack years	-0.004	0.003	-0.05	0.289	- 0.010,0.003

Notes: Dependent variable: PPT (Assembly). Explanatory variable: Oral function score. Covariate: Sex, Age, BMI, Years of education, MMSE, Exercise habits, Hypertension, Diabetes, Pack years. Adjusted R²: 0.332.

Table 7 Multiple Regression Analysis for PPT (Right hand) (Model 2)

Predictor	Unstandardized Coefficient (B)	SE	Standardized Coefficient (β)	P-Value	95% CI
Oral function score	-0.45	0.15	-0.18	0.002	-0.74,-0.16
Sex	2.18	0.53	0.45	<0.001	1.14,3.23
Age	-0.08	0.03	-0.20	0.002	-0.13,-0.03
BMI	-0.07	0.06	-0.09	0.233	-0.18,0.05
Years of education	-0.03	0.07	-0.03	0.613	-0.16,0.09
MMSE	0.19	0.08	0.12	0.025	0.02,0.35

(Continued)

Table 7 (Continued).

Predictor	Unstandardized Coefficient (B)	SE	Standardized Coefficient (β)	P-Value	95% CI
Exercise habits	0.49	0.25	0.10	0.052	−0.004,0.98
Hypertension	0.12	0.25	0.03	0.64	−0.38,0.61
Diabetes	−0.09	0.40	−0.01	0.831	−0.88,0.71
Pack years	0.001	0.01	0.01	0.921	−0.02,0.02
Maximum handgrip strength	0.10	0.03	0.36	<0.001	0.04,0.16
Serum albumin	−0.35	0.45	−0.04	0.435	−1.24,0.54
SMI	−0.32	0.33	−0.13	0.334	−0.96,0.33

Notes: Dependent variable: PPT (Right hand). Explanatory variable: Oral function score. Covariate: Sex, Age, BMI, Years of education, MMSE, Exercise habits, Hypertension, Diabetes, Pack years, Maximum handgrip strength, Serum albumin, SMI. Adjusted R^2 : 0.296.

Table 8 Multiple Regression Analysis for PPT (Left hand) (Model 2)

Predictor	Unstandardized Coefficient (B)	SE	Standardized Coefficient (β)	P-Value	95% CI
Oral function score	−0.33	0.13	−0.15	0.01	−0.58,−0.08
Sex	1.13	0.46	0.26	0.015	0.22,2.03
Age	−0.13	0.02	−0.35	<0.001	−0.17,−0.08
BMI	−0.004	0.05	−0.01	0.937	−0.10,0.10
Years of education	−0.09	0.06	−0.08	0.123	−0.20,0.02
MMSE	0.21	0.07	0.15	0.004	0.07,0.36
Exercise habits	0.25	0.22	0.06	0.248	−0.18,0.68
Hypertension	0.12	0.22	0.03	0.568	−0.30,0.55
Diabetes	−0.10	0.35	−0.02	0.77	−0.79,0.58
Pack years	0.002	0.01	0.01	0.791	−0.01,0.02
Maximum handgrip strength	0.07	0.03	0.26	0.012	0.02,0.12
Serum albumin	−0.12	0.39	−0.02	0.757	−0.89,0.65
SMI	−0.57	0.28	−0.25	0.044	−1.13,−0.02

Notes: Dependent variable: PPT (Left hand). Explanatory variable: Oral function score. Covariate: Sex, Age, BMI, Years of education, MMSE, Exercise habits, Hypertension, Diabetes, Pack years, Maximum handgrip strength, Serum albumin, SMI. Adjusted R^2 : 0.333.

Table 9 Multiple Regression Analysis for PPT (Both hands) (Model 2)

Predictor	Unstandardized Coefficient (B)	SE	Standardized Coefficient (β)	P-Value	95% CI
Oral function score	−0.21	0.12	−0.10	0.080	−0.45,0.03
Sex	1.68	0.43	0.42	<0.001	0.83,2.54
Age	−0.11	0.02	−0.33	<0.001	−0.15,−0.07
BMI	−0.04	0.05	−0.07	0.354	−0.14,0.05
Years of education	−0.11	0.05	−0.11	0.034	−0.22,−0.01

(Continued)

Table 9 (Continued).

Predictor	Unstandardized Coefficient (B)	SE	Standardized Coefficient (β)	P-Value	95% CI
MMSE	0.20	0.07	0.15	0.004	0.06,0.33
Exercise habits	0.51	0.20	0.13	0.014	0.10,0.91
Hypertension	0.04	0.20	0.01	0.856	-0.36,0.44
Diabetes	0.39	0.33	0.06	0.235	-0.26,1.04
Pack years	-0.003	0.01	-0.02	0.702	-0.02,0.01
Maximum handgrip strength	0.09	0.03	0.38	<0.001	0.04,0.14
Serum albumin	-0.80	0.37	-0.11	0.031	-1.52,-0.07
SMI	-0.38	0.27	-0.18	0.159	-0.90,0.15

Notes: Dependent variable: PPT (Both hands). Explanatory variable: Oral function score. Covariate: Sex, Age, BMI, Years of education, MMSE, Exercise habits, Hypertension, Diabetes, Pack years, Maximum handgrip strength, Serum albumin, SMI. Adjusted R^2 : 0.334.

Table 10 Multiple Regression Analysis for PPT (Assembly) (Model2)

Predictor	Unstandardized Coefficient (B)	SE	Standardized Coefficient (β)	P-Value	95% CI
Oral function score	-0.15	0.11	-0.08	0.161	-0.37,0.06
Sex	0.96	0.40	0.27	0.016	0.18,1.75
Age	-0.10	0.02	-0.33	<0.001	-0.14,-0.06
BMI	-0.06	0.04	-0.11	0.17	-0.15,0.03
Years of education	0.04	0.05	0.04	0.46	-0.06,0.13
MMSE	0.11	0.06	0.10	0.077	-0.01,0.23
Exercise habits	0.56	0.19	0.16	0.003	0.19,0.92
Hypertension	0.07	0.19	0.02	0.72	-0.30,0.43
Diabetes	-0.12	0.30	-0.02	0.693	-0.71,0.47
Pack years	-0.01	0.01	-0.05	0.431	-0.02,0.01
Maximum handgrip strength	0.01	0.02	0.06	0.605	-0.03,0.06
Serum albumin	0.15	0.34	0.02	0.663	-0.52,0.81
SMI	0.003	0.24	0.001	0.991	-0.48,0.48

Notes: Dependent variable: PPT (Assembly). Explanatory variable: Oral function score. Covariate: Sex, Age, BMI, Years of education, MMSE, Exercise habits, Hypertension, Diabetes, Pack years, Maximum handgrip strength, Serum albumin, SMI. Adjusted R^2 : 0.270.

Table 11 Attenuation Rate

	Standardized Coefficient (β)	Standardized Coefficient (β)	Attenuation Rate (%)
	Model 1	Model 2	
Right hand	- 0.20	- 0.18	9.2
Left hand	- 0.19	- 0.15	22.0
Both hands	- 0.11	- 0.10	12.5
Assembly	- 0.13	- 0.08	33.1

$B = -0.49$ for right hand in Model 1) indicate that a 1-point increase in oral dysfunction score corresponds to approximately 0.5 fewer pins placed, which may represent a meaningful decline in fine motor speed in daily activities.

Discussion

This is the first large-scale population-based study investigating the relationship between oral function and hand dexterity. Our results demonstrated that in community-dwelling adults aged ≥ 60 years, hand dexterity (as measured by PPT) was significantly associated with declining oral function, establishing an association between the oral function and hand dexterity.

Relationship Between Oral Function and Cognitive Function

Regarding the relationship between oral function and cognitive function, a unidirectional causal relationship was traditionally assumed, where cognitive decline makes self-care difficult, leading to oral function decline.^{7–9} However, recent reports suggest the possibility of a bidirectional causal relationship, in which oral function decline is related to cognitive decline. For example, tooth loss has been associated with increased risk of MCI and dementia development,¹⁰ and in community-dwelling elderly with physical frailty, oral frailty may increase the hazard ratio for new-onset MCI.¹³ Consequently, denture use may reduce dementia risk.^{26–28} Specific mechanisms by which oral function decline may be related to cognitive decline include decreased cerebral blood flow due to reduced masticatory ability,^{29,30} nutritional deterioration accompanying reduced masticatory ability affecting neural function,^{31,32} and promotion of neurodegeneration through chronic inflammation.^{33–35} Takeuchi et al conducted a prospective cohort study following approximately 1500 individuals for 5 years and reported that fewer remaining teeth were associated with increased risk of developing dementia.³⁶ Furthermore, Yamamoto et al conducted a prospective cohort study following approximately 4400 individuals for 4 years and noted that those with few teeth and no denture use had a 1.9-fold higher risk of developing dementia compared to those with 20 or more teeth.²⁸

Relationship Between Hand Dexterity and Cognitive Function

In comparative studies of elderly individuals with normal and impaired cognitive function, manual tasks primarily requiring sensorimotor integration, motor speed, and inhibition have been shown to be related to aging, whereas manual tasks requiring attention and working memory are related to cognitive status.³⁷ In elderly individuals, hand dexterity has been suggested to be associated with decreased interhemispheric inhibition. For example, Naito et al reported that bimanual training improved right-hand dexterity and suggested the possibility of effectively improving hand dexterity in older adults by reactivating decreased interhemispheric inhibition.³⁸ Additionally, Manolis et al investigated the relationship between hand dexterity and brain structure in healthy elderly adults using the 9-hole peg test (9HPT) and MRI scans, and found that decreased dexterity in dominant and non-dominant hands was associated with increased left choroid plexus volume, which is involved in neuroinflammation and demyelination, and with decreased myelin content in the left frontal operculum, involved in motor imagery and higher motor function.³⁹ Myelin content is related to cognitive function, with reduced myelin content associated with rapid decline in mental function, particularly executive function and verbal fluency.⁴⁰ A 7-year longitudinal study by Kobayashi-Cuya et al showed that baseline decline in executive function and processing speed significantly predicted subsequent decline in hand dexterity.⁴¹ In another study, Beeri et al conducted a 7-year prospective study of 1160 elderly individuals and revealed that decline in multiple motor abilities, including hand dexterity, grip strength, and gait function, was associated with increased risk of developing MCI and Alzheimer's disease (AD).⁴²

Hand dexterity declines with normal aging independent of dementia. For example, Schiffman et al examined grip strength, grasping patterns, and execution time in participants aged 24–87, showing that these remained relatively stable until age 65, then gradually decreased, with a marked decline after age 75.¹⁷ Additionally, Michimata et al used the Manual Function Test to examine 333 healthy individuals aged 20–90 years and demonstrated that hand dexterity declines with age.¹⁸

Mechanistic Considerations of Oral Function and Hand Dexterity

While this study demonstrated an association between hand dexterity and oral function, elucidating the mechanism involved is difficult based on cross-sectional study results. Although both functions are known to decline with aging, the association between oral function and hand dexterity persisted in our multivariate analysis even when age was included as an independent variable, indicating that this relationship is not simply due to aging.

In Model 2 analysis, which adjusted for sarcopenia-related factors (SMI, grip strength, serum albumin), the association between oral function and hand dexterity remained significant for simple motor tasks (right and left hand), with attenuation of standardized β coefficients (9.2% and 22.0%, respectively). This suggests that this association is not primarily mediated by generalized sarcopenia or nutritional status. Moreover, the magnitude of these associations (eg, $B = -0.45$ for right hand in Model 2) is clinically relevant, with a 1-point worsening in oral function corresponding to 0.5 fewer pegs in PPT performance, potentially affecting tasks like buttoning or writing. Conversely, non-significance for complex tasks (both hands and assembly) suggest that these tasks are more susceptible to overall physical condition.

The differential results between simple and complex tasks in Model 2 indicate that the association may be partially independent for basic motor functions but potentially mediated by sarcopenia-related factors in more coordinated tasks. For example, the 33.1% attenuation in the assembly task suggests that muscle mass and strength partly explain the link, possibly through shared pathways like nutritional deficiency or systemic frailty. This is consistent with previous evidence that sarcopenia affects both oral and manual dexterity.²⁰ While our cross-sectional design precludes formal mediation analysis, these findings highlight the need for longitudinal studies to disentangle mediation from confounding.

Several potential mechanisms may explain the association between oral function and hand dexterity. Considering the reported effects of oral function on cognitive function^{10–13} and the relationship between cognitive function and hand dexterity,^{37,41} cognitive impairment may partially mediate this relationship. Additionally, nutritional deterioration accompanying oral function decline may cause muscle function decline and neural function decline, contributing to reduced hand dexterity. Although the mechanisms linking oral and hand function are not fully understood, research on mastication suggests broader impacts on motor-cognitive systems,^{29,30} while hand dexterity research identifies associations with brain structure and neural integrity.^{38,39}

A pathway in which decreased hand dexterity is related to oral function decline is also conceivable. Reduced hand dexterity makes appropriate oral care difficult, worsening oral hygiene. This increases the risk of dental caries and periodontal disease, leading to tooth loss and subsequent oral function decline.

Thus, several pathways can be inferred between oral function and hand dexterity. However, longitudinal studies are required to clarify these relationships and their directionality.

Although our study was conducted in a Japanese community-dwelling population, the underlying physiological and biological pathways connecting oral function and hand dexterity (such as nutrition, sarcopenia, and neurocognitive function) are likely universal among older adults. Regardless, cultural factors—including diet, oral hygiene practices, and healthcare systems—may influence the prevalence of oral hypofunction and hand dexterity as well as their clinical assessment. Further studies in other ethnicities and countries are warranted to clarify the external validity and applicability of our results to broader populations.

Limitations

This study has several important limitations. First, this cross-sectional study cannot establish the causal relationship between oral function and hand dexterity. Second, Model 2 analyses were conducted on 294 participants due to missing data for sarcopenia-related measurements, reducing the sample size from 419, which may introduce selection bias and affect the generalizability of results and detection power for associations. Third, although we adjusted for multiple potential confounders including sarcopenia-related factors, residual confounding from unmeasured variables such as physical activity levels, medications (eg, anticholinergics), inflammatory markers, or subclinical cerebrovascular disease cannot be excluded. Fourth, participants in this study are predicted to be relatively healthy community residents and may not represent a random sample, potentially representing a population with high oral, cognitive, and motor function. Finally, while this study used three criteria to diagnose oral hypofunction (ie, the number of remaining teeth, tongue

pressure, and ODK), investigating oral dryness, masticatory function, and swallowing function might enable more accurate oral function assessment.

Clinical Implications

Multiple longitudinal studies have reported that oral function decline and hand dexterity decline are risk factors for developing MCI and dementia, suggesting their potential utility as screening tools for early detection. The association between oral function and hand dexterity demonstrated in this study suggests that combining these tests may improve the sensitivity and specificity of MCI screening. However, further evaluation and analysis using ROC curves is needed.

Conclusion

This cross-sectional study revealed that hand dexterity is significantly associated with declining oral function. This association persisted after adjusting for age and general cognitive function, and was partially independent of sarcopenia-related factors, specifically for simple motor tasks. Oral function and hand dexterity are known to be associated with cognitive function. Although our cross-sectional design precludes causal inference, these findings suggest that longitudinal studies investigating whether interventions targeting oral function and hand dexterity can reduce dementia risk are warranted.

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Disclosure

The authors report no conflicts of interest related to this work.

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