

Lower-Extremity Physical Performance and Field-Based Oral Function Measures in Community-Dwelling Older Women: A Cross-Sectional Study

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Article

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Abstract

Given the age-related declines in physical and oral function, this study investigated the link between lower-extremity performance and oral function in 102 community-dwelling women aged 65–85 in Incheon, Republic of Korea. Participants were categorized into robust or low physical performance groups based on their Five-Times Sit-to-Stand Test (FTSTS) completion time (low physical performance ≥ 12 seconds). Oral function was assessed using oral diadochokinesis (ODK), the Eating Assessment Tool-10 (EAT-10), the Repetitive Saliva Swallowing Test (RSST), and masticatory function. The low FTSTS performance group exhibited poorer physical performance (e.g., lower handgrip strength, slower gait speed) and poorer oral function (e.g., lower ODK values, higher EAT-10 scores, fewer RSST swallows, lower masticatory function). All oral function indicators were significantly associated with low FTSTS performance in univariable analyses. In multivariable models, EAT-10, RSST, and masticatory function remained significantly associated with low FTSTS performance, even after accounting for sarcopenia-related indicators and ankle muscle strength. These findings suggest that reduced lower-extremity performance is associated with poorer oral-motor, swallowing, and masticatory function in older women. Field-based oral function measures could be valuable additions to integrated functional assessments for older adults with reduced lower-extremity physical performance.

1. Introduction

Aging is accompanied by progressive declines in skeletal muscle mass, muscle strength, physical performance, and physiological reserve, which collectively contribute to sarcopenia, frailty, mobility limitation, and reduced independence in activities of daily living [1, 2]. Among the domains of physical function, lower-extremity physical performance is particularly important because it reflects the integrated capacity required for standing, walking, balance control, and functional mobility. Performance-based measures, such as chair-stand performance, gait speed, and balance tests, are therefore widely used to identify older adults at risk of functional decline and frailty [2, 3].

Among performance-based measures, the Five-Times Sit-To-Stand Test (FTSTS) is a simple and clinically feasible assessment that reflects lower-extremity muscle strength, balance control, neuromuscular coordination, and transitional mobility. Sit-to-stand performance has been used as an indicator of physical performance in sarcopenia assessment, and the Asian Working Group for Sarcopenia (AWGS) 2019 criteria include an FTSTS completion time of ≥ 12 seconds as a criterion for low physical performance [4]. Previous research has also shown that sit-to-stand test performance is associated with functional fitness and sarcopenia-related measures in community-dwelling older adults [5].

The oral cavity performs several functions that are essential for sustaining life and daily activities. However, oral health status and oral function may deteriorate with aging. Oral function encompasses multiple domains, including masticatory ability, swallowing function, tongue-lip motor function, tongue pressure, and occlusal force [6, 7]. Declines in these oral functions may impair dietary intake, reduce

nutritional quality and contribute to weight loss, social withdrawal, and diminished quality of life. Increasing attention has therefore been given to oral hypofunction and oral frailty as multidimensional conditions that are not limited to dental problems, and may represent part of a broader continuum of systemic functional decline in older adults [7, 8].

Previous studies have reported significant associations between oral function and physical performance in older adults. For example, Miyoshi et al. reported that physical performance was associated with oral function in older women participating in community-based health exercise programs [9]. Similarly, Murotani et al. examined 511 community-dwelling older Japanese adults aged 77–81 years and found that tongue pressure and occlusal force were associated with grip strength, whereas swallowing function and tongue-lip motor function were associated with walking speed [6]. These findings suggest that oral function is not only related to local oral health status but may also reflect systemic muscle strength and physical performance.

Evidence from frailty-oriented research further supports the interrelationship between oral health and physical function. Nogueira et al. examined oral-motor function in older people and proposed that oral-motor performance may represent an additional dimension of frailty, thereby expanding the understanding of frailty beyond conventional physical indicators [8]. In addition, longitudinal evidence from two prospective cohorts in the United Kingdom and the United States showed that oral health markers, including periodontal status and dry mouth, were associated with subsequent declines in muscle strength and physical performance in later life [10]. These findings suggest that the relationship between oral health and physical function may not be merely cross-sectional but may reflect shared vulnerability to age-related functional decline.

Despite these findings, several gaps remain. Previous studies have differed in participant characteristics, oral health assessments, physical performance measures, and analytical approaches, making it difficult to draw consistent conclusions. In particular, evidence remains limited regarding the association between lower-extremity physical performance and oral functional status, rather than oral disease-based conditions, in community-dwelling older women. Moreover, few studies have comprehensively examined whether simple lower-extremity performance-based measures, such as the FTSTS, are associated with multiple domains of oral function, such as oral-motor, swallowing, and masticatory functions, within the same study population. Therefore, this study aimed to examine the association between lower-extremity physical performance and oral function in community-dwelling older women. Specifically, we compared oral-motor, swallowing, and masticatory functions according to FTSTS performance status and explored the physical performance parameters associated with oral function. We hypothesized that lower-extremity physical performance would be associated with reduced oral-motor, swallowing, and masticatory function.

2. Method

2.1. Study design and participants

This cross-sectional study was conducted to examine the association between lower-extremity physical performance and oral function in community-dwelling older women. The participants were recruited from welfare and daycare facilities for older adults in Incheon, Republic of Korea. Eligible participants were women aged 65–85 years living in the community who were able to participate in the study procedures. Before participation, all participants received a detailed explanation of the study purpose, procedures, potential risks, and the right to withdraw from the study at any time. Only those participants who provided written informed consent were included in the study.

In total, 102 women were included in the final analysis (Fig. 1). The participants were classified into a robust physical performance group and a low physical performance group based on their performance on the FTSTS. The FTSTS was used as the primary indicator of lower-extremity physical performance in this study. Low physical performance was defined as requiring 12 s or longer to complete the FTSTS, based on the AWGS 2019 criteria [4].

This study was approved by the Institutional Review Board of Gachon University (IRB No. 1044396-202309-HR-188-01), and all procedures were conducted in accordance with the principles of the Declaration of Helsinki.

2.2. Oral function assessment

Three domains of oral function were assessed: oral motor function, swallowing function, and masticatory performance. Self-perceived oral health-related factors were assessed using structured questionnaires.

Oral-motor function

Oral-motor function was evaluated using oral diadochokinesis (ODK), which evaluates the motor speed and dexterity of the tongue and lips [7, 11]. Participants were instructed to pronounce the syllables /pa/, /ta/, and /ka/ as quickly and clearly as possible for 5 seconds. The number of syllables produced per second was measured using an automatic counter (Kenkokun Handy; Takei Scientific Instruments Co., Japan). The /pa/ syllable was used to assess lip motor function, whereas /ta/ and /ka/ were used to assess anterior and posterior tongue motor functions, respectively. Higher values indicated better oral motor function. An ODK rate < 6 syllables/s was considered indicative of decreased tongue-lip motor function [7, 11].

Swallowing function

Swallowing function was assessed using the Eating Assessment Tool-10 (EAT-10) and the repetitive saliva swallowing test (RSST). The EAT-10 is a self-administered questionnaire developed to screen for swallowing-related symptoms [12]. Each item was scored from 0 (no problem) to 4 (severe problem), resulting in a total score ranging from 0 to 40. Higher scores indicate greater swallowing-related difficulty, and a total score of ≥ 3 was considered indicative of swallowing difficulty [7, 12].

Because older adults may not fully recognize the mild symptoms of swallowing dysfunction [13], the RSST was also administered as an objective screening measure of swallowing function. The participants were instructed to swallow saliva as many times as possible within 30 s. During the test, the examiner palpated the larynx and recorded the number of successful swallows. The RSST results were expressed as the number of swallows within 30 s, with lower values indicating poorer swallowing function [14].

Masticatory function

Masticatory function was objectively assessed using color-changeable chewing gum (Masticatory Function Evaluating Gum XYLITOL, Lotte Co., Tokyo, Japan) [15]. The participants were instructed to chew the gum habitually for 1 min. After chewing, the gum was collected on a disposable dental mixing pad and flattened to a thickness of approximately 1.5 mm thickness. The color change was compared with the manufacturer-provided reference color chart. Scores ranged from 1 to 10, with higher scores indicating better masticatory function [16].

Self-perceived oral health-related items

The self-perceived oral health-related items included general oral health status, chewing discomfort, pronunciation discomfort, and toothache in the previous month. General oral health status was assessed using a 5-point Likert scale ranging from very poor to very good. Chewing discomfort, pronunciation discomfort, and toothache within the previous month were assessed using yes/no responses.

2.3. Physical performance-related parameters

Physical performance was assessed using performance-based and muscle strength-related measures, including the FTSTS, handgrip strength, the Short Physical Performance Battery (SPPB), the Timed Up and Go (TUG) test, gait speed, the two-Minute Step Test (2MST), ankle muscle strength, calf circumference, and SARC-F. These measures were used to evaluate lower-extremity function, mobility, balance, walking capacity, functional endurance, and muscle strength in community-dwelling older women.

The **FTSTS** was used as the primary indicator of lower-extremity physical performance and as a grouping variable in this study. The participants were seated on a standard chair with their arms crossed over their chest and instructed to stand up and sit down five times as quickly as possible. The time required to complete the five repetitions was recorded in seconds. Participants were not allowed to use their arms for support during the test. A longer completion time indicated poorer lower-extremity physical performance. Low physical performance was defined as an FTSTS completion time of ≥ 12 seconds according to the AWGS 2019 criteria [4].

Handgrip strength was measured using a Smedley hand dynamometer (TKK-5401, TAKEI, Japan). The participants stood upright with their feet shoulder-width apart and their arms naturally positioned at their sides without touching their bodies. The dynamometer handle was adjusted according to the hand size

of the participants. The participants were instructed to grip the dynamometer with maximal effort for 3 seconds. Measurements were performed three times, with sufficient rest between trials, and the mean value was used for analysis. Low handgrip strength was defined as HGS < 18 kg in women according to the AWGS 2019 criteria [4].

Gait speed was assessed using the 4-m usual walking test. The participants were instructed to walk at their usual pace over a 4-m distance, and the time required to complete the distance was recorded in seconds. Gait speed was calculated in m/s by dividing 4 m by the walking time in seconds. Lower gait speed indicated poorer walking performance. Low gait speed was defined as < 1.0 m/s according to the AWGS 2019 criteria [4].

Lower-extremity function and mobility were further assessed using the SPPB, TUG, and 2MST. The SPPB consists of three components: standing balance, usual gait speed, and chair-stand performance. Each component was scored from 0 to 4, and the total score ranged from 0 to 12, with higher scores indicating better lower-extremity physical performance [17]. The TUG test was used to assess functional and dynamic balance. The participants were seated on a chair, stood up, walked 3 meters, turned around, walked back to the chair, and sat down. The time required to complete the task was recorded in seconds, with longer times indicating poorer functional mobility [18]. The 2MST was used to assess functional endurance. The participants were instructed to march in place for 2 minutes while raising each knee to a predetermined height. The number of steps completed within 2 min was recorded, with higher values indicating better functional endurance [19].

Ankle plantar flexion and dorsiflexion strength were assessed using a handheld dynamometer (microFET2, Hoggan Scientific, Salt Lake City, UT, USA). The participants performed maximal plantar flexion against the resistance of the device under standardized positioning and stabilization procedures [20]. The participants performed maximal dorsiflexion under the same standardized conditions. Each measurement was performed three times, and the highest value was used for analysis. Higher values indicated greater ankle muscle strength [21,22].

Calf circumference was measured as a sarcopenia-related anthropometric indicator. The SARC-F was also assessed as a simple screening questionnaire for sarcopenia-related functional limitations [4]. These variables were included to describe sarcopenia-related characteristics and functional status in relation to FTSTS performance.

2.4. Sarcopenia- and aging-related physiological and metabolic markers

Sarcopenia- and aging-related physiological and metabolic markers included the appendicular skeletal muscle mass index (ASMI), glycated hemoglobin, skin autofluorescence, and blood pressure. These variables were assessed to characterize the participants' muscle-related, metabolic, and vascular health status.

Appendicular skeletal muscle mass was estimated using the anthropometric prediction equation proposed by Lee et al. [23]. Body weight was measured using a bioelectrical impedance analyzer (InBody 120; InBody Co., Seoul, Republic of Korea), and height, age, sex, and race were used in the prediction equation. ASM was calculated as follows:

$$\text{ASM (kg)} = 0.244 \times \text{body weight (kg)} + 7.8 \times \text{height (m)} + 6.6 \times \text{sex} - 0.098 \times \text{age (years)} + \text{race} - 3.3,$$

where sex was coded as 1 for men and 0 for women, and race was coded as 0 for White, 1.4 for Black, and - 1.2 for Asian participants [23]. Because all participants in this study were Asian women, sex was coded as 0 and race as - 1.2. ASMI was calculated as ASM divided by height squared (kg/m^2). Low ASMI was defined as $< 5.7 \text{ kg/m}^2$ in women according to the AWGS 2019 criteria [4]. According to the same criteria, sarcopenia was defined as low muscle mass accompanied by low muscle strength or physical performance [4].

Glycated hemoglobin (HbA1c) was measured in venous blood samples using NGSP-certified and IFCC-traceable methods. HbA1c values were reported as percentages. HbA1c was included as a metabolic marker of long-term glycemic status.

Skin autofluorescence (SAF) was measured using an AGE Reader™ (DiagnOptics Technologies BV, Groningen, Netherlands) as a non-invasive indicator of accumulated advanced glycation end-products in the skin. During the measurement, excitation light with a peak wavelength of approximately 370 nm was applied to the skin of the forearm, and the emitted and reflected light were analyzed by the device. SAF values were expressed in arbitrary units (AU), with higher values indicating greater accumulation of advanced glycation end products in the skin. The AGE Reader method has been described as a non-invasive approach for estimating skin AGE accumulation using autofluorescence signals from the forearm [24].

Blood pressure was measured once using an electronic blood pressure meter (BPBIO330, BioSpace, Seoul, Republic of Korea). Before measurement, the participants were asked to avoid caffeine intake, smoking, and exercise for at least 30 min and to rest in a seated position for at least 5 min. Blood pressure was measured in the upper arm using an appropriately sized cuff positioned at heart level. Two measurements were obtained at 1–2-minute intervals, and the mean value was used for analysis. These procedures were consistent with the commonly recommended practices for accurate blood pressure measurement, including avoidance of caffeine, smoking, and exercise before measurement, and the use of repeated measurements [25].

2.5. Statistical analysis

All statistical analyses were performed using SPSS version 26.0 (SPSS Inc., Chicago, IL, USA). Continuous variables are presented as means and standard deviations, and categorical variables are presented as frequencies and percentages. Participants were classified into the robust physical performance group and the low physical performance group according to their FTSTS performance, with low physical performance defined as an FTSTS completion time of ≥ 12 seconds. Between-group

differences in participant characteristics, physical performance, and oral function were analyzed using independent-samples t-tests for continuous variables and Chi-square or Fisher's exact tests for categorical variables, as appropriate.

Univariate logistic regression analysis was performed to examine the association between each oral function indicator and low FTSTS performance. In these analyses, low FTSTS performance was used as the dependent variable, and ODK/pa/, ODK/ta/, ODK/ka/, EAT-10 score, RSST, and masticatory function were entered separately as independent variables.

Multivariate logistic regression models were constructed to examine whether the selected oral function indicators remained associated with low FTSTS performance after additionally considering sarcopenia-related and lower-extremity muscle strength indicators. Model 1 included selected oral function indicators. Model 2 also included sarcopenia-related indicators such as low gait speed and ASMI. Model 3 included ankle plantar flexion and dorsiflexion strengths. In the multivariate models, ODK/pa/ was selected as the representative oral-motor indicator to avoid potential multicollinearity among ODK/pa/, /ta/, and /ka/. Multicollinearity among independent variables was assessed using collinearity diagnostics, including condition indices and proportions of variance decomposition. Problematic multicollinearity was considered present when a high condition index was accompanied by high variance proportions for two or more predictors in the same dimension. Logistic regression results were presented as odds ratios (ORs) with 95% confidence intervals (CIs). Statistical significance was set at $P < 0.05$.

3. Results

3.1. Participant characteristics according to FTSTS performance status

In total, 102 community-dwelling older women were included in the final analysis and classified according to their FTSTS performance status. The participant characteristics are presented in Table 1. Age, living alone, alcohol consumption, smoking habits, body mass index, systolic blood pressure, and ASMI did not differ significantly between the robust and low FTSTS performance groups. However, educational level differed between the groups, and weekly walking time was significantly lower in the low FTSTS performance group than in the robust group. HbA1c and skin autofluorescence levels were significantly higher, whereas diastolic blood pressure was significantly lower in the low FTSTS performance group. The prevalence of sarcopenia was significantly higher in the low FTSTS performance group than in the robust group.

Table 1
Participant characteristics according to five-times sit-to-stand (FTSTS) performance status

Characteristics		Normal FTSTS (n = 53)	Low FTSTS (n = 49)	P
Demographic characteristics	Age	71.66 ± 6.43	73.22 ± 6.60	0.460
	Education (level) (%)			0.016*
	Elementary school	2 (3.77)	-	
	Middle school	4 (7.55)	7 (14.28)	
	High school	8 (15.09)	20 (40.81)	
	College	32 (60.38)	18 (36.73)	
	Graduate school	7 (13.21)	4 (8.16)	
	Living alone (%)	14 (26.41)	6 (12.24)	0.072
Lifestyle factors	Regular alcohol consumption, n (%)	13 (24.52)	14 (28.57)	0.074
	Regular smoker, n (%)	7 (13.20)	2 (4.08)	0.104
	Walking time, min/week	344.09 ± 203.34	118.78 ± 77.90	< 0.001***
Metabolic characteristics	Body mass index, kg/m ²	24.11 ± 3.38	24.37 ± 3.67	0.710
	< 18.5 (%)	2 (3.77)	0	0.345
	18.5–22.9 (%)	19 (35.85)	19 (38.77)	
	23.0–29.9 (%)	29 (54.71)	24 (48.97)	
	≥ 30.0 (%)	3 (5.66)	6 (12.24)	
	HbA1c (%)	5.63 ± 0.81	6.07 ± 1.07	0.021*
	Skin autofluorescence, SAF	2.85 ± 0.45	3.29 ± 0.48	< 0.001***
	Blood pressure: SBP (mmHg)	126.72 ± 14.29	127.86 ± 15.81	0.703

*P < 0.05, **P < 0.01, and ***P < 0.001. Data are presented as mean ± standard deviation or n (%). P values were calculated using the independent-samples t test for continuous variables and the chi-square test or Fisher's exact test for categorical variables, as appropriate. Low FTSTS performance was defined as an FTSTS time of ≥ 12 s. FTSTS, five-times sit-to-stand; BMI, body mass index; HbA1c, glycated hemoglobin; SAF, skin autofluorescence; SBP, systolic blood pressure; DBP, diastolic blood pressure; ASMI, appendicular skeletal muscle mass index.

Characteristics		Normal FTSTS (n = 53)	Low FTSTS (n = 49)	P
	DBP (mmHg)	78.17 ± 8.70	75.48 ± 8.67	0.121
Sarcopenia characteristics	Sarcopenia, n (%)	10 (18.87)	24 (48.97)	0.001**
	ASMI (kg/m ²)	6.38 ± 1.25	6.20 ± 1.15	0.452
*P < 0.05, **P < 0.01, and ***P < 0.001. Data are presented as mean ± standard deviation or n (%). P values were calculated using the independent-samples t test for continuous variables and the chi-square test or Fisher's exact test for categorical variables, as appropriate. Low FTSTS performance was defined as an FTSTS time of ≥ 12 s. FTSTS, five-times sit-to-stand; BMI, body mass index; HbA1c, glycated hemoglobin; SAF, skin autofluorescence; SBP, systolic blood pressure; DBP, diastolic blood pressure; ASMI, appendicular skeletal muscle mass index.				

3.2. Physical performance and oral function according to FTSTS performance status

Physical performance and oral function measures according to FTSTS performance status are shown in Table 2. As expected, the low FTSTS performance group required a significantly longer time to complete the FTSTS than the robust FTSTS performance group. In addition, the low FTSTS performance group showed significantly lower handgrip strength, lower SPPB scores, poorer 2MST performance, longer TUG time, slower gait speed, and lower ankle plantar flexion and dorsiflexion strengths than the robust group. However, calf circumference and SARC-F scores did not differ significantly between the groups.

Table 2
Physical performance and oral function according to FTSTS performance status

Physical performance measures	Normal FTSTS (n = 53)	Low FTSTS (n = 49)	P
Five-times sit-to-stand, s	9.07 ± 2.10	15.01 ± 2.97	< 0.001 ^{***}
Handgrip strength, kg	22.85 ± 5.59	18.56 ± 5.62	< 0.001 ^{***}
Short physical performance battery, score	11.19 ± 1.04	9.53 ± 1.50	< 0.001 ^{***}
Two-minute step test, steps	112.09 ± 20.62	102.29 ± 24.62	0.031 [*]
Timed Up and Go, s	7.38 ± 1.74	8.64 ± 3.07	0.012 [*]
Gait speed, m/s	1.02 ± 0.23	0.90 ± 0.29	0.049 [*]
Ankle Plantar flexion, kgf	13.46 ± 3.33	9.88 ± 1.79	< 0.001 ^{***}
Ankle Dorsalflexion, kgf	12.19 ± 3.24	7.82 ± 2.56	< 0.001 ^{***}
Calf circumference, cm	34.07 ± 2.63	33.95 ± 2.48	0.810
SARC-F, score	2.51 ± 1.98	3.12 ± 1.87	0.113
Oral function measures			
Oral diadochokinesis (ODK)			
ka	4.81 ± 1.14	4.01 ± 1.17	< 0.001 ^{***}
pa	4.80 ± 1.04	4.02 ± 1.11	< 0.001 ^{***}
ta	4.88 ± 1.07	3.90 ± 1.12	< 0.001 ^{***}
EAT-10, score	2.32 ± 3.03	7.35 ± 6.66	< 0.001 ^{***}
RSST, swallows/30 s	3.57 ± 1.46	2.16 ± 0.87	< 0.001 ^{***}
Masticatory function, score	9.00 ± 0.87	7.76 ± 1.23	< 0.001 ^{***}

*P < 0.05, **P < 0.01, and ***P < 0.001. Data are presented as mean ± standard deviation or n (%). P values were calculated using the independent-samples t test for continuous variables and the chi-square test or Fisher's exact test for categorical variables, as appropriate. FTSTS, five-times sit-to-stand; SPPB, Short Physical Performance Battery; TUG, Timed Up and Go; SARC-F, Strength, Assistance with walking, Rise from a chair, Climb stairs, and Falls; ODK, oral diadochokinesis; EAT-10, Eating Assessment Tool-10; RSST, repetitive saliva swallowing test.

Physical performance measures	Normal FTSTS (n = 53)	Low FTSTS (n = 49)	P
Poor self-rated oral health, n (%)	41(77.36)	33(67.34)	0.258
Chewing discomfort, n (%)	13(24.52)	21(42.85)	0.050
Pronunciation discomfort, n (%)	10(18.86)	15(30.61)	0.168
Toothache within the past month, n (%)	11(20.75)	15(30.61)	0.254
*P < 0.05, **P < 0.01, and ***P < 0.001. Data are presented as mean ± standard deviation or n (%). P values were calculated using the independent-samples t test for continuous variables and the chi-square test or Fisher's exact test for categorical variables, as appropriate. FTSTS, five-times sit-to-stand; SPPB, Short Physical Performance Battery; TUG, Timed Up and Go; SARC-F, Strength, Assistance with walking, Rise from a chair, Climb stairs, and Falls; ODK, oral diadochokinesis; EAT-10, Eating Assessment Tool-10; RSST, repetitive saliva swallowing test.			

Oral function also differed significantly according to FTSTS performance status. The low FTSTS performance group showed significantly lower ODK values for /pa/, /ta/, and /ka/, indicating reduced oral motor function. In addition, EAT-10 scores were significantly higher, whereas RSST values and masticatory function scores were significantly lower in the low FTSTS performance group. Among the self-perceived oral health-related items, chewing discomfort differed significantly between groups, whereas poor self-rated oral health, pronunciation discomfort, and toothache within the past month did not show significant differences between the groups. Overall, these findings indicate that older women with low FTSTS performance had poorer lower-extremity physical performance and concurrent declines in oral motor function, swallowing, and masticatory function.

3.3. Univariable associations between oral function indicators and low FTSTS performance

Univariable logistic regression analysis was performed to examine the association between each oral function indicator and low FTSTS performance. Each oral function indicator was entered separately into the model. As shown in Table 3, ODK/pa/, /ta/, and /ka/ were significantly associated with poor FTSTS performance. Higher ODK values were associated with lower odds of low FTSTS performance, indicating that better oral motor function was related to better lower-extremity physical performance.

Table 3
Univariable logistic regression analysis of oral function indicators associated with low FTSTS performance

Factor	Low five-times sit-to-stand performance	
	OR (95%CI)	P
ODK /pa/		0.874 (0.806–0.948) < 0.001***
ODK /ka/		0.888 (0.825–0.957) 0.002**
ODK /ta/		0.849 (0.781–0.924) < 0.001***
EAT-10, score	1.328 (1.141–1.545)	< 0.001***
RSST, swallows/30 s	0.335 (0.206–0.546)	< 0.001***
Masticatory function, score	0.343 (0.216–0.545)	< 0.001***
*P < 0.05, **P < 0.01, and ***P < 0.001. Values are presented as odds ratios (ORs) with 95% confidence intervals (CIs). The dependent variable was low FTSTS performance, defined as an FTSTS time of ≥ 12 s. Each oral function indicator was entered separately into a univariable logistic regression model. FTSTS, five-times sit-to-stand; ODK, oral diadochokinesis; EAT-10, Eating Assessment Tool-10; RSST, repetitive saliva swallowing test.		

Swallowing-related indicators were significantly associated with low FTSTS performance. Higher EAT-10 scores were associated with increased odds of low FTSTS performance, whereas higher RSST values were associated with decreased odds of low FTSTS performance. Additionally, higher masticatory function scores were significantly associated with lower odds of low FTSTS performance. These findings suggest that oral motor function, swallowing, and masticatory function indicators were individually associated with lower-extremity physical performance.

3.4. Multivariable logistic regression models for low FTSTS performance

Multivariate logistic regression models were constructed to examine whether the selected oral function indicators remained associated with low FTSTS performance after adjusting for sarcopenia-related and lower-extremity muscle strength indicators. Model 1 included selected oral function indicators. Model 2 also included sarcopenia-related indicators such as low gait speed and ASMI. Model 3 included ankle plantar flexion and dorsiflexion strengths.

Collinearity diagnostics showed no evidence of problematic multicollinearity among the independent variables. Although one dimension showed a condition index slightly above 30, high variance proportions were not simultaneously observed for two or more substantive predictors. In particular, EAT-10 and RSST,

which represent subjective swallowing-related symptoms and objective swallowing performance, respectively, did not show evidence of problematic multicollinearity.

In Model 1, ODK /pa/, EAT-10, RSST, and masticatory function were significantly associated with low FTSTS performance. After the adjustment for sarcopenia-related indicators to Model 2, ODK/pa/, EAT-10, RSST, and masticatory function remained significantly associated with low FTSTS performance. In Model 3, after further inclusion of ankle muscle strength indicators, EAT-10, RSST, and masticatory function remained significantly associated with low FTSTS performance, whereas the association between ODK/pa/ and low FTSTS performance was attenuated.

Swallowing-related symptoms, repetitive saliva swallowing performance, and masticatory function were consistently associated with lower-extremity physical performance, even after adjusting for sarcopenia-related indicators and ankle muscle strength. In contrast, the association of ODK/pa/ appeared to be less robust after accounting for lower-extremity muscle strength indicators.

4. Discussion

The main finding of this study was that low FTSTS performance was associated with poorer oral motor, swallowing, and masticatory functions in community-dwelling older women. Specifically, participants with low FTSTS performance had lower ODK values, higher EAT-10 scores, fewer RSST swallows, and poorer masticatory function than those with robust FTSTS performance. In the univariable logistic regression analyses, each oral function indicator was significantly associated with low FTSTS performance. Furthermore, in the multivariable models, EAT-10, RSST, and masticatory function remained significantly associated with low FTSTS performance, even after adjusting for sarcopenia-related indicators and ankle muscle strength. These findings suggest that core oral functions, particularly mastication and swallowing, may be closely linked to lower-extremity physical performance in older women.

The present findings are consistent with those of previous studies that reported associations between oral function and physical performance in older adults. For instance, a previous study reported that physical performance was associated with oral function in older women who participated in community-based health exercise programs [9]. Similarly, Cicek et al. found that masticatory function was most strongly associated with TUG performance and suggested that this oral function may be a useful indicator of physical function in older adults [26]. Murotani et al. also demonstrated that oral function domains, including tongue pressure, occlusal force, swallowing function, and tongue-lip motor function, were associated with grip strength and walking speed in community-dwelling older adults [6]. Nogueira et al. suggested that oral motor function may represent an additional dimension of frailty in older people [8]. Additionally, longitudinal evidence has shown that oral health markers are associated with subsequent decline in muscle strength and physical performance in later life [10]. Our findings extend this body of evidence by focusing on FTSTS performance as a lower-extremity performance-based

indicator and examining its association with multiple oral function domains, including oral motor, swallowing, and masticatory functions.

The FTSTS is not only a measure of lower-extremity muscle strength but also a performance-based indicator that reflects lower-extremity power, balance control, neuromuscular coordination, transitional mobility, and functional reserve required for repeated sit-to-stand movements [4, 5, 27]. Rising from and sitting down on a chair are some of the most fundamental transitional movements in daily life and require lower-extremity support and postural stability before walking can be initiated [27]. Therefore, reduced FTSTS performance may indicate not only reduced lower-extremity strength but also impaired integrated physical performance required for independent mobility and activities of daily living in older adults [28].

The functional interpretation of the FTSTS is closely related to frailty. Frailty is a multidimensional state of vulnerability characterized by a decline in muscle strength, mobility, physical activity, nutritional status, and physiological reserve, rather than dysfunction in a single organ system [2]. Oral functional decline may also affect dietary intake, nutritional status, social participation in meals, and overall functional maintenance through the impairment of mastication, swallowing, and oral motor control. Moreover, oral motor function has been proposed as an additional dimension of frailty in older adults [8]. Therefore, the coexistence of reduced FTSTS performance and impaired oral function may not represent independent problems in separate body regions; rather, it may reflect a shared vulnerability related to age-associated neuromuscular decline, reduced functional reserve, and frailty-related functional deterioration. Although grip strength and gait speed have been frequently used as physical function indicators in previous studies examining oral function [6, 9], relatively few studies have focused on the FTSTS as the primary physical performance indicator when examining oral motor, swallowing, and masticatory functions. Therefore, the present study adds a distinct perspective by focusing on FTSTS performance and demonstrating its coexistence with impairments in field-applicable oral function measures.

The consistent associations of the EAT-10, RSST, and masticatory function with low FTSTS performance are particularly noteworthy. The EAT-10 is a validated screening tool that reflects subjective swallowing-related symptoms [12] and has been used as an indicator of swallowing problems in the assessment of oral hypofunction [7]. In contrast, the RSST is an objective screening test for functional dysphagia based on the number of repeated saliva swallows within 30 seconds [14]. The finding that both subjective swallowing-related symptoms and objective swallowing performance were associated with low FTSTS performance suggests that swallowing function may be meaningfully linked to physical performance in older women. Masticatory function was consistently associated with a low FTSTS performance across all models. Masticatory function reflects the functional ability to comminute and mix food and may be closely related to food selection, dietary variety, and nutritional intake in older adults [15,16]. Previous studies have also reported that oral function indicators were associated with grip strength, walking speed, and a subsequent decline in physical performance [6, 10], further supporting the functional link between oral function and physical performance. Although the present cross-sectional design does not allow for causal inference, these findings suggest that swallowing and masticatory function may be

important functional domains to consider together with lower-extremity performance in community-based geriatric health assessments.

The multivariate findings presented in Table 4 provide an important basis for interpreting the results. In the univariate analyses, oral motor function, swallowing, and masticatory function indicators were all associated with low FTSTS performance. However, the multivariable models further accounted for the potential overlap among oral function indicators as well as the influence of sarcopenia-related and lower-extremity muscle strength indicators. The EAT-10, RSST, and masticatory function remained significantly associated with low FTSTS performance even after adjustment for sarcopenia-related indicators, including low gait speed and low ASMI. These associations persisted in the fully adjusted model, which included ankle plantar flexion and dorsiflexion strengths. These findings suggest that swallowing-related symptoms, repetitive saliva swallowing performance, and masticatory function were not fully explained by sarcopenia-related status or ankle muscle strength and remained relevant oral function domains associated with low FTSTS performance.

Table 4
Multivariable logistic regression models for low FTSTS performance

Factor	Model 1		Model 2		Model 3	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
ODK /pa/	0.865 (0.757–0.989)	0.034*	0.857 (0.748–0.982)	0.026*	0.910 (0.771–1.075)	0.268
EAT-10	1.325 (1.091–1.609)	0.004**	1.298 (1.079–1.560)	0.006**	1.323 (1.056–1.657)	0.015*
RSST, swallows/30 s	0.457 (0.257–0.815)	0.008**	0.446 (0.244–0.814)	0.008**	0.411 (0.198–0.853)	0.017*
Masticatory function, score	0.287 (0.141–0.583)	< 0.001***	0.246 (0.109–0.555)	0.001**	0.279 (0.106–0.736)	0.010*
Low gait speed (< 1m/s)			1.606 (0.399–6.464)	0.505	1.130 (0.168–7.594)	0.900
Low ASMI (< 5.7kg/m ²)			0.351 (0.085–1.153)	0.148	0.155 (0.023–1.055)	0.057
Ankle Plantar flexion, kgf					0.650 (0.421–1.001)	0.051
Ankle Dorsiflexion, kgf					0.835 (0.586–1.189)	0.316
*P < 0.05, **P < 0.01, and ***P < 0.001. Values are presented as odds ratios (ORs) with 95% confidence intervals (CIs). The dependent variable was low FTSTS performance, defined as an FTSTS time of ≥ 12 s. Model 1 included the selected oral function indicators. Model 2 additionally included the sarcopenia-related indicators. Model 3 further included the lower-extremity muscle strength indicators. Low gait speed was defined as < 1.0 m/s, and low ASMI was defined as < 5.7 kg/m² in women. FTSTS, five-times sit-to-stand; ODK, oral diadochokinesis; EAT-10, Eating Assessment Tool-10; RSST, repetitive saliva swallowing test; ASMI, appendicular skeletal muscle mass index.						

Nutritional and hydration factors may play important roles in the mechanisms underlying the association between oral function, particularly swallowing and mastication, and low FTSTS performance. Previous studies have reported that older adults with impaired mastication or swallowing function tend to avoid hard or tough foods, prefer softer foods, and reduce food intake [29,30]. Additionally, impaired swallowing function may increase the risk of dehydration because difficulties in swallowing liquids can lead to reduced fluid intake [31]. In community-dwelling older women, lower hydration status has been

associated with poorer muscle strength and slower gait [32]. Therefore, inadequate nutrient intake and reduced hydration linked to impaired mastication and swallowing function may contribute to poorer lower-extremity physical performance. In contrast, the association between ODK/pa/ and low FTSTS performance was attenuated in the fully adjusted model, suggesting that oral motor function may partly overlap with lower-extremity strength or broader neuromuscular characteristics. Taken together, the present findings indicate that, among the oral function domains assessed in this study, swallowing- and mastication-related indicators were more consistently associated with lower-extremity physical performance. However, owing to the cross-sectional design of this study, these associations should not be interpreted causally. Future longitudinal studies are needed to clarify the temporal relationship between lower-extremity physical decline and oral functional deterioration.

From a community health perspective, the present findings support the need for an integrated assessment of physical and oral functions in older adults. The FTSTS is a simple and time-efficient tool for assessing lower-extremity physical performance, while the ODK, EAT-10, RSST, and color-changeable chewing gum are practical field-based measures of oral function. The combined use of these assessments may help identify older adults with concurrent decline in lower-extremity physical performance and oral function. These findings provide a basis for developing multidisciplinary community health strategies that integrate exercise, oral function management, nutrition, and frailty prevention.

This study has several strengths. First, it comprehensively assessed multiple domains of oral function, including oral motor, swallowing, and masticatory functions, using a combination of subjective and objective measures. Second, lower-extremity physical performance was evaluated using objective performance-based measures, with the FTSTS used as the primary classification indicator. Third, both univariate and multivariate logistic regression models were used to examine whether oral function indicators remained associated with low FTSTS performance after adjusting for sarcopenia-related indicators and ankle muscle strength. In addition, this study has practical relevance because it used assessment tools that were feasible in community settings such as older adult welfare facilities and day-care centers.

Despite its strengths, several limitations of this study should be noted. First, because this was a cross-sectional study, the causal relationships between oral function and lower-extremity physical performance could not be determined. Second, the study only included community-dwelling older women, which may limit its generalizability to older men or institutionalized older adults. Third, although field-applicable oral function measures were used, detailed dental and oral physiological measures such as tongue pressure, occlusal force, number of remaining teeth, denture status, salivary flow, and periodontal status were not included. Therefore, the present findings should be interpreted as associations between lower-extremity physical performance and functional oral indicators, rather than comprehensive oral health status. In addition, some estimates in the regression models have wide confidence intervals, suggesting limited precision and the need for cautious interpretation. Future

longitudinal studies with larger and more diverse samples are needed to clarify the temporal and mechanistic relationships between oral function and lower-extremity physical performance.

In conclusion, low FTSTS performance was associated with poorer subjective and objective assessments of swallowing and masticatory function in community-dwelling older women. In particular, poor swallowing function was assessed both subjectively and objectively, and masticatory function remained associated with low FTSTS performance after adjusting for sarcopenia-related and ankle muscle strength indicators. These findings suggest that oral function should be considered part of an integrated functional assessment framework for older adults with reduced lower-extremity physical performance.

Declarations

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Author contributions

S-J, Choi & J, Kim conceived and designed the study. S-J, Choi & J, Kim coordinated participant recruitment and data collection. S-J, Choi & J, Kim conducted the assessments and curated the data J, Kim performed the statistical analyses. J, Kim interpreted the findings. [Author initials] drafted the original manuscript. S-J, Choi & J, Kim critically reviewed and revised the manuscript for important intellectual content. J, Kim supervised the study and acquired funding. All authors reviewed and approved the final version of the manuscript.

Data availability statement

The datasets generated and/or analysed during the current study are available from the corresponding author upon reasonable request. The data are not publicly available because they contain information that could compromise the privacy of the research participants.

Competing interests

The authors declare no competing interests.

Ethical declarations

This study was conducted in accordance with the principles of the Declaration of Helsinki. The study protocol was reviewed and approved by the Institutional Review Board of Gachon University (IRB No. 1044396-202309-HR-188-01). All participants received a detailed explanation of the study procedures, potential risks, and benefits, and provided written informed consent before participation.

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Figures

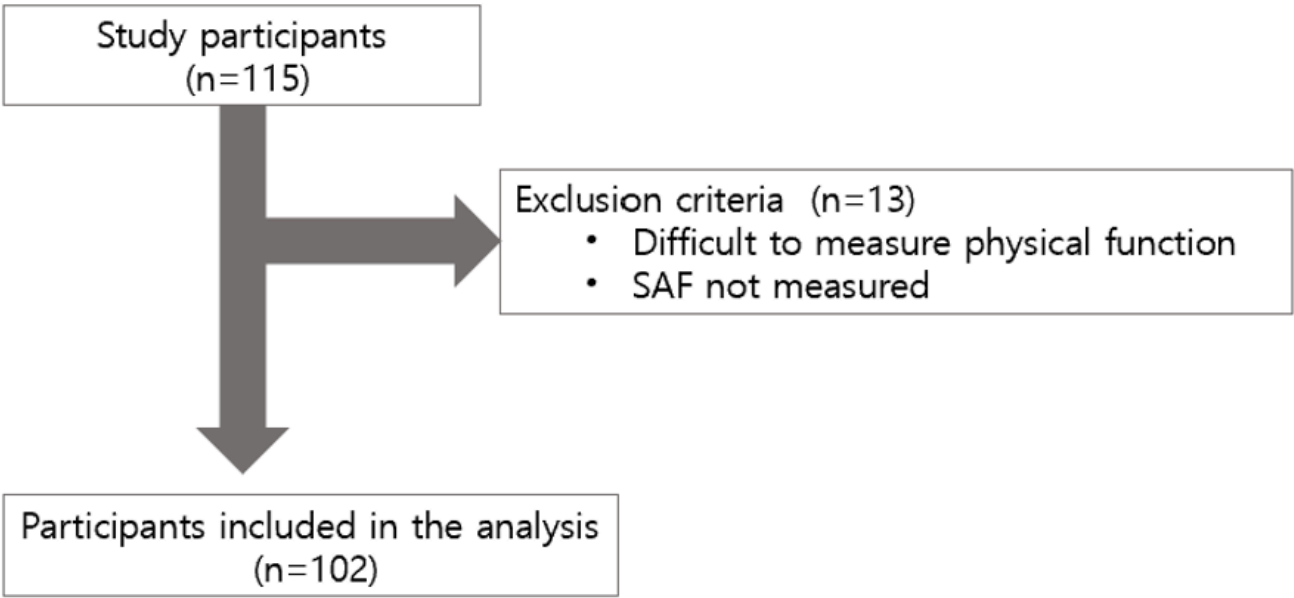


Figure 1

Flow diagram of participant selection. Of the 115 study participants, 13 were excluded because physical function could not be assessed or skin autofluorescence was not measured. A total of 102 participants

were included in the final analysis. SAF, skin autofluorescence.