Clinical Nutrition 38 (2019) 303–309

Contents lists available at ScienceDirect

Clinical Nutrition

journal homepage: http://www.elsevier.com/locate/clnu

Original article

Diagnostic accuracy of lip force and tongue strength for sarcopenic dysphagia in older inpatients: A cross-sectional observational study

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ARTICLE INFO

Article history:
Received 11 August 2017
Accepted 9 January 2018

Keywords:
Deglutition disorders
Sarcopenia
Tongue
Lip
Rehabilitation

SUMMARY

Background & aims: Dysphagia can be caused by sarcopenia in older adults. Although sarcopenic dysphagia has been reported to be associated with low tongue strength, whether tongue strength can be useful as a diagnostic index for sarcopenic dysphagia remains unclear. In addition, the association between sarcopenic dysphagia and lip force is unknown. The aim of the present study was to clarify the association of lip force and tongue strength with sarcopenic dysphagia, and their diagnostic accuracy for sarcopenic dysphagia.

Methods: A cross-sectional study was conducted in consecutive 245 (166 women) inpatients aged ≥65 years in the post-acute phase of illness. The presence of sarcopenic dysphagia, lip force, and tongue strength were assessed. Additional factors were also assessed: cognitive function, nutritional status, comorbidity, oral intake level, occlusion status, physical function, and inflammatory status. Multivariable logistic regression analysis was conducted with the presence of sarcopenic dysphagia as a dependent variable. Lip force and tongue strength were assessed with the area under the receiver operating characteristic curve (AUC) to clarify diagnostic accuracy for sarcopenic dysphagia. In addition, the cut-off values of lip force and tongue strength for identifying sarcopenic dysphagia were determined according to sex.

Results: In total, 86 patients (35.1%) had sarcopenic dysphagia. Both men and women with sarcopenic dysphagia had lower lip force and tongue strength than men and women without dysphagia or sarcopenic dysphagia ($p < 0.001$ for all). In multivariable logistic regression analysis, sarcopenic dysphagia was significantly associated with lip force (OR = 0.63, 95% CI 0.53–0.74, $p < 0.001$) and tongue strength (OR = 0.92, 95% CI 0.87–0.98, $p = 0.011$). The AUCs for lip force in patients with sarcopenic dysphagia were 0.88 (CI 0.81–0.95, $p < 0.001$) for men and 0.84 (CI 0.77–0.90, $p < 0.001$) for women. The AUCs for tongue strength were 0.79 (CI 0.69–0.89, $p < 0.001$) for men and 0.74 (CI 0.65–0.82, $p < 0.001$) for women. The cut-off values for sarcopenic dysphagia in men were 10.4 N for lip force and 24.3 kPa for tongue strength; the cut-off values in women were 8.5 N for lip force and 23.9 kPa for tongue strength.

Conclusion: In older inpatients who are suspected as having dysfunction due to sarcopenia, lip force and tongue strength can be independently useful indices for diagnosing sarcopenic dysphagia, and may be factors that prevent and improve sarcopenic dysphagia.

Abbreviations: AUC, area under the receiver operating characteristic curve; BI, Barthel Index; CC, calf circumference; CCI, Charlson Comorbidity Index; CI, confidence interval; CRP, C-reactive protein; EI, Eichner Index; FOIS, functional oral intake scale; IQR, interquartile range; MMSE, mini-mental state examination; MNA-SF, Mini Nutritional Assessment Short-Form; NPV, negative predictive value; OR, odds ratio; PPV, positive predictive value; ROC, receiver operating characteristic; WST, water swallow test.

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https://doi.org/10.1016/j.clnu.2018.01.016
0261-5614/

1. Introduction

With the increasing aging population worldwide, serious health problems due to sarcopenia are emerging. Sarcopenia is defined as concurrent loss of muscle mass and strength, and a multifactorial syndrome caused by aging, disuse, inadequate nutrition, and disease [1]. The prevalence of sarcopenia is approximately 50% in older adults during post-acute care and rehabilitation [2]. Sarcopenia can increase one's risk for functional decline and death [3]. Sarcopenia can not only reduce muscle mass and strength in appendicular skeletal muscle, but it is also known to affect swallowing, to the extent of causing swallowing difficulties called "sarcopenic dysphagia" [4]. The prevalence of sarcopenic dysphagia has been reported to be approximately 32.2% in older inpatients undergoing post-acute rehabilitation [5]. Dysphagia increases one's risk of developing aspiration pneumonia, low quality of life, malnutrition, and death [6]. Thus, the diagnosis and management of sarcopenic dysphagia should be prioritized in older inpatients.

Older adults with sarcopenia reportedly have low tongue strength, which is known to be associated with dysphagia [7]. In addition, tongue strength has been associated with handgrip as a sarcopenia-diagnostic factor [8]. These previous studies have indicated that tongue strength is strongly associated with sarcopenic dysphagia. Furthermore, tongue strength has been proposed to be a diagnosis index of sarcopenic dysphagia [9]. However, the diagnostic accuracy of tongue strength to sarcopenic dysphagia has not been investigated. Additionally, lip function is also important for feeding. Poor lip muscle closure can cause leakage through the corners of the mouth [10]. Lip force has been associated with hand grip, and lip drooping has been associated with aging [11,12]. Although decreased lip force has been suggested to be caused by sarcopenia, and to be related to dysphagia, the association between lip force and sarcopenic dysphagia has not been investigated. Because sarcopenia is a condition of low generalized muscle strength, both lip force and tongue strength may be sensitive indices for sarcopenic dysphagia. By establishing simple diagnostic criteria for sarcopenic dysphagia, further knowledge about the cause of dysphagia and its treatment may be determined.

The present study aimed to investigate the association of lip force and tongue strength with sarcopenic dysphagia, and the diagnostic accuracy of lip force and tongue strength for sarcopenic dysphagia. We hypothesized that lip force and tongue strength are independently associated with sarcopenic dysphagia and are useful diagnostic indices for sarcopenic dysphagia.

2. Materials and methods

2.1. Participants

A cross-sectional study was performed in consecutive older adult inpatients aged ≥65 years in the post-acute phase of illness who were hospitalized for rehabilitation between April 2015 and October 2016. Inclusion criteria were as follows; patients who had no history of cerebrovascular diseases or head and neck cancers, or underlying neuromuscular diseases that were known as diseases that affect oral strength and swallowing; a Mini–Mental State Examination (MMSE) score of 21 points or higher that reflects mildly impaired or normal cognitive functioning [13], and the presence of all upper and lower central incisors to measure oral strength. Exclusion criteria were as follows: patients diagnosed with depression by their attending physician owing to possible difficulties that arise and disrupt accurate measurement of muscle strength; ill-fitting dentures or mobile central incisors; chronic respiratory disease such as chronic obstructive pulmonary disease that can be diagnosed as dysphagia due to incoordination between respiration and swallowing but not by low oral strength as a result of sarcopenia. Informed consent was obtained from all patients and their families or legal representatives, and the present study was approved by our hospital's ethics committee.

2.2. Assessment of sarcopenic dysphagia

Patients were diagnosed with sarcopenic dysphagia if they had both sarcopenia and dysphagia. Patients without dysphagia and those with non-sarcopenic dysphagia were included in the normal/non-sarcopenic dysphagia group. Sarcopenia was diagnosed if participants had both low skeletal muscle mass and low muscle strength based on the criteria of the Asian Working Group for Sarcopenia [14]. Low muscle strength was assessed by grip strength with cut-off values defined by the Asian Working Group for Sarcopenia (<26 kg for men, and <18 kg for women). To determine low skeletal muscle mass, calf circumference (CC) was assessed using cut-off values from a previous study (<34 cm for men, and <33 cm for women) [15]. CC has been validated to measure skeletal muscle mass for diagnosing sarcopenia [16]. We did not include gait speed in the evaluation of physical performance, although it is one of the diagnostic factors for sarcopenia in the algorithm of the Asian Working Group for Sarcopenia, because our study included participants with orthopedic disease of the legs, such as femoral neck fractures, which could affect gait speed. Grip strength was measured using a digital grip strength dynamometer (TKK 5401; Takei Scientific Instruments, Tokyo, Japan). Participants were asked to sit in a relaxed position and grip the instrument as hard as possible three times with each hand by physical therapists or occupational therapists. The highest measurement was defined as individual grip strength. To measure CC, a tape measure was placed around the calf of the participant's non-dominant lower leg, and moved to obtain the maximal circumference without compressing subcutaneous tissues when the participants were in a seated position. In patients who had fractures in their non-dominant lower leg, measurements were taken on the healthy side. CC was measured by one trained rehabilitation therapist to eliminate inter-examiner variation. Grip strength and CC were measured within 1 week after hospitalization.

Dysphagia was assessed using the 100-mL water swallow test (WST) [17] on the first day of hospitalization. Patients were seated upright and asked to place a 100-ml glass of water to their lips. They drank the water in the cup as quickly as possible upon a start signal given by trained speech-language pathologists. The swallowing time was measured using a stopwatch from the beginning to completion of the last swallow, indicated visually by the return of the thyroid cartilage to its resting position. Swallowing speed (ml/s) was calculated by dividing the amount of water swallowed by the swallowing time. In addition, cough from the beginning of WST to 1 min after WST and a wet-hoarse voice after testing were recorded. Patients with abnormal swallowing speed (<10 ml/s), cough, or wet-hoarse voice were considered as having dysphagia in accordance with WST criteria. The reported sensitivity and specificity of the WST are up to 85.5% and 91.7%, respectively (using video fluoroscopic evaluation of swallowing as the reference standard), when evaluating the combined dysphagia symptoms of slow swallowing speed, cough, and wet-hoarse voice. If patients had been prescribed thickened liquids, we screened for dysphagia three times by first using 3 ml of water. In patients who experienced no problem with the first 3 ml of water, WST was then implemented. Patients who had cough or a wet-hoarse voice while consuming the 3 ml of water were considered to have dysphagia. Because it can be ethically problematic to perform video fluoroscopic examination of swallowing or fiberoptic endoscopic evaluation of swallowing, which are somewhat invasive, in patients without dysphagia symptoms,

we assessed dysphagia using WST with high sensitivity and specificity. If patients displayed choking symptoms, they were asked to stop drinking immediately and diagnosed with dysphagia.

2.3. Measurement of lip force and tongue strength

We measured lip force and tongue strength as index tests. Maximal isometric lip force and tongue strength were measured with patients in a relaxed sitting position. Measurements were taken by trained speech-language pathologists who were blinded to these participants' diagnosis of sarcopenic dysphagia within 1 week after hospitalization. Tongue strength was measured using an instrument (JMS, Hiroshima, Japan) with a balloon-type oral probe affixed to its end. This instrument measures the strength of the front part of a tongue by the tongue pushing the balloon. We instructed the participants, "We will place the balloon at the front part of your mouth. Then, close your lips with the probe placed stably between your upper and lower incisors, and push the balloon with your tongue as hard as you can." Lip force was measured using Lip de Cum (Cosmo Instruments Co., Ltd., Tokyo, Japan) [18]. This instrument records forces acting in the vertical direction using sensors inserted into the upper and lower plastic lip holder, and displays the maximum value combined with upper and lower lip force. We instructed participants, "We will place the lip holders on your upper and lower lips. Then, close your lips as hard as you can." Measurements were taken three times for 5 s, with a 30-second break between each measurement. Each of the highest three measurements were defined as individual lip force and tongue strength.

2.4. Other parameters

Cognitive function was assessed by trained rehabilitation therapists with the Mini–Mental State Examination, which is used for cognitive screening. Occlusion status at the molar region was assessed using the Eichner index [19] by trained dental hygienists. Occlusion status is a factor that can be related to swallowing function [20] and food texture, which is shown as oral intake level. This index is based on the number of occlusal support zones, and has three groups that consist of A (occlusal support for molars and premolars on both sides), B (reduced occlusal support), and C (no occlusal support). Inflammatory status was assessed with the C-reactive protein (CRP) concentration. Comorbidity was evaluated using the Charlson Comorbidity Index (CCI) with 19 comorbid conditions assigned a weight from 1 to 6 (Table 1) [21]. A higher CCI score indicated greater comorbidity. As the causal factors of sarcopenia, age, and low activity were assessed using Barthel Index [22] by physical therapists, while malnutrition was assessed using the Mini Nutritional Assessment Short-Form (MNA-SF) [23] by dietitians. Malnutrition is also related to dysphagia [24]. The oral intake level, which can be affected by dysphagia, was assessed by speech-language pathologists with the Functional Oral Intake Scale [25]. This scale ranges from level 1 (Nothing by mouth) to 7 (Total oral diet with no restrictions means). Level 5 or less indicates that special preparation or compensations are required. In a previous study, the Functional Oral Intake Scale (assessed by speech-language pathologists) was found to be associated with the presence of dysphagia, as identified with video fluoroscopic examination of swallowing [25].

Table 1
Charlson comorbidity index.

Assigned weight	Conditions
1	Myocardial infarct, Congestive heart failure, Peripheral vascular disease Cerebrovascular disease, Dementia, Chronic pulmonary disease, Connective tissue disease Ulcer disease, Mild liver disease, Diabetes
2	Hemiplegia, Moderate or severe renal disease, Diabetes with end organ damage Any tumor, Leukemia, Lymphoma
3	Moderate or severe liver disease
6	Metastatic solid tumor, AIDS

2.5. Statistical analysis

We performed sample size calculation on the basis of previous estimates of tongue strength as a continuous response and a mean effect size of 5 kPa (standard deviation: 5) between the sarcopenic dysphagia group and the normal/non-sarcopenic dysphagia group, with two normal/non-sarcopenic dysphagia patients per sarcopenic dysphagia patient. The minimum sample size was 77 sarcopenic dysphagia patients and 154 normal/non-sarcopenic dysphagia patients for two-sided tests, with a significance level of 5% and a statistical power of 90%. To compare differences between groups, unpaired t test and Mann–Whitney U test was used for parametric data and nonparametric data, respectively. The categorical variables were compared using chi-squared test. Correlation coefficients between lip force, tongue strength, and sarcopenia factors were assessed using Spearman's rank-correlation coefficients. In addition, multivariable logistic regression analysis was conducted using sarcopenic dysphagia as the dependent variable. For independent variables, we selected parameters that showed significant differences in univariate analyses and that could be confounding factors for sarcopenic dysphagia. To calculate the diagnostic accuracy of lip force and tongue strength for sarcopenic dysphagia, receiver operating characteristic (ROC) curve analysis was used. The cut-off values of lip force and tongue strength for identifying sarcopenic dysphagia were determined with Youden's index. Statistical analyses were performed using Stata version 13 (College Station, TX) for comparison of the area under the receiver operating characteristic curve (AUC) between lip force and tongue strength. SPSS version 24 (IBM, Japan, Tokyo, Japan) was used for other analyses. $p < 0.05$ was considered statistically significant. No data were missing; thus, all data were available for analyses.

3. Results

A total of 245 patients (79 men, 166 women) participated in the present study. Table 2 shows the study participants' characteristics. The sarcopenic dysphagia group comprised 86 patients (35.1%) and the normal/non-sarcopenic dysphagia group comprised 159 patients (151 without dysphagia, eight with non-sarcopenic dysphagia) (64.9%). Among the patients in the sarcopenic dysphagia group, 69 experienced choking and 17 had abnormal swallowing speed in the WST. The participants' median age (interquartile range, IQR) was 84 years (range 79–88 years). The primary reason for hospitalization was orthopedics, accounting for 57.1% of all primary injuries or diseases. The median duration (IQR) of acute hospital stay before admission to our hospital was 37 days (range 24–53.5 days). Significant differences in age ($p < 0.001$), Barthel Index ($p < 0.001$), and MNA-SF score ($p < 0.001$) were found between the sarcopenic dysphagia group and the normal/non-sarcopenic dysphagia group. The median Functional Oral Intake Scale level (IQR) was 5 (range 5–6) in the sarcopenic dysphagia group, which was significantly different ($p < 0.001$) to that of the normal/non-sarcopenic dysphagia group with a level of 7 (range 6–7). Table 3 shows the characteristics of participants in the sarcopenic dysphagia group and the normal/non-sarcopenic dysphagia group according to sex and the presence of sarcopenic

Table 2
Clinical characteristics of study participants.

	Total (n = 245)	Sarcopenic dysphagia (n = 86)	Normal/non-sarcopenic dysphagia (n = 159)	*p*-value
Age (years)	84 [79–88]	86.5 [83–90]	83 [77–87]	<0.001[a]
Men	79 (32.2)	35 (40.7)	44 (27.7)	0.037[b]
MMSE	26 [23–28]	23.5 [22–26.2]	27 [24–29]	<0.001[a]
Primary disease				0.019[b]
Orthopedics	140 (57.1)	41 (47.7)	99 (62.3)	
Cardiology	20 (8.2)	10 (11.6)	10 (6.3)	
Pneumonia	28 (11.4)	16 (18.6)	12 (7.5)	
Others	57 (23.3)	19 (22.1)	38 (23.9)	
CCI	1 [0–2]	1 [1–3]	1 [0–2]	<0.001[a]
CRP (mg/dl)	0.21 [0.09–0.74]	0.35 [0.11–1.00]	0.19 [0.09–0.55]	0.021[a]
MNA-SF	7 [6–9]	6 [4–7]	8 [7–9]	<0.001[a]
BMI (kg/m^2)	19.4 [17.2–22.3]	17.9 [15.9–20.1]	20.3 [17.9–23.2]	<0.001[c]
BI	65 [50–80]	60 [43.8–75]	75 [50–90]	<0.001[a]
EI: Group A	192 (78.4)	63 (73.3)	129 (81.1)	0.153[b]
Duration at acute hospital (days)	37 [24–53.5]	36 [22–51.5]	38 [24–54]	0.555[a]

Data are expressed as n (%) or median [interquartile range]. BI: Barthel Index, BMI: body mass index, CCI: Charlson Comorbidity Index.
CRP: C-reactive protein, EI: Eichner Index, MMSE: Mini-Mental State Examination, MNA-SF: Mini Nutritional Assessment Short-Form.
[a] Mann–Whitney U test.
[b] Chi-squared test.
[c] Unpaired t test.

Table 3
Clinical characteristics of the study participants according to sex and the presence of sarcopenic dysphagia.

	Sarcopenic dysphagia (n = 86)		Normal/non-sarcopenic dysphagia (n = 159)		*p*-value			
	Men (n = 35)	Women (n = 51)	Men (n = 44)	Women (n = 115)	a	b	c	d
FOIS	5 [5–5]	5 [5–6]	7 [6–7]	7 [6–7]	0.001	0.97	<0.001	<0.001
CC (cm)	27.9 [25–30]	27.0 [25.0–29.0]	31.3 [28.1–33.5]	30 [27.2–32.0]	0.192	0.051	<0.001	<0.001
Grip strength (kg)	15.1 [11.4–19.8]	11.7 [9.2–13.6]	22.3 [16.6–26.7]	15 [11.9–18.4]	<0.001	<0.001	<0.001	<0.001
Tongue strength (kPa)	21.6 [17–25.6]	22.5 [17.7–27.9]	29.1 [24.8–35.2]	28.9 [24.8–35.0]	0.372	0.707	<0.001	<0.001
Lip force (N)	7.1 [5.2–10.1]	6.3 [5.0–7.7]	12.5 [10.5–15.1]	9.7 [8.4–11.1]	0.050	<0.001	<0.001	<0.001

Data are expressed as median [interquartile range]. All analyses were performed with Mann–Whitney U test.
CC: calf circumference, FOIS: functional oral intake scale. a: comparison between men and women in the sarcopenic dysphagia group, b: comparison between men and women in the normal/non-sarcopenic dysphagia group, c: comparison between two groups in men, d: comparison between two groups in women.

dysphagia. Lip force and tongue strength were significantly different between the two groups in both men and women ($p < 0.001$ for all). Lip force was significantly different between men and women in the normal/non-sarcopenic dysphagia group ($p < 0.001$); lip force in the sarcopenic dysphagia group and tongue strength in both groups did not differ according to sex. The median number of times (IQR) required to obtain the maximal isometric strength was 1 (range 1–2) for lip force and 2 (range 1–2) for tongue strength from measurements taken three times. During measurements of lip force and tongue strength, no adverse events occurred.

Table 4 shows the correlation coefficients of lip force and tongue strength with sarcopenia factors in men and women. Lip force and tongue strength were significantly correlated with all sarcopenia factors in both men and women. Multivariable logistic regression analysis revealed that sarcopenic dysphagia was significantly associated with lip force (OR = 0.63, 95% CI 0.53–0.74, $p < 0.001$) and tongue strength (OR = 0.92, 95% CI 0.87–0.98, $p = 0.011$), after controlling for age, sex, CCI, CRP, MMSE, grip strength, and CC (Table 5).

Figure 1 shows ROC curve analysis of lip force and tongue strength for sarcopenic dysphagia. The AUC of lip force for sarcopenic dysphagia was 0.88 (CI 0.81–0.95, $p < 0.001$) among men and 0.84 (CI 0.77–0.90, $p < 0.001$) among women. The AUC of tongue strength for sarcopenic dysphagia was 0.79 (CI 0.69–0.89, $p < 0.001$) among men and 0.74 (CI 0.65–0.82, $p < 0.001$) among women. No significant difference was observed between the AUC for lip force and that for tongue strength in either men or women ($p = 0.16$ for men, $p = 0.06$ for women). For men, the cut-off value for sarcopenic dysphagia was 10.4 N for lip force (sensitivity 88.6%, specificity 77.3%, positive predictive value [PPV] 75.6%, negative predictive value [NPV] 89.5%) and 24.3 kPa for tongue strength (sensitivity 65.7%, specificity 79.5%, PPV 71.9%, NPV 74.5%). For women, the cut-off value for sarcopenic dysphagia was 8.5 N for lip force (sensitivity 86.3%, specificity 72.2%, PPV 57.9%, NPV 92.2%) and 23.9 kPa for tongue strength (sensitivity 58.8%, specificity 81.7%, PPV 58.8%, NPV 81.7%).

When both lip force and tongue strength were considered at the cut-off values for sarcopenic dysphagia, the sensitivity of the combined markers was 57.1%, specificity was 97.7%, PPV was 95.2%, and NPV was 74.1% for men. For women, sensitivity was 51.0%, specificity was 93.0%, PPV was 76.5%, and NPV was 81.1%. Figure 2 shows a flow diagram of the patients' results.

4. Discussion

The present study showed that when lip force or tongue strength increased, the likelihood of sarcopenic dysphagia decreased. In addition, each factor served as a useful index for diagnosing sarcopenic dysphagia. The present study is the first to demonstrate the association of both lip force and tongue strength with sarcopenic dysphagia and their diagnostic accuracy for sarcopenic dysphagia.

Lip force and tongue strength were lower in the sarcopenic dysphagia group than in the normal/non-sarcopenic dysphagia group. In addition, lip force and tongue strength were significantly correlated with sarcopenia factors. However, the correlations of lip force and tongue strength with grip strength, CC, and MNA-SF in

Table 4
Correlation coefficients between lip force and tongue strength and sarcopenia factors, according to sex.

		Grip strength	CC	Age	BI	MNA-SF
Lip force	Men	0.48**	0.36*	−0.45**	0.40**	0.49**
	Women	0.40**	0.31**	−0.17*	0.20*	0.42**
Tongue strength	Men	0.45**	0.45**	−0.26*	0.29*	0.47**
	Women	0.42**	0.42**	−0.16*	0.28**	0.34**

*$p < 0.05$, **$p < 0.001$. BI: Barthel Index, CC: calf circumference, MNA-SF: Mini Nutritional Assessment Short-Form.

Table 5
Multivariable logistic regression analysis for sarcopenic dysphagia.

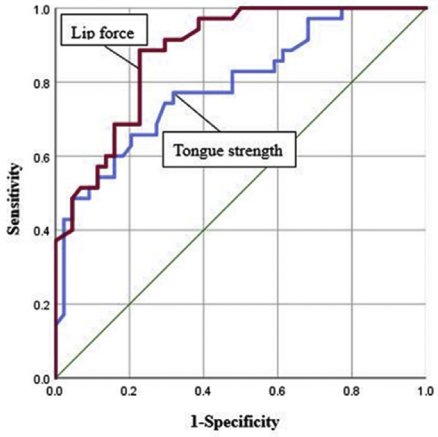
	Odds ratio	95% CI	*p*-value
Age	1.08	1.02 1.16	0.016
Men	6.94	2.42 19.89	<0.001
CCI	1.35	0.92 1.98	0.122
CRP	0.95	0.73 1.23	0.704
MMSE	0.98	0.86 1.13	0.823
Grip strength	0.92	0.83 1.02	0.102
CC	0.90	0.80 1.02	0.103
Lip force	0.63	0.53 0.74	<0.001
Tongue strength	0.92	0.87 0.98	0.011

CC: calf circumference, CCI: Charlson Comorbidity Index, CI: confidence interval. CRP: C-reactive protein, MMSE: Mini-Mental State Examination.

both sexes and the correlations of lip strength with age and Barthel Index in men were weak to moderate; other correlations were very weak. This result for lip force and tongue strength was consistent with previous findings that showed an association with grip strength or sarcopenia [7,8,11]. Thus, both lip force and tongue strength could be decreased as a result of sarcopenia.

Few studies have demonstrated the association between lip force and dysphagia. Lip force has been correlated with swallowing capacity in stroke patients [26], while lip force has not been found to be different between patients with and without facial palsy. Another study has shown improved swallowing capacity after lip muscle training in stroke patients [27]. Although stroke-related sarcopenia has been recently reported [28], the presence of sarcopenia in those studies' participants was not investigated. Thus, the relationship between lip force and sarcopenic dysphagia remain

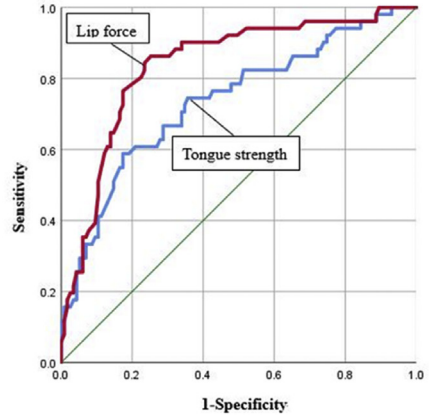
Men



	AUC	Standard Error	95% CI	*p*-value
Lip force	0. 88	0. 04	0. 81–0. 95	<0.001
Tongue strength	0. 79	0. 05	0. 69–0. 89	<0.001

AUC: area under the curve, CI: confidence interval.

Women



	AUC	Standard Error	95% CI	*p*-value
Lip force	0. 84	0. 03	0. 77–0. 90	<0.001
Tongue strength	0. 74	0. 04	0. 65–0. 82	<0.001

AUC: area under the curve, CI: confidence interval.

Fig. 1. Receiver operating characteristic curve analysis of lip force and tongue strength for sarcopenic dysphagia.

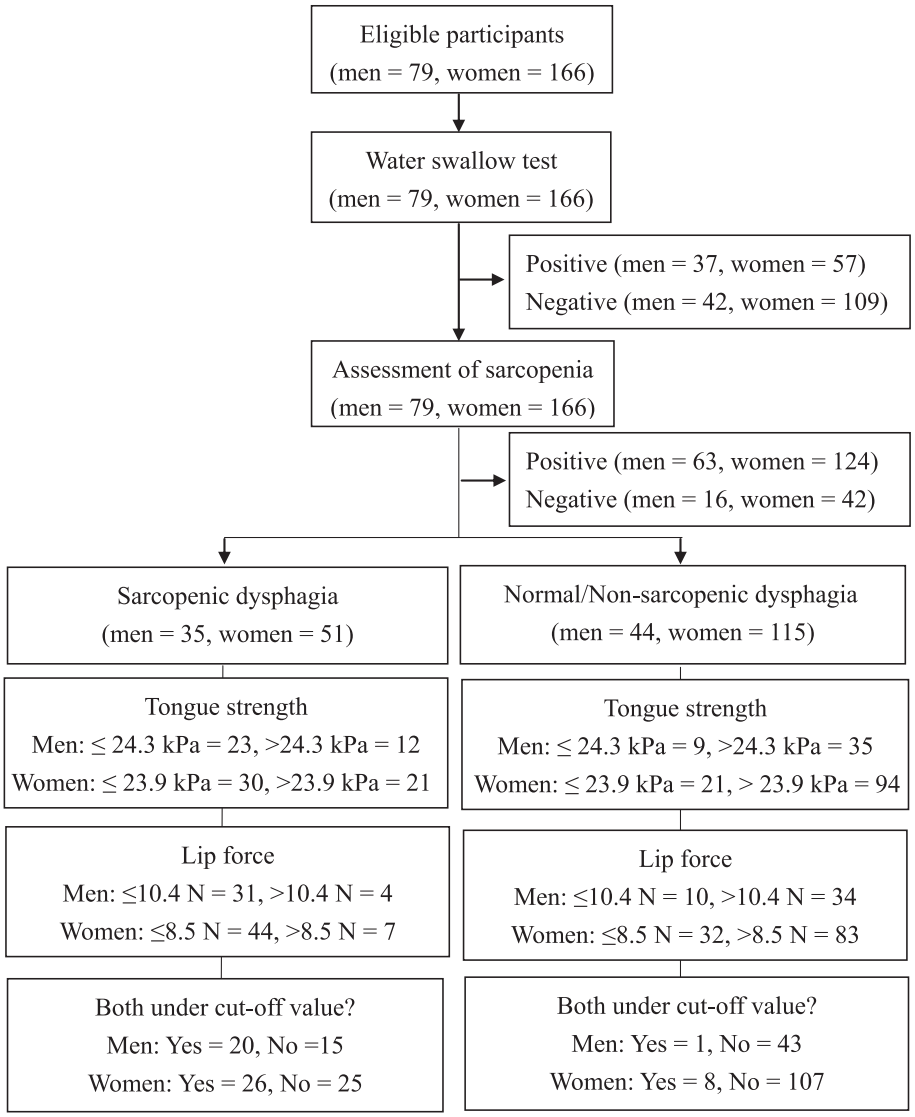


Fig. 2. Flow diagram of patients' results.

unclear. Furthermore, older people who choke on food have low lip pressure during ingestion [29]. The present study's result was consistent with those of previous studies that indicated a relationship between lip force and dysphagia. Moreover, the relationship between lip force and swallowing function can be explained anatomically. The lip muscle is a part of the buccinator mechanism that also includes the buccinator muscles and superior muscles of the pharyngeal constrictor [30]. Thus, lip force might represent pharyngeal strength involved in swallowing.

Lip force and tongue strength were independently associated with sarcopenic dysphagia, and the diagnostic accuracy for sarcopenic dysphagia was not significantly different between them. Tongue strength has been previously indicated to be a diagnostic factor for sarcopenic dysphagia [9]. However, the present study results indicated that lip force can be also a useful predictor for sarcopenic dysphagia. In addition, lip force may be easier to measure than tongue strength because the median number of times required to obtain maximal isometric strength tended to be less in lip-force measurement. The instruction for measuring lip force, “close your lips as hard as you can”, might be easier to imagine and understand than the instructions provided for measuring tongue strength in older participants. Thus, lip force might be a more efficient diagnostic index for sarcopenic dysphagia in older people. Some dysphagia studies have used WSTs to define dysphagia, and clinicians usually use them as screening tests for dysphagia. However, tests using water put people with dysphagia at risk of choking. Thus, measurements of lip force or tongue strength may be considered to be alternative indicators that present no choking risk. The cut-off value of tongue strength for sarcopenic dysphagia was 24.3 kPa for men and 23.9 kPa for women in the present study. Previously, <20 kPa for tongue strength was used as a diagnostic criterion for sarcopenic dysphagia [9]. This difference in tongue strength values may be caused by the method used to determine the cut-off value. The same study based the cut-off value of tongue strength on the mean value in patients with and without dysphagia. From the AUC of lip force and that of tongue strength, each index can be independently useful for diagnosing sarcopenic dysphagia. However, if patients had values that were lower than the cut-off values both for lip force and tongue strength, certainly that for sarcopenic dysphagia would be higher. The cut-off values used in the present study may work as criteria values for diagnosing sarcopenic dysphagia, as

would the target value in lip and tongue exercises used in dysphagia rehabilitation.

Several important limitations should be noted regarding the current study. First, the muscle mass used as a diagnostic index for sarcopenia was CC, not Dual-energy X-ray absorptiometry, computed tomography, magnetic resonance imaging, or bio-impedance analysis, which were recommended by the European Working Group on Sarcopenia in Older People [1]. Although CC has been validated for measuring skeletal muscle mass in the diagnosis of sarcopenia, inaccuracies may occur. Moreover, dysphagia was assessed with the WST as a screening test for dysphagia, not with video fluoroscopic examination of swallowing or fiberoptic endoscopic evaluation of swallowing. This may have also affected the accuracy of dysphagia diagnosis. Furthermore, we did not investigate medications that can affect swallowing function. This might have resulted in bias for sarcopenic dysphagia in the present study.

5. Conclusions

Increased lip force or tongue strength was associated with a decreased likelihood of sarcopenic dysphagia. Furthermore, both lip force and tongue strength were useful factors for diagnosing sarcopenic dysphagia. In older inpatients suspected as experiencing dysfunction due to sarcopenia, both lip force and tongue strength can serve as independently useful indices for diagnosing sarcopenic dysphagia, and may be factors that could prevent and improve sarcopenic dysphagia in older inpatients.

Conflict of interest

None declared.

Funding sources

This work was supported by the Japan Society for the Promotion of Science KAKENHI (grant number 16K19262) and the Sato Fund, Nihon University School of Dentistry.

Statement of authorship

KS: conception and design of the study, acquisition of data, analysis and interpretation of data, and drafting of the article.

OT: conception of the study, analysis and interpretation of data.

TT, YT: conception and design of the study, acquisition of data.

EN, HT: conception and design of the study, interpretation of data, preparation of manuscript.

SO, HT, MH, KU: conception and design of the study, interpretation of data.

Acknowledgement

We thank Edanz Group (www.edanzediting.com/ac) for editing a draft of this manuscript.

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