

# Performance of Japanese community-dwelling older adults in the 100-mL water swallowing test

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**Background:** Although the 100-mL water swallowing test (WST) is used to measure swallowing capacity (SC), volume per swallow (VS), time per swallow (TS), and the presence/absence of choking signs, the performance of each indicator is not clearly understood. The purpose of this study was to identify the relationship between performance in each indicator in the 100-mL WST and risk factors for dysphagia in community-dwelling older adults.

**Methods:** Participants included 304 Japanese community-dwelling older adults aged  $\geq 65$  years. We investigated participant characteristics including age, sex, body mass index (BMI), medical history, number of prescribed medications, laryngeal function (maximum phonation time [MPT]), subjective dysphagia (the 10-item eating assessment tool [EAT-10]), and all indicators of the 100-mL WST. We compared each of the four indicators in the 100-mL WST and investigated their relationship with potential risk factors for dysphagia.

**Results:** Multivariate analyses showed that age, BMI, MPT, and EAT-10 were independently associated with SC. Age, sex, BMI, and EAT-10 were independently associated with VS. BMI, MPT, and EAT-10 were independently associated with TS. Men were more likely to have choking signs in the 100-mL WST than women.

**Conclusions:** These findings indicated that all of three quantitative indicators in the 100-mL WST may predict the risk of sarcopenic dysphagia. Moreover, the presence of choking signs in men suggested the risk of aspiration. We propose that SC and choking signs in the 100-mL WST could be a simple and useful dysphagia assessment tool for community-dwelling older people.

ACTA MEDICA NAGASAKIENSIA 63: 1–10, 2019

**Key words:** 100-mL water swallowing test, dysphagia, community-dwelling elderly

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## Introduction

Swallowing function is considered to be an important determinant of oral function since dysphagia contributes to aspiration pneumonia among older adults.<sup>1,2</sup> According to a 2015 statistical report from the Japanese Ministry of Health, Labour and Welfare, pneumonia is the third leading cause of all-cause mortality. In addition, aspiration is considered a leading cause of pneumonia, which affects approximately 85% of elderly people aged  $\geq 65$  years.<sup>2</sup>

Videofluoroscopic (VF) examination of swallowing has been widely recommended as the gold standard for identifying dysphagia. However, VF examination is not useful for community-dwelling older people because it involves radiation exposure and is costly and time consuming.<sup>3</sup> Previous studies revealed that the water swallowing test (WST) is useful as a screening tool for the early detection of dysphagia among older adults in the clinical setting.<sup>4</sup> In Japan, either amounts of water, 3 or 30 mL, are used in the WST as part of a bedside dysphagia screening test,<sup>4</sup> whereas from 90 to 150 mL

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Received January 21, 2019; Accepted May 7, 2019

amounts are used to detect dysphagia in most other countries.<sup>3,5</sup> Relatively higher amounts have been recommended for use in the WST to identify people with dysphagia who are capable of eating and drinking orally. The merits of using relatively high amounts of water are that observation findings for continuous drinking can be obtained, and the results for swallowing at slow speed are highly sensitive for detecting dysphagia.<sup>4</sup> Wu et al.<sup>3</sup> revealed that the 100-mL WST was a sensitive screening test for older adult outpatients with stroke suspected of having dysphagia. The 100-mL WST has the benefit of being a multidimensional assessment for dysphagia screening. The four components of the 100-mL WST are swallowing capacity (SC),<sup>3</sup> volume per swallow (VS),<sup>6</sup> time per swallow (TS),<sup>6,7</sup> and choking signs.<sup>3</sup>

Aspiration is defined as the entry of a bolus below the level of the true vocal fold, while laryngeal penetration is defined as the bolus entering the laryngeal inlet but remaining above the level of the vocal folds, which can result in coughing, throat clearing, or wet voice quality.<sup>7,8</sup> In the 100-mL WST, reduced swallowing speed is considered to be a compensatory or defensive reaction against swallowing dysfunction, which is reflected as aspiration or laryngeal penetration in VF examination.<sup>3</sup> Moreover, the presence of choking signs including choking-free cases (i.e., wet voice quality) could screen, with high sensitivity and specificity, not only aspiration but also silent aspiration, which is reflected only as aspiration in VF examination.<sup>3</sup> The sensitivity and specificity of SC are 85.5% and 50%, respectively, while the sensitivity and specificity of choking signs are 47.8% and 91.7%, respectively.<sup>3</sup> However, to the best of our knowledge, the screening sensitivity and specificity of all four indicators in 100-mL WST, compared to VF examination and other common criteria, has not been determined. Because each of the four indicators has its own properties, it is important to assess them in combination.

Previous studies investigating the risk factors for dysphagia among older populations have shown that malnutrition, cerebrovascular disease, chronic obstructive pulmonary disease (COPD), decline in laryngeal function, and polypharmacy were dominantly considerable.<sup>9-13</sup> The 100-mL WST has been recommended for suspected dysphagia in subjects who are capable of eating and drinking orally.<sup>3</sup> However, to our knowledge, the 100-mL WST has not been used in investigations focusing on community-dwelling older people. Hence, the precise characteristics of community-dwelling older individuals with swallowing disorder detected by the 100-mL WST are unknown. Furthermore, the relationship between the each of the four indicators in the 100-mL WST and relating factors for dysphagia is also unclear.

Further investigation of the methods of screening tests for swallowing disorder in community-dwelling older adults is important because oral frailty is considered reversible when detected in the early stage.<sup>14</sup> In addition, many Japanese older adults perceive a decline in swallowing function and hope to receive swallowing rehabilitation or preventive care for oral frailty within their community.<sup>14</sup> The purpose of this study was therefore to identify the relationship between multidimensional performance on the 100-mL WST and relating factors for dysphagia in community-dwelling older adults.

## Materials and Methods

### *Setting and Participants*

This study had a cross-sectional design. The ethics committee of Sasebo-Chuo Hospital approved the study protocol, and the study was conducted from July 10, 2017 to November 30, 2017 in a suburban area in Sasebo City and Hirado City, Nagasaki Prefecture, Japan. Informed consent was obtained from all individuals included in this study.

The study participants were recruited from individuals with long-term care insurance utilizing daycare services at five facilities and participating in voluntary circle activities for care prevention at 11 public halls. The inclusion criteria were age  $\geq 65$  years and living at home, The exclusion criteria were having a psychiatric disorder, severe dementia, and receiving treatment for severe disease (e.g., cancer).

### *Measurements*

First, a dentist or a public health nurse visited the study participants at the public hall or daycare center and conducted face-to-face interviews on basic attributes. The data collected in the interviews included age, sex, height, weight, number of prescribed medications, and medical history (cerebrovascular disease, COPD, and history of pneumonia within the last year).

Second, a self-reported dysphagia questionnaire was conducted using the 10-item Eating Assessment Tool (EAT-10). After completing the interview and questionnaire survey, the 100-mL WST and the maximum phonation time (MPT) test were conducted. The 100-mL WST was conducted by a dentist or a public health nurse with the help of a speech therapist or social worker. When tests were performed at daycare centers, the dentist was assisted by a social worker, and when tests were performed at public halls, the public health nurse was assisted by a speech therapist or social worker. The public health nurse, speech therapist, and social worker were adequately trained by an experienced dentist before the study.

### *The EAT-10*

The EAT-10 was used as an indicator of self-reported dysphagia.<sup>15</sup> The EAT-10 is composed of 10 questions with responses given on a five-point Likert (0-4 score) scale. The score ranges from 0 to 40, with higher scores indicating severe dysphagia symptoms. The reliability and validity of the EAT-10 were demonstrated by Belafsky et al.<sup>15</sup> We used the Japanese version of the EAT-10 which was translated by Wakabayashi et al.<sup>16</sup>, who also demonstrated its reliability and validity.

### *100-mL WST*

The 100-mL WST was performed to assess swallowing function. The four indicators in the 100-mL WST are SC, VS, TS and choking signs. Participants were asked to drink 100 mL of water as quickly as comfortably possible in a seated position with the lip on the glass.<sup>3</sup> The swallowing time was measured from the “go” signal until the participant finished drinking the water using a stopwatch. For those who successfully finished the glass of water, the end of the swallowing test was defined as the completion of the last swallow, indicated visually by the return of the thyroid cartilage to its resting position. The number of swallows was counted acoustically using a microphone (Nanzu Electric Co. Ltd.; Shizuoka, Japan) during the test. Choking signs (i.e., coughing or a wet, hoarse voice) within 1 minute of the test were recorded. Participants who showed signs of choking in the middle of drinking finished the test immediately regardless of whether they had completed all of the water or not. In such cases, the amount of water drunk was determined by subtracting the volume of residual water from 100 mL. This test was performed only once, and confirmation of the wet voice quality was confirmed by speaking after testing. SC [mL/sec], defined as the amount of water drunk divided by the swallowing time, was calculated. VS [mL/n] was defined as amount of water drunk in one swallow, calculated by the total amount of water drunk divided by the total number of swallows. TS [sec/n] was defined as the time for one swallow, calculated by the total swallowing time divided by total number of swallows. In the 100-mL WST, the faster the SC, the greater the VS and the shorter the TS, the higher the swallowing performance.

In the present study, SC, VS, and TS measurements were defined as quantitative indicators of swallowing performance, while choking signs was a qualitative indicator of swallowing performance.

### *MPT*

The MPT was used to measure laryngeal function. Participants were instructed to sustain the vowel /a/ as long as possible, at their normal speaking volume while sitting upright.<sup>17</sup> The trial was conducted three times, with a rest of at least 15 seconds and allowing for maximal inhalation. The duration of the MPT was measured using a stopwatch and the mean time of the three trials was calculated. The longer the MPT, the higher the laryngeal function.

### *Statistical analysis*

Age, BMI, MPT, and the three quantitative indicators (SC, VS, and TS) of the 100-mL WST are expressed as mean values with standard deviation (SD). EAT-10 score is expressed as median with interquartile range (IQR). We calculated the number and percentage of participant characteristics (sex, medical history, and number of prescribed medications). We also calculated the number and percentage for the qualitative indicator choking signs in the 100-mL WST.

Pearson's correlation analysis was performed by calculating the correlation coefficient to examine the relationship between the three quantitative indicators (SC, VS, and TS) in the 100-mL WST and participant characteristics (age and BMI) or dysphagia related measurements (MPT and EAT-10). Spearman's correlation analysis was also performed by calculating the correlation coefficient to examine the relationship between the three quantitative indicators (SC, VS, and TS) in the 100-mL WST and number of prescribed medications. The t-test was used to examine the difference in participant characteristics (sex and medical history). Furthermore, multiple linear regression analysis was used to determine which variables were independently associated with each of the three quantitative indicators. Dependent variables were accordingly, SC, VS, and TS. Covariates selected in the model were age, sex, BMI, history of cerebrovascular disease, COPD, history of pneumonia within the past year, number of prescribed medications, MPT and EAT-10.

To examine the relationship between choking signs in the 100-mL WST and participant characteristics (sex and medical history) the chi-square test was used. The t-test was also used to examine the differences in participant characteristics (age and BMI) and dysphagia related measurements (MPT). The Cochran-Armitage test was used to examine the associations between choking signs and number of prescribed medications. The Mann-Whitney U-test was used to examine the difference in the EAT-10 score according to the presence/absence of choking signs. Furthermore, multiple logistic

regression analysis was used to determine which variables were independently associated with choking signs in the 100-mL WST. Independent variables selected for the model were age, sex, BMI, history of cerebrovascular disease, COPD, history of pneumonia within the past year, number of prescribed medications, MPT, and EAT-10.

All statistical analyses were conducted using SPSS software (version 23.0 for Windows; IBM, Tokyo, Japan).

## Results

### *Participant characteristics*

Three-hundred and twenty-three community-dwelling older adults met the inclusion criteria; however, six participants did not consent to participate in the study and 13 participants returned incomplete questionnaire responses leaving 304 participants (65 men, 239 women) for the final analyses.

The mean age (SD) of the study participants was 79.9 (7.2) years old. Cerebrovascular disease, COPD and history of pneumonia within the past year were observed in 40 (13.2%), 26 (8.6%) and 17 (5.6%) participants, respectively (Table 1).

### *Swallowing performance and dysphagia questionnaire*

Table 2 summarizes the results of the three quantitative indicators of swallowing performance in the 100-mL WST and the dysphagia questionnaire. The mean (SD) values for SC, VS and TS were 12.0 (6.3) [mL/sec], 23.5 (9.5) [mL/n], and 2.3 (1.2) [sec/n], respectively. The median (IQR) of EAT-10 score was 0 (0, 3).

### *Quantitative indicators of swallowing performance in the 100-mL WST*

Table 3 and Table 4 show the results of the relationship between each of the three quantitative indicators and basic characteristics, risk factors for dysphagia. SC in the 100-mL WST was negatively correlated with age ( $r=-0.41$ ,  $p<0.001$ ), number of prescribed medications ( $r=-0.13$ ,  $p=0.022$ ), and EAT-10 ( $r=-0.38$ ,  $p<0.001$ ), and positively correlated with BMI ( $r=0.30$ ,  $p<0.001$ ) and MPT ( $r=0.37$ ,  $p<0.001$ ). Participants with cerebrovascular disease had significantly slower SC than those without cerebrovascular disease (10.0 [mL/sec] vs. 12.3 [mL/sec],  $p=0.03$ ). Participants with a history

of pneumonia within the past year also had significantly slower SC than those without a history of pneumonia within the past year (7.9 [mL/sec] vs. 12.3 [mL/sec],  $p=0.005$ ).

VS in the 100-mL WST was negatively correlated with age ( $r=-0.3$ ,  $p<0.001$ ), number of prescribed medications ( $r=-0.16$ ,  $p=0.006$ ), and EAT-10 ( $r=-0.28$ ,  $p<0.001$ ), and positively correlated with BMI ( $r=0.25$ ,  $p<0.001$ ) and MPT ( $r=0.17$ ,  $p=0.003$ ). Participants with a history of pneumonia within the past year had significantly lower VS than those without a history of pneumonia within the past year (17.9 [mL/n] vs. 23.8 [mL/n],  $p=0.013$ ).

TS in the 100-mL WST was positively correlated with age ( $r=0.23$ ,  $p<0.001$ ) and EAT-10 ( $r=0.33$ ,  $p<0.001$ ), and negatively correlated with BMI ( $r=-0.22$ ,  $p<0.001$ ) and MPT ( $r=-0.37$ ,  $p<0.001$ ). None of the medical history variables had a significant relationship with TS. On the other hand, men had significantly longer TS compared to women (2.7 [sec/n] vs. 2.2 [sec/n],  $p=0.028$ ).

Table 5 shows the results of the multiple linear regression analysis for each of the three quantitative indicators after adjusting for potential risk factors of dysphagia. The multivariate analyses showed that age (regression coefficient ( $b$ )  $=-0.216$ ,  $p<0.001$ ), BMI ( $b=0.357$ ,  $p<0.001$ ), MPT ( $b=0.276$ ,  $p<0.001$ ), and EAT-10 ( $b=-0.465$ ,  $p<0.001$ ) were independently associated with SC. BMI and EAT-10 were independently associated with all three quantitative indicators. Men had an independent association with VS only ( $b=3.491$ ,  $p=0.006$ ).

### *Qualitative swallowing performance in the 100-mL WST*

Of the 304 study participants, 35 (11.5%) participants showed choking signs in the 100-mL WST. Table 6 shows the results of the relationship between choking signs and basic characteristics and risk factors for dysphagia. The chi-square test showed that men (21.5%) had a significantly higher rate of choking signs compared to women (8.8%) ( $p=0.004$ ). The t-test showed that participants with choking signs were significantly older than those without choking signs (83.3 years vs. 79.5 years,  $p=0.003$ ). Also, participants with choking signs had a significantly lower BMI than those without choking signs (21.1 kg/m<sup>2</sup> vs. 22.7 kg/m<sup>2</sup>,  $p=0.008$ ). After adjusting for potential risk factors, multiple logistic regression analysis also revealed that men were more likely to have choking signs than women (odds ratio [OR], 2.75; 95% confidence interval [CI], 1.21-6.26), and that choking signs were associated with EAT-10 (OR, 1.10; 95%CI, 1.01-1.21) (Table 7).

**Table 1.** Characteristics of the study participants

Characteristics	n (%)	Mean (SD)
Sex		
Men	65 (21.4)	
Women	239 (78.6)	
Age (years)		79.9 (7.2)
BMI (kg/m <sup>2</sup> )		22.5 (3.4)
Medical history		
Cerebrovascular disease	40 (13.2)	
COPD	26 (8.6)	
History of pneumonia within the past year	17 (5.6)	
Number of prescribed medications		
0	51 (16.8)	
1-2	72 (23.7)	
3-4	74 (24.3)	
≥ 5	107 (35.2)	

SD: standard deviation, BMI: body mass index, COPD: chronic obstructive pulmonary disease.

**Table 2.** Results of the 100-mL WST and the dysphagia questionnaire

Examination	Mean (SD)	Median (1st quartile, 3rd quartile)
100-mL WST		
Swallowing time (sec)	12.0 (9.4)	
Number of swallows (n)	5.0 (2.0)	
SC (mL/sec)	12.0 (6.3)	
VS (mL/n)	23.5 (9.5)	
TS (sec/n)	2.3 (1.2)	
Choking signs (n, %)	35 (11.5)	
MPT (sec)	12.7 (5.4)	
EAT-10 score		0 (0, 3)

WST: water swallowing test, SD: standard deviation, SC: swallowing capacity, VS: volume per swallow, TS: time per swallow, MPT: maximum phonation time, EAT-10: 10-item Eating Assessment Tool.

**Table 3.** Relationship between the three quantitative indicators in the 100-mL WST and risk factors for dysphagia

Characteristics	SC		VS		TS	
	r <sup>c)</sup>	p	r <sup>c)</sup>	p	r <sup>c)</sup>	p
Age <sup>a)</sup>	-0.41	p<0.001	-0.30	p<0.001	0.23	p<0.001
BMI <sup>a)</sup>	0.30	p<0.001	0.25	p<0.001	-0.22	p<0.001
Number of prescribed medications <sup>b)</sup>						
0	-0.13	0.022	-0.16	0.006	0.02	0.728
1-2						
3-4						
≥ 5						
MPT <sup>a)</sup>	0.37	p<0.001	0.17	0.003	-0.37	p<0.001
EAT-10 <sup>a)</sup>	-0.38	p<0.001	-0.28	p<0.001	0.33	p<0.001

<sup>a)</sup> Pearson's correlation coefficient

<sup>b)</sup> Spearman's correlation coefficient

<sup>c)</sup> r=correlation coefficient

WST: water swallowing test, SC: swallowing capacity, VS: volume per swallow, TS: time per swallow, MPT: maximum phonation time, EAT-10: 10-item Eating Assessment Tool.

**Table 4.** Relationships between the three quantitative indicators in the 100-mL WST and sex and medical history based on the t-test

Characteristics	SC		VS		TS	
	Mean (SD)	p	Mean (SD)	p	Mean (SD)	p
Sex <sup>a)</sup>						
Men	11.2 (6.2)	0.263	24.6 (9.9)	0.257	2.7 (1.6)	0.028
Women	12.2 (6.4)		23.1 (9.3)		2.2 (1.1)	
Medical history <sup>a)</sup>						
Cerebrovascular disease						
Presence	10.0 (7.1)	0.03	21.3 (9.9)	0.120	2.8 (1.7)	0.063
Absence	12.3 (6.2)		23.8 (9.4)		2.3 (1.1)	
COPD <sup>c</sup>						
Presence	11.3 (5.7)	0.537	23.6 (12.0)	0.917	2.4 (1.1)	0.915
Absence	12.1 (6.4)		23.4 (9.2)		2.3 (1.2)	
History of pneumonia within the past year						
Presence	7.9 (5.4)	0.005	17.9 (6.1)	0.013	2.8 (1.3)	0.141
Absence	12.3 (6.3)		23.8 (9.5)		2.3 (1.2)	

<sup>a)</sup> t-test

SC: swallowing capacity, VS: volume per swallow, TS: time per swallow, SD: standard deviation, COPD: chronic obstructive pulmonary disease.

**Table 5.** Independent predictors of the three quantitative indicators in the 100-mL WST among Japanese elderly persons aged  $\geq 65$  years

Variable	SC			VS			TS		
	b <sup>a)</sup>	SE	p	b <sup>a)</sup>	SE	p	b <sup>a)</sup>	SE	p
Age	-0.216	0.047	p<0.001	-0.232	0.077	0.003	0.013	0.01	0.188
Sex (Women=0, Men=1)	0.601	0.76	0.43	3.491	1.259	0.006	0.216	0.157	0.169
BMI	0.357	0.094	p<0.001	0.473	0.155	0.003	-0.059	0.019	0.003
Cerebrovascular disease (Absence=0, Presence=1)	0.009	0.973	0.993	0.096	1.611	0.952	0.214	0.201	0.286
COPD (Absence=0, Presence=1)	-0.651	1.121	0.562	1.039	1.857	0.576	0.013	0.231	0.806
History of pneumonia within the past year (Absence=0, Presence=1)	0.468	1.488	0.753	-1.641	2.464	0.506	-0.101	0.307	0.082
Number of prescribed medications	-0.014	0.293	0.962	-0.644	0.486	0.186	-0.097	0.061	0.076
MPT	0.276	0.06	p<0.001	0.112	0.099	0.26	-0.289	0.012	p<0.001
EAT-10	-0.465	0.092	p<0.001	-0.584	0.152	p<0.001	0.26	0.019	p<0.001

<sup>a)</sup> b=regression coefficient

WST: water swallowing test, SC: swallowing capacity, VS: volume per swallow, TS: time per swallow, SE: standard error, BMI: body mass index, COPD: chronic obstructive pulmonary disease, MPT: maximum phonation time, EAT-10: 10-item Eating Assessment Tool.

**Table 6.** Relationship between the qualitative indicator in the 100-mL WST and risk factors for dysphagia

Characteristics	Choking signs		p
	Presence	Absence	
Sex <sup>a)</sup>			
Men	14 (21.5%)	51 (78.5%)	0.004
Women	21 (8.8%)	218 (91.2%)	
Age <sup>b)</sup>	83.3 (6.7)	79.5 (7.2)	0.003
BMI <sup>b)</sup>	21.1 (3.2)	22.7 (3.4)	0.008
Medical history <sup>a)</sup>			
Cerebrovascular disease			
Presence	6 (15.0%)	34 (85.0%)	0.458
Absence	29 (11.0%)	235 (89.0%)	
COPD			
Presence	3 (11.5%)	23 (88.5%)	0.997
Absence	32 (11.5%)	246 (88.5%)	
History of pneumonia within the past year			
Presence	3 (17.6%)	14 (82.4%)	0.415
Absence	32 (11.1%)	255 (88.9%)	
Number of prescribed medications <sup>c)</sup>			
0	4 (7.8%)	47 (92.2%)	0.907
1-2	13 (18.1%)	59 (81.9%)	
3-4	4 (5.4%)	70 (94.6%)	
≥ 5	14 (13.1%)	93 (86.9%)	
MPT <sup>b)</sup>	11.1 (5.0)	13.0 (5.4)	0.054
EAT-10 score <sup>d)</sup>	4.1 (5.6)	1.8 (3.3)	0.004

<sup>a)</sup> Chi-square test

<sup>b)</sup> t-test

<sup>c)</sup> Cochran Armitage-test

<sup>d)</sup> Mann-Whitney U-test

WST: water swallowing test, BMI: body mass index, COPD: chronic obstructive pulmonary disease, MPT: maximum phonation time, EAT-10: 10-item Eating Assessment Tool.

**Table 7.** Independent predictors of choking signs in the 100-mL WST among Japanese elderly persons aged ≥ 65 years

Variable	Comparison	OR	95% CI	p
Age		1.06	1.00-1.13	0.052
Sex	Women=0, Men=1	2.75	1.21-6.26	0.016
BMI		0.89	0.78-1.01	0.064
Cerebrovascular disease	Absence=0, Presence=1	0.99	0.30-3.31	0.989
COPD	Absence=0, Presence=1	1.60	0.41-6.29	0.499
History of pneumonia within the past year	Absence=0, Presence=1	0.49	0.09-2.55	0.394
Number of prescribed medications		0.84	0.58-1.22	0.358
MPT		0.98	0.90-1.06	0.524
EAT-10		1.10	1.01-1.21	0.035

WST: water swallowing test, OR: odds ratio, 95% CI: 95% confidence interval, BMI, body mass index, COPD: chronic obstructive pulmonary disease, MPT: maximum phonation time, EAT-10: 10-item Eating Assessment Tool.

## Discussion

Swallowing difficulty is an important issue for the older population. Here, we investigated the utility of dysphagia screening using the 100-mL WST. The 100-mL WST has the advantage of evaluating swallowing performance both quantitatively (SC, VS, and TS) and qualitatively (signs of choking). We aimed to explore the associations between each indicator in the 100-mL WST and potential risk factors for dysphagia. Our results of both single and multivariate analysis revealed that all four indicators in the 100-mL WST were commonly associated with EAT-10 score. The EAT-10 is a validated dysphagia questionnaire that has high reliability.<sup>16</sup> This suggests the utility of the 100-mL WST as a multidimensional dysphagia screening tool among community-dwelling older people.

Furthermore, the characteristics of each indicator in the 100-mL WST were demonstrated in this study. Slower SC (i.e., slower swallowing speed) and longer TS (i.e., longer time taken for one swallow) were independently related to low BMI and poor MPT, and this was confirmed by multivariate analysis. Sarcopenic dysphagia is highlighted as a cause of oral frailty and is considered to result from extreme muscle mass reduction in the muscles related to swallowing (e.g., suprahyoid muscles and infrahyoid muscles).<sup>18,19</sup> Sarcopenia is not only an abnormal decrease in muscle mass and muscular strength but is also accompanied by malnutrition.<sup>20</sup> Low BMI and MPT indicate poor nutritional status and weak laryngeal performance, respectively.<sup>17,21</sup> Notably, it was reported that participants with swallowing difficulty had a higher prevalence of weak cough reflex and dysphonia.<sup>22</sup> In addition, the direct cause of sarcopenic dysphagia is not considered to be associated with cerebrovascular disease or drugs.<sup>19</sup> In the present study, multivariate analysis showed that none of the four indicators in the 100-mL WST, including SC and TS, were associated with cerebrovascular disease or polypharmacy, a finding congruent with the previous study by Mori et al.<sup>19</sup> It is thought that if tongue strength declines, VS would decrease.<sup>7</sup> However, in our multivariate analysis, VS was associated with BMI, but not with MPT. We suspect that older adults with dysphagia would prolong the time taken for one swallow rather than reduce the bolus volume as a strategy to compensate for swallowing difficulty. Alternatively, slower SC in the 100-mL WST could comprehensively represent a mechanism of compensating for or adapting to dysphagia.

Considering the need for early detection and intervention, development of a sensitive dysphagia assessment tool for presbyphagia, which indicates declining swallowing perfor-

mance with age and is considered the pre-stage of sarcopenic dysphagia, is required. Although, all three quantitative indicators can be predictors of sarcopenic dysphagia in our results, we propose measuring SC only. Because SC in the 100-mL WST is only a timed test, it has the merit of being simple. The 100-mL WST involves a relatively high number of sequential swallows, which is demanding due to the fine coordination of breathing and swallowing.<sup>7</sup> Participants with a swallowing disorder would drink the 100 mL of water taking care not to aspirate. Consequently, slower swallowing speed is considered to be a compensatory or adaptive mechanism to prevent aspiration.<sup>3,7</sup> If the SC in 100-mL WST is positive (i.e., SC; >10 [mL/sec]),<sup>3</sup> it may be a dysphagia that requires medical treatment, so it is necessary to refer to home doctor or specialist (dentist or speech therapist). In addition, even though in the case of medical treatment is not necessary in hospital, positive subjects in the 100-mL WST had better initiate or continue swallowing rehabilitation in the community.

We revealed that men are more likely to have choking signs compared to women based on the qualitative assessment of choking signs in the 100-mL WST. Moreover, our multivariate analysis results also showed that men have a higher VS value compared to women, whereas SC and TS showed no sex differences in the quantitative measurements. These findings suggest that aspiration or penetration is induced easily in men and they may not swallow as carefully women. In fact, according to a Spanish retrospective cohort study from 2003 to 2013,<sup>11</sup> and a 2009 statistical report from the Japanese Ministry of Health, Labour and Welfare,<sup>23</sup> in older populations, men showed higher morbidity and mortality for aspiration pneumonia compared to women. In the present study, the prevalence of pneumonia within the past year was significantly higher in men compared to women (13.3% vs. 3.3%,  $p=0.001$ ) (data not shown). These results indicate that among older populations, men are more sensitive to aspiration pneumonia than women. However, a previous study reported that women have more complaints about dysphagia symptoms compared to men based on a questionnaire survey.<sup>24</sup> It is possible that conflicting results might exist due to sex differences in self-reported assessments and performance-based evaluations of swallowing function.<sup>25</sup> The main advantage of assessing choking signs with the 100-mL WST is the utility of monitoring the progression of aspiration.<sup>3</sup> We therefore propose that in the case of men with choking signs, the risk of aspiration pneumonia should be taken into consideration.

This study had several limitations. First, because of the nature of the cross-sectional study design, causal relationships could not be determined. Second, our results might include selection bias because we did not use random sampling.

Accordingly, our results should be interpreted with caution and cannot be completely generalized to other older adult populations. A prospective study is needed to identify further associations between performance in the 100-mL WST and relating factors for dysphagia in community-dwelling older people. Third, we measured MPT and BMI as risk factors for sarcopenic dysphagia; however, a definition of sarcopenic dysphagia has not yet been established. Further study is needed to investigate the associations between swallowing performance in the 100-mL WST and sarcopenia related markers such as hand grip strength, skeletal muscle mass index, and nutritional status, or tongue strength. Finally, we did not identify cut-off points for each indicator of the 100-mL WST in this study. Although Wu et al.<sup>3</sup> defined >10 [mL/sec] in the 100-mL WST as SC positive for stroke patients, the characteristics of our study participants differed from that previous study. Further study is required to identify the cut-off points for each indicator in the 100-mL WST by comparing VF examination for dysphagia as the gold standard.

Although early detection of oral frailty is gaining importance in Japan, dysphagia screening methods have not been established in the community. The strength of this study is that it is the first attempt at using the 100-mL WST as a dysphagia assessment tool in Japanese community-dwelling older populations. In the present study, we recruited 323 older adults aged  $\geq 65$  years, and 317 individuals agreed to participate (only six individuals refused). An excellent response rate (about 98%) for undergoing the 100-mL WST was shown among community-dwelling older adults. In addition, no participant had an adverse event on the 100-mL WST, indicating the test is safe and feasible. The novelty and importance of this study lie in its identifying which of the 100-mL WST indicators should be adopted in dysphagia screening. Specifically, low SC was the remarkable factor for predicting sarcopenic dysphagia among older adults.

## Conclusions

All three quantitative indicators (SC, VS, and TS) in the 100-mL WST were associated with dysphagia risk factors among community-dwelling older adults aged  $\geq 65$  years. Men were more likely to have choking signs in the qualitative assessment of the 100-mL WST compared to women, suggesting the utility of monitoring the progression of aspiration. The 100-mL WST is feasible as a dysphagia screening test among community-dwelling older adults and can detect sarcopenic dysphagia at least by observing swallowing speed.

We propose that in assessing oral frailty, the two indicators of SC and choking signs in the 100-mL WST be included in a dysphagia screening tool for community-dwelling older people.

## Conflict of interest

The authors have no conflicts of interest to declare.

## Acknowledgment

We are grateful to all participants for their valuable contributions to the study. We also thank Ms. Fumiko Iwai and Ms. Chinatu Rokutanzone for their support with the data collection.

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