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Research Article

Cut-Off Value of Tongue Pressure on the Ability to Perform Activities of Daily Living in Hospitalized Old-Old and Very Old Patients

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ABSTRACT

Background: The cut-off value of tongue pressure on the ability to perform activities of daily living could be a useful indicator for preventing deterioration of the ability to perform activities of daily living. This study aimed to investigate the relationships among swallowing function, including tongue pressure, nutrition status, and physical function and ability to perform activities of daily living and establish a cut-off value in hospitalized old-old and very old patients.

Methods: A total of 98 hospitalized patients aged ≥ 75 years were recruited in this cross-sectional study. Swallowing function (tongue pressure and Dysphagia Risk Assessment for the Community-dwelling Elderly), nutrition status (body mass index, albumin, and Mini Nutritional Assessment Short Form version), physical function (timed up and go test), and ability to perform activities of daily living (Barthel index) were measured. Patients were divided into two groups based on the ability to perform activities of daily using Barthel index (Group 1, high ability, and Group 2, low ability).

Results: Group 2 had lower swallowing function, nutrition status, and physical function compared with Group 1 ($p<0.05$). In the multiple logistic regression analysis, tongue pressure was an independent explanator for Barthel index ($p<0.05$), and the cut-off value of tongue pressure for the ability to perform activities of daily living could be set using receiver operating characteristic curves.

Conclusion: The cut-off value of tongue pressure could be a useful indicator for maintaining or improving the ability to perform activities of daily living in hospitalized old-old and very old patients.

Keywords: Tongue pressure; Activities of daily living; Nutrition status; Physical function; Old-old and Very old inpatient

Abbreviations: ADL: Activities of Daily Living; DRACE: Dysphagia Risk Assessment for Community-dwelling Elderly; BMI: Body Mass Index; Alb: Albumin; MNA-SF: Mini Nutritional Assessment Short Form version; TUG: Timed Up and Go test; BI: Barthel Index; SD: Standard Deviation; AUC: Area Under the Curve; ROC: Receiver Operating Characteristic; OR: Odds Ratio; 95% CI: 95% Confidence Interval

INTRODUCTION

The swallowing function plays an extremely important role in the intake of food from the oral cavity [1]. The tongue is a powerful source for sending a bolus from the oral cavity to the pharynx during swallowing [2]. Tongue pressure is necessity in creating a bolus, which is blended food and saliva, and carrying it through the pharynx in the feeding and swallowing process [3]. Low tongue pressure is associated with prolonged mealtime, reduced intake, and dysphagia [4]. The rate of malnutrition in older individuals with dysphagia is higher compared with those without dysphagia, and malnutrition is a risk factor for deterioration of physical function or ability to perform Activities of Daily Living (ADL) [5-7]. It has also been reported that maximum voluntary tongue pressure was positively correlated with the ability to perform ADL [8]. Therefore, the negative pathway may be considered cycles of low tongue pressure, dysphagia, malnutrition, and poor ability to perform ADL. Moreover, tongue pressure is lower in the people in their seventies than that in younger individuals and older individuals in the hospital, long-term care health facilities, and nursing home

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compared with those in the community [9,10]. Hence, evaluating and treating tongue pressure for preventing deterioration of the ability to perform ADL are important, particularly in hospitalized old-old and very old patients.

Tongue pressure is additionally related to handgrip strength, which reflects not only upper extremity muscle strength but also muscle strength of other body parts (e.g., lower extremities or trunk muscle strength) [11-13]. Older individuals who are dependent in performing ADL have low muscle strength [14,15]. There is a possibility that older individuals with lower tongue pressure may also have low ability to perform ADL due to low muscle strength. Thus, tongue pressure could be a direct and indirect indicator for the ability to perform ADL. The cut-off value is useful in the decision of the presence or absence of disease [16]. However, little is known about the cut-off value of tongue pressure for the ability to perform ADL in hospitalized old-old and very old patients. Clarifying the cut-off value of tongue pressure for the ability to perform ADL could be a direct and indirect useful indicator for preventing deterioration of the ability to perform ADL in hospitalized old-old and very old individuals.

This study aimed to investigate the relationships among swallowing function, including tongue pressure, nutrition status, physical function, and ability to perform ADL, and establish a cut-off value of tongue pressure, which is used to predict the ability to perform ADL in hospitalized old-old and very old individuals. We hypothesized that lower tongue pressure was related to malnutrition, deterioration of physical function, and ability to perform ADL, and a cut-off value of tongue pressure to predict the ability to perform ADL existed.

MATERIALS AND METHODS

Participants

A total of 98 hospitalized patients aged ≥ 75 were recruited in this cross-sectional study. This study was conducted from March 2016 to August 2017 in Public Morimachi Hospital. Primary diseases in inpatients were orthopedic disease (femur fracture, 37.8%; spinal compression fracture, 18.4%; leg fracture, 10.2%; pelvic fracture, 6.1%; artificial joint replacement, 5.1%; total, 77.6%), cardiovascular disease (cerebral hemorrhage, 2.0%; cerebral infarction, 4.1%; total, 6.1%), and others (disuse syndrome, 14.3%; respiratory failure, 2%; total, 16.3%). The average duration from the onset of primary disease was 63.1 ± 25.0 days. The exclusion criteria were as follows: 1) inability to cooperate, 2) incomplete measurement, 3) severe cognitive disorder and inability to understand instructions, and 4) readmission. All subjects provided written informed consent, and this study was approved for implementation by Public Morimachi Hospital.

Swallowing function

Maximum tongue pressure was measured using a hand-held balloon probe and manometer (JM-TPM; JMS Co., Ltd., Hiroshima, Japan). Based on a previous study, the measurement was performed in a relaxed sitting position, and the balloon on the device was placed into the oral cavity, the tongue probe between the front teeth was lightly clamped, the lips were closed, and the balloon was positioned on the anterior part of the palate [9,17]. Participants compressed the balloon with maximal voluntary muscular effort for approximately 7s. Tongue pressure was measured three times, and the average values of tongue pressure were used as a representative value.

We also used the Dysphagia Risk Assessment for Community-dwelling Elderly (DRACE) to evaluate swallowing function. DRACE is a tool with reliability and validity to detect latent risk of swallowing disorders and dysphagia [18]. DRACE is a questionnaire composed of 12 items. For each item, the frequency of occurrence is answered in three ranks: "None at all, 0 points"; "Sometimes, 1 point"; and "Frequently, 2 points". Higher scores indicated a serious case of dysphagia. When the DRACE score is ≥ 3, the subject is considered at risk of decline in swallowing function [19].

Nutritional status

Nutritional status were measured using Body Mass Index (BMI), Albumin level (Alb), and Mini Nutritional Assessment Short Form version (MNA-SF). BMI was calculated as body weight divided by height squared (kg/m^2). Height was calculated using estimate formula in this study and the estimated heights could be measured without dependence on ADL ability [20]. The height-estimation formula was height (cm)=2.1 × total length of forearm and leg below the knee+37.0 [20]. The length of the forearm was measured from the proximal olecranon to the distal ulnar styloid process, lower leg length was measured from the proximal the head of fibula to the distal malleolus lateralis [20]. The weight and Alb were used from the latest date against the initiation of this study in the medical examination, which was obtained from the results of regular medical examinations. The MNA-SF was developed as a simplified assessment of nutritional deficiency, with a total score ranging from 0 to 14 [21]. MNA-SF can recognize older Japanese patients with at risk of malnutrition or malnutrition [22]. We calculated the score of MNA-SF with BMI in this study.

Physical function

Timed Up and Go Test (TUG) was used to evaluate physical function, and subjects were timed while they rise from a chair, walk 3m, turns, walk back, and sit down again as soon as possible. The TUG is widely used to measure functional mobility in elderly individuals [23,24]. TUG is associated with balance ability and ADL [23]. The measurement was performed twice, and the values of higher gait speed were used in the analysis. The patients were permitted to use walking aids, which were normally used.

Ability to perform ADL

Barthel Index (BI) calculated the total score of each question item and evaluated it on a 100-point scale [25]. BI was based on 10 items: moving from a wheelchair to a bed and back, walking, eating, getting on and off the toilet, ascending and descending the stairs, dressing, bowel control, bladder control, grooming activity, and bathing. A higher point indicates less need for assistance in ADL. If the total score was ≥ 85, patients have independent conditions of ADL with minimum help [26-28].

Statistical analysis

The characteristics of participants were presented as mean ± Standard Deviation (SD). Minimal sample sizes (Area Under the Curve [AUC]=0.80, significant level=0.05, power 0.90; AUC=0.70, significant level=0.05, power=0.90] using R Package "pROC"

(version 1.16.2) were 16.6 (total 33.2) and 40.2 (total 80.4), respectively. Statistical evaluation was conducted using the JMP 11 software (SAS Institute Inc., Cary, NC, USA). Participants were divided into two groups: Group 1 (BI ≥ 85 points) and Group 2 (BI<85 points). The differences in the two groups were analyzed using a chi-squared test or Wilcoxon rank sum test (either or both nonparametric data) or unpaired *t*-test (both parametric data) based on the Shapiro-Wilk test. In regard to the items with significant differences, multiple logistic regression analysis in stepwise method was performed to determine which variables were associated with BI (response variables; BI [≥ 85 points, 1;<85 points, 2]), and the odds ratios and 95% Confidence Intervals (CI) were calculated. Moreover, the cut-off value as an index to predicting a decrease in the ability to perform ADL (between BI [≥ 85 points and <85 points]) was evaluated using Receiver Operating Characteristic (ROC) curves. Statistical significance was set at a p-value of <0.05.

RESULTS

Table 1 presents characteristics of the entire inpatients and groups, which were classified according to the 85-point BI. There were significant differences in age, weight, BMI, Alb, tongue pressure, MNA-SF, DRACE, TUG, and BI in the two groups (all p<0.05), (Table 1). In the multiple logistic regression analysis in stepwise method (response variables, BI [≥ 85 points, 1;<85 points, 2]); predictor variables, age, BMI, Alb, tongue pressure, MNA-SF, DRACE, and TUG excluding weight], tongue pressure, MNA-SF, and TUG were extracted as independent explanators for BI (tongue pressure, Odds Ratio (OR)=1.15, 95% CI 1.03-1.30; MNA-SF, OR=1.93, 95% CI 1.26-3.15; TUG, OR=0.93, 95% CI 0.86-0.98, all p<0.05) (Table 2). Moreover, the OR and 95% CI in each item (tongue pressure, MNA-SF, and TUG) for BI are also shown in Table 3 (tongue pressure, OR=1.25, 95% CI 1.14-1.39; MNA-SF, OR=2.82, 95% CI 1.92-4.49; TUG, OR=0.89, 95% CI 0.83-0.94, all p< 0.05) (Table 3). DRACE adjusted for tongue pressure, MNA-SF, and TUG, except age, BMI, and Alb, was not also an independent explanator of BI in the multiple logistic regression analysis (OR=0.98, 95% CI 0.73-1.31, p=0.92).

In regard to the ROC curves, the cut-off values of tongue pressure, MNA-SF, and TUG (all) for BI (85 points) were 25.2 kPa, 8 points and 13.55s, respectively (AUC, 0.88; sensitivity, 0.82; specificity, 0.83) (Figure 1). Moreover, AUC, sensitivity, and specificity and cut-off value for BI in each item (tongue pressure, MNA-SF, and TUG) were 0.81, 0.78, 0.73, and 24.2 kPa; 0.84, 0.80, 0.83, and 8 points; and 0.78, 0.72, 0.79, and 17.07 s, respectively (Figure 2).

Furthermore, we divided participants into two groups according to the cut-off values of tongue pressure, MNA-SF, and TUG (each item) which was set for BI in this study (24.2 kPa, 8 points, and 17.07s). MNA-SF, TUG, and BI in the low tongue pressure group (Group 4) were significantly lower than those in the high tongue pressure group (Group 3) (all p<0.05) (Table 4). Tongue pressure, TUG, and BI in the low MNA-SF score group (Group 6) were also significantly lower compared with those in the high MNA-SF score group (Group 5) (all p<0.05) (Table 5). Moreover, low TUG speed group (Group 8) had significantly lower tongue pressure, nutritional status, and ability to perform ADL compared with those in the high TUG speed group (Group 7) (all p<0.05) (Table 6).

DISCUSSION

In inpatients aged ≥ 75 years, those with the low ability to perform ADL had lower swallowing function, such as tongue pressure, nutrition status, and physical function. The multiple logistic regression analysis also demonstrated that tongue pressure, MNA-SF, and TUG were independent explanators for BI as the ability to perform ADL, and the cut-off value of tongue pressure for BI could

Table 1: Characteristics of inpatients in this study.

Characteristics	All (n=98)	Group 1 (n=48)	Group 2 (n=50)	P-value
Sex (n, Male/Female)	26/72	14/34	12/38	0.56[a]
Age (years)	85.3 ± 5.4	84.2 ± 5.0	86.4 ± 5.6	0.043[b]
Height (cm)	151.1 ± 0.1	152.0 ± 0.1	150.3 ± 0.1	0.17[c]
Weight (kg)	42.8 ± 8.6	45.6 ± 8.3	40.0 ± 8.0	0.001[b]
BMI (kg/m^2)	18.7 ± 3.2	19.7 ± 3.0	17.7 ± 3.1	0.001[b]
Diagnosis (%)				
Cardiovascular disease	6.1	4.1	2.0	
Orthopedic disease	77.6	37.8	39.8	0.63[a]
Others	16.3	7.1	9.2	
Duration from the onset (days)	63.1 ± 25.0	60.1 ± 28.1	65.9 ± 21.5	0.25[b]
Tongue pressure (kPa)	23.9 ± 6.9	27.7 ± 6.3	20.4 ± 5.5	<.0001[b]
Albumin (g/dL)	3.4 ± 0.4	3.6 ± 0.3	3.3 ± 0.4	0.0001[b]
MNA-SF (points)	8.5 ± 1.7	9.5 ± 1.4	7.5 ± 1.5	<.0001[c]
DRACE (points)	2.2 ± 2.2	1.7 ± 1.8	2.6 ± 2.4	0.023[c]
TUG (seconds)	19.3 ± 10.4	14.7 ± 6.6	23.8 ± 11.4	<.0001[c]
BI (points)	78.5 ± 14.8	90.6 ± 5.5	66.9 ± 11.2	<.0001[c]

Note: Value are expressed as mean ± Standard Deviation (SD) unless otherwise specified

Group 1, Barthel index ≥ 85 points; Group 2, Barthel index <85 points

[a]Chi-squared test; [b] Unpaired t-test; [c]Wilcoxon rank sum test

BMI, Body mass index; MNA-SF, Mini Nutritional Assessment Short Form version; DRACE, Dysphagia Risk Assessment for the Community-dwelling Elderly; TUG, Timed up and go test; BI, Barthel index

Table 2: Association of BI with swallowing function, nutrition status and physical function using multiple logistic regression analysis (n=98).

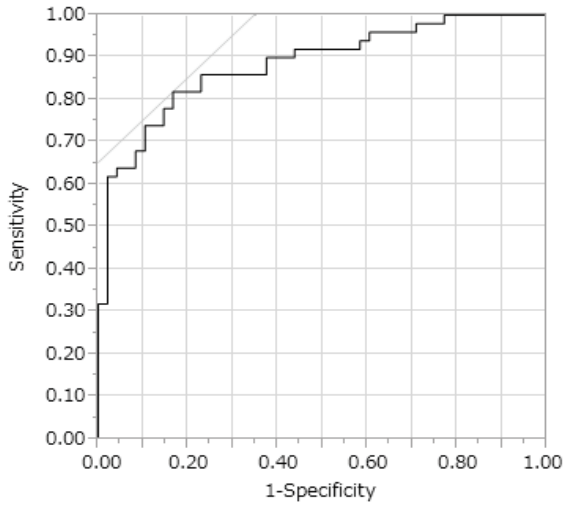
Explanators	OR	95%CI	P-value
Tongue pressure	1.15	1.03-1.30	0.013
MNA-SF	1.93	1.26 -3.15	0.002
TUG	0.93	0.86-0.98	0.011

Note: OR: Odds Ratio; CI: Confidence Interval; BI: Barthel Index; MNA-SF: Mini Nutritional Assessment Short Form version; TUG: Timed Up and Go test

Table 3: Association of BI with swallowing function, nutrition status and physical function in each item using multiple logistic regression analysis (n=98).

Explanators	OR	95%CI	P-value
Tongue pressure	1.25	1.14-1.39	<.0001
MNA-SF	2.82	1.92-4.49	<.0001
TUG	0.89	0.83-0.94	<.0001

Note: OR: Odds Ratio; CI: Confidence Interval; BI: Barthel Index; MNA-SF: Mini Nutritional Assessment Short Form version; TUG: Timed Up and Go test



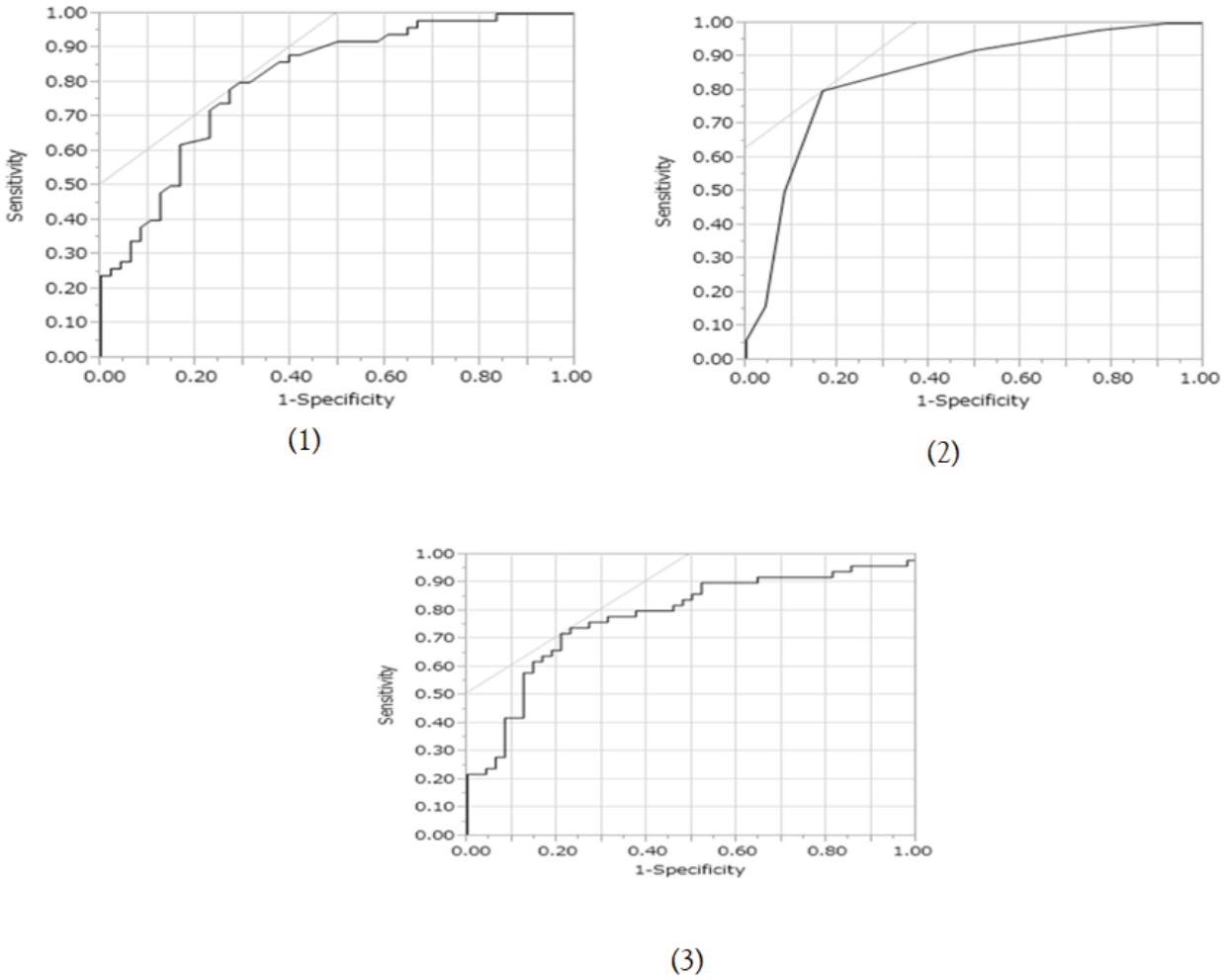
Note: AUC 0.88, sensitivity: 0.82, specificity: 0.83
Cut-off value: Tongue pressure, 25.2 kPa; MNA-SF, 8 points; TUG, 13.55 s
BI: Barthel Index; MNA-SF: Mini Nutritional Assessment Short Form version; TUG: Timed Up and Go test

Figure 1: ROC curves of the relationship between BI and tongue pressure, MNA-SF, and TUG

be set using ROC curves. These results suggest that the cut-off value of tongue pressure could be a useful direct and indirect indicator on whether to provide an exercise prescription for maintaining and improving the ability to perform ADL in hospitalized old-old and very old patients.

Tongue pressure is positively correlated with the ability to perform ADL [8]. Moreover, the relationship between dysphagia and low ability to perform ADL has been observed [29]. Furthermore, malnutrition is a factor in the declining ability to perform ADL [7]. Therefore, groups with low ability to perform ADL might have lower tongue pressure and higher DRACE and malnutrition in this study. Tongue pressure is also associated with clinical symptoms of dysphagia, and relationships between dysphagia and serious diseases, such as malnutrition and pneumonia, are observed [5,30]. The decline in physical function or ability to perform ADL is caused by malnutrition [6,7]. Thus, the negative pathway may be considered cycles of low tongue pressure, dysphagia, malnutrition, physical function, and poor ability to perform ADL. Maintaining and improving tongue pressure could reduce the risk of dysphagia and malnutrition and decreased physical function or ability to perform ADL.

In the ROC curve, the AUC values from 0.78 to 0.88 had moderate accuracy in this study [16]. The cut-off values of tongue pressure for BI as the ability to perform ADL in this study were also calculated as 25.2 kPa (all) and 24.2 kPa (each item). The average maximum tongue pressure in people in their seventies without dysphagia was 31.9 ± 8.9 kPa [9]. Maeda et al. also reported that the average tongue pressure in hospitalized older individuals (average age, 84.1 years; average BI score, 48.1 points) was 20.8 ± 9.4 kPa [8]. The average values of age, BI, and tongue pressure of our inpatients (all) were 85.2 ± 5.4 years, 78.5 ± 14.8 points, and 23.9 ± 6.9 kPa, respectively. Thus, the values of tongue pressures ranged from 24.0 to 25.0 kPa could be suitable for dividing 85 points for BI into two groups. The cut-off value of MNA-SF for 2 groups was 8 points in this study. In regard to MNA-SF, malnutrition is indicated by a score of ≤ 7, risk of malnutrition by a score of 8-11, and favorable nutritional status by a score of ≥ 12 [21]. Malnutrition is related to the decline in physical function and ability to perform ADL [6,7]. Therefore, MNA-SF cut-off value is 8 points, so it could be considered an appropriate value even when considering the ability to perform ADL. Moreover, the cut-off values of TUG were approximately 13.5 (all) and 17.0 s (each item) in this study. Shumway-Cook et



(1): Tongue pressure AUC 0.81, sensitivity 0.78, specificity 0.73, Cut-off value: 24.2 kPa.
(2): MNA-SF AUC 0.84, sensitivity 0.80, specificity 0.83 Cut-off value: 8 points.
(3): TUG AUC 0.78, sensitivity 0.72, specificity 0.79 Cut-off value: 17.07 s.
Note: BI: Barthel Index; MNA-SF: Mini Nutritional Assessment Short Form version; TUG: Timed Up and Go test.

Figure 2: ROC curves of the relationships between BI and tongue pressure, MNA-SF, and TUG in each item.

Table 4: Comparison of nutritional status, physical function, and abilities to perform ADL between patients with high and low tongue pressures (n=98).

Characteristics	Group 3 (high tongue pressure) (n=46)	Group 4 (low tongue pressure) (n=52)	P-value
MNA-SF (points)	9.5 ± 1.5	7.6 ± 1.5	<.0001[b]
TUG (seconds)	15.9 ± 8.5	22.4 ± 11.0	0.0004[b]
BI (points)	87.2 ± 9.7	70.9 ± 14.4	<.0001[b]

Note: High tongue pressure >24.2 kPa; low tongue pressure ≤ 24.2 kPa
[a] Unpaired *t*-test, [b]Wilcoxon rank sum test
ADL: Activities of Daily Living; MNA-SF: Mini Nutritional Assessment Short Form version; TUG: Timed up and go test; BI: Barthel index

Table 5: Comparison of tongue pressure, physical function, and abilities to perform ADL between patients with high and low MNA-SF scores (n=98).

Characteristics	Group 5 (high MNA-SF score) (n = 50)	Group 6 (low MNA-SF score) (n = 48)	P-value
Tongue pressure (kPa)	27.2 ± 6.3	20.5 ± 5.8	<.0001[a]
TUG (seconds)	14.7 ± 6.5	24.1 ± 11.5	<.0.001[b]
BI (points)	87.2 ± 9.7	69.5 ± 13.8	<.0001[b]

Note: High MNA-SF score >8 points; low MNA-SF score ≤ 8 points
[a]Unpaired *t*-test, [b]Wilcoxon rank sum test
ADL: Activities of Daily Living; MNA-SF: Mini Nutritional Assessment Short Form version; TUG: Timed Up and Go test; BI: Barthel Index

Table 6: Comparison of tongue pressure, nutritional status, and abilities to perform ADL between patients with high and low TUG speed (n=98).

Characteristics	Group 7 (high TUG speed) (n=52)	Group 8 (low TUG speed) (n=46)	P-value
Tongue pressure (kPa)	26.7 ± 6.6	20.8 ± 5.9	<.0001[a]
MNA-SF (points)	9.1 ± 1.6	7.8 ± 1.7	0.0001[b]
BI (points)	86.3 ± 12.0	69.8 ± 12.8	<.0001[b]

Note: High TUG speed <17.07 s; low TUG speed ≥ 17.07 s

[a] Unpaired *t*-test, [b]Wilcoxon rank sum test

ADL: Activities of Daily Living; MNA-SF: Mini Nutritional Assessment Short Form version; TUG: Timed Up and Go test; BI: Barthel Index

al. and Podsiadlo et al. reported that the cut-off values, which were divided into older adults with and without a history of falls and the propriety for conducting ADL within doors, were 13.5 and 20.0 s, respectively [23,24]. An individual with impairment of ADL has higher risk of fall compared with an individual without impairment of ADL [31]. Moreover, the patients had independent conditions of ADL with minimum help when the total BI score was ≥85 [26-28]. The average BI score in our group with high ability to perform ADL was 90.6 ± 5.5 points. Therefore, the cut-off value of TUG in this study could be useful in considering the ability to perform ADL.

CONCLUSION AND LIMITATIONS

The cut-off value of tongue pressure could be a useful direct and indirect indicator on whether to provide an exercise prescription for maintaining and improving the ability to perform ADL in hospitalized old-old and very old patients. There are some limitations in this study. First, the small number of subjects and we need to recruit more subjects in future studies. Furthermore, since all participants were Japanese, the results of this study may be limited when targeting other ethnic groups. Second, this study had a cross-sectional design for investigating relationships among the ability to perform ADL, swallowing function, nutrition status, and physical function. An association between cause and effect could not be revealed due to the cross-sectional design of this study. It is necessary to investigate relationships among the ability to perform ADL, swallowing function, nutrition status, and physical function using a longitudinal study in future studies. Third, we recruited in patients who had limited durations from the onset of primary diseases, and it is difficult to apply in inpatients.

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