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ORIGINAL ARTICLE

Decreased Tongue Pressure is Associated with Sarcopenia and Sarcopenic Dysphagia in the Elderly

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Abstract The aim of this study was to clarify the association between tongue pressure and factors related to sarcopenia such as aging, activities of daily living, nutritional state, and dysphagia. One-hundred-and-four patients without a history of treatment of stroke and without a diagnosis of neurodegenerative disease (36 men and 68 women), with a mean age of 84.1 ± 5.6 years, hospitalized from May 2013 to June 2013 were included in this study. Maximum voluntary tongue pressure against the palate (MTP) was measured by a device consisting of a disposable oral balloon probe. Nutritional and anthropometric parameters such as serum albumin concentration, Mini-Nutritional Assessment short form (MNA-SF), body mass index, arm muscle area (AMA), and others and presence of sarcopenia and dysphagia were analyzed to evaluate their relationships. Correlation analysis and univariate or multivariate analysis were performed. Simple correlation analysis showed that MTP correlated with Barthel index (BI), MNA-SF, serum albumin concentration, body mass index, and AMA. Univariate and multivariate analysis showed that sarcopenia, BI, MNA-SF, and age were the independent explanatory factors for decreased MTP, and the propensity score for dysphagia, including causes of primary or secondary sarcopenia, and the presence of sarcopenia were significantly associated with the presence of dysphagia. Decreased MTP and dysphagia were related to sarcopenia or the causes of sarcopenia in the studied population. Furthermore, the clinical condition of sarcopenic dysphagia may be partially interpreted as the presence of sarcopenia and causal factors for sarcopenia.

Keywords Tongue pressure · Sarcopenia · Sarcopenic dysphagia · Elderly · Deglutition · Deglutition disorders

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Introduction

Swallowing requires a complex and coordinated interaction with many head and neck muscles and structures. The swallowing process is conceptualized as a continuous sequence of events that are subdivided intelligibly into 4 phases [1]. In these phases, the tongue plays one of the most important roles. The roles are the formation, placement, and manipulation of a bolus in the preparation phase; the posterior transfer of a bolus to the pharyngeal cavity in the oral transit phase; and concerted motion in pharyngeal reflex to propel the bolus downwards. During swallowing, the tongue muscles change the shape and the position of the tongue [2–4]. Therefore, the evaluation of the function of tongue muscles may be necessary for the evaluation of the swallowing function. Abnormal tongue function is associated with oral and pharyngeal dysphagia [1, 5, 6]. One of the ways to examine the function of tongue muscles is to measure maximum tongue pressure. Although a decrease in maximum tongue pressure has been reported in elderly people [7–12], it is unclear what other factors are associated with a decrease in maximum tongue pressure. Tsuga et al. [13] reported that activities of daily living (ADL), which was categorized into 4 classes according to the Japanese criteria for evaluating the degree of independence of disabled elderly subjects, was related to tongue pressure, and that elderly subjects with disability had significantly lower maximum tongue pressure. Although Tamura et al. [14] did not examine tongue pressure, they reported the association between tongue thickness and mid-arm muscle area (AMA) as systemic nutritional status (correlation coefficient $r = 0.424$, $p < 0.001$). Kuroda et al. [15] reported that sarcopenia and dysphagia may be associated because their results showed that swallowing difficulty assessed by the water-swallowing test was correlated with arm muscle circumference in the elderly (correlation coefficient $r = 0.48$, $p < 0.001$).

Sarcopenia is a syndrome characterized by a progressive and systemic decrease in skeletal muscle mass and skeletal muscle power, and it is accompanied by physical impairment, deterioration of the quality of life, and death [16, 17]. The European Working Group on Sarcopenia in Older People (EWGSOP) [18] categorized this multifactorial syndrome as primary sarcopenia by aging or secondary sarcopenia by other causes. Secondary sarcopenia includes activity-related sarcopenia caused by bed rest, sedentary lifestyle, deconditioning, or zero gravity conditions. Disease-related sarcopenia caused by organ failure, inflammatory disease, malignancy, or endocrine disease and nutrition-related sarcopenia caused by inadequate dietary intake of energy and/or protein are also included in secondary sarcopenia. It seems that the relevance of sarcopenia and dysphagia has been capturing the spotlight recently [19].

The risk of dysphagia increases with age; however, the swallowing function in healthy elderly people is not naturally compromised [20, 21]. Twenty or more muscles of the head and neck are involved in the movement of swallowing from the mouth to the stomach, working together through a complex mechanism [2, 22]. However, it is very difficult to evaluate the strength or amount of muscle required for swallowing. Therefore, our hypotheses is that sarcopenic dysphagia, defined as dysphagia related to sarcopenia, can be explained in part by the relationship between maximum tongue pressure, aging, ADL, nutrition, and presence of sarcopenia. Furthermore, sarcopenic dysphagia may occur because of secondary sarcopenia in addition to aging. The purpose of this research, therefore, was to clarify the relationship between maximum tongue pressure and other factors related to sarcopenia, such as aging, ADL, nutritional state, and dysphagia.

Materials and Methods

Subjects

One-hundred-and-four patients (36 men and 68 women), with a mean age of 84.1 ± 5.6 years, hospitalized in our hospital, which was a local base hospital in a city with a population of about 100 thousand, among which 30 % of the people are over 65 years old, from May 2013 to June 2013 were included in this study. Since previous studies have already shown an age-related decrease in tongue pressure [7–12], in order to minimize the impact of age in this study, only elderly subjects over 65 years of age were included. In addition, patients with a history of treatment of stroke or with neurodegenerative disease, which could possibly affect tongue motion directly, such as amyotrophic lateral sclerosis, Parkinson's disease, progressive supranuclear palsy, or spinocerebellar degeneration, were excluded. Subjects included in this study were admitted in our hospital for treatment of infectious disease (47.1 %), gastroenterological disease (21.2 %), rehabilitation (10.6 %), surgical operation (9.6 %), and other reasons (11.5 %). Since there were many patients with infectious disease, maximum voluntary tongue pressure against the palate (MTP) was examined in all subjects under the condition of having no inflammation as determined by a serum C-reactive protein (CRP) concentration under 1.5 mg/dL. Subjects with chronic inflammation, such as advanced cancer, rheumatoid arthritis, and organ failure, and those with high CRP levels were also excluded based on the CRP cut-off. Tongue pressure was measured in all subjects 2 weeks after admission. No patient with endocrine disease such as thyroid disease, adrenal disease, and pituitary gland disorder, among others, was admitted to our hospital in this study period. Subjects who could not understand or follow our instructions were also excluded. None of the subjects included in this study presented differences between right and left movements of the tongue. A speech therapist examined the suitability of the dentures and oral function, and none of the subjects had any diseases that worsened their oral function.

Tongue Pressure Measurement

MTP was measured by a device consisting of a disposable oral balloon probe (Fig. 1, JMS tongue pressure measuring instrument, JMS, Hiroshima, Japan). Using this device, it is possible to measure increasing air pressure in the balloon, which occurs when the balloon at the tip part of the plastic pipe probe is pressed between the front part of the palate and the tongue.

We replaced the probe for each subject; measurement and standardization of air pressure was in compliance with the mechanical manual. Measurements were performed after the calibration of inner-balloon pressure stabilized to 19.6 kPa. This calibration was automatically performed by the instrument, and the display screen showed 0.0 kPa when the instrument was successfully calibrated. Maximum pressure and real-time pressure appeared on examination. Before measurement, the method of measurement

Fig. 1 Maximum tongue pressure measurement instrument (JMS, Hiroshima, Japan)

was explained to the subjects as follows: they would be placed in a relaxed sitting position; the balloon would be placed in their mouth; they would hold the plastic pipe at the midpoint of their central incisors with closed lips, compressing a small balloon attached to the tip of the probe between the tongue and anterior part of the hard palate for 5 s with maximum voluntary effort. The pressures were recorded 3 times with 30-s intervals, and data were averaged as described by Utanohara et al. [10].

Parameters

Weight and height were measured using standardized equipment and procedures. Body mass index (BMI) was calculated as weight divided by height squared (kg/m^2). Mid-upper arm circumference (AC, cm) and triceps skinfold thickness (TSF, mm) were measured by a trained registered dietitian. AMA (cm^2), an indicator of total muscle mass, was calculated using AC and TSF according to the following equation: $\text{AMA} = [\text{AC} - (\text{TSF} \times \pi/10)]^2/4\pi$. The nutritional status of subjects was determined using the Mini-Nutritional Assessment short form (MNA-SF) scores questionnaire, recommended for screening of older people [23], via an interview conducted by trained nurses. CONUT, a nutritional assessment tool that assesses protein metabolism, lipid metabolism, and immune function using 3 parameters (serum albumin, total cholesterol, and total lymphocyte count) [24], was calculated. CONUT was scored on a 0–12 point scale, wherein a lower score indicates a higher level of nutritional status. To assess the ADL, the Barthel index (BI) [25], a widely accepted measure of ADL function, was scored on a 0–100 point scale, wherein a higher score indicates a higher level of functional independence.

Swallowing difficulty was assessed by the Functional Oral Intake Scale (FOIS) [26], which is a 1–7 point ordinal scale, wherein a higher score indicates a normal swallowing ability. Dysphagia was defined as having a FOIS level of 5 or less. A FOIS level of 5 indicates the ability to swallow a total oral diet with multiple consistencies, but requiring special preparation or compensations.

Sarcopenia was diagnosed by both skeletal muscle loss and low handgrip strength, which is one of the criteria according to the consensus report [18]. The fifth percentile value of the AMA data, which were measured in all the Japanese age groups was considered the cutoff value of skeletal muscle mass decrease [27]. According to the Japanese Anthropometric Reference Data [28], 28.32 cm^2 and 20.93 cm^2 of AMA are the cutoff value for men and women, respectively. The cutoff values of the handgrip strength were <30 and <20 kg for men and women, respectively [18].

Statistical Analysis

Continuous and interval scale data are presented as the mean ± SD, and differences were analyzed by Student's *t* test or Mann–Whitney *U* test. Categorical data are expressed as percentage, and differences were analyzed by χ^2 statistics. Correlations between parameters were assessed using the bivariate simple correlation analysis, calculating with Pearson's product-moment correlation coefficient for parametric values or Spearman's rank-correlation coefficient for non-parametric values. Multivariate linear regression analysis was performed to determine which variables were independently associated with MTP. Logistic regression analysis was performed to determine which variables were independently associated with the presence of dysphagia. To analyze this, because of the low number of subjects with dysphagia, it was necessary to reduce the number of variables included in the logistic model. Propensity scores [29] were calculated by logistic regression analysis, including age, albumin, BMI, MNA-SF, CONUT, and BI as explanatory variables. Values of $p < 0.05$ were considered statistically significant. The analysis was performed using SPSS 21.0 software (IBM Japan, Tokyo, Japan).

This study was approved by the ethics committee of our hospital, and informed consent was obtained from the patients or their legal guardians.

Results

Among the 104 subjects, the mean age was 84.1 ± 5.6 years, and 36 (34.6 %) were men. Characteristics of the study subjects are summarized in Table 1. The mean MTP was

Table 1 Characteristics of the study population

Variable	All ($n = 104$)
MTP (kPa)	20.8 ± 9.4
Age (years)	84.1 ± 5.6
AC (cm)	23.4 ± 3.9
TSF (mm)	11.3 ± 6.9
AMA (cm^2)	31.9 ± 8.7
BMI (kg/m^2)	20.4 ± 4.2
Albumin (g/dL)	3.2 ± 0.7
MNA-SF (points)	8.7 ± 3.1
CONUT (points)	4.6 ± 2.9
Barthel index (points)	48.1 ± 38.0
Sex (men, %)	34.6
Dentures (%)	59.6
Dysphagia (%)	42.3

MTP maximum voluntary tongue pressure against the palate, *AC* mid-upper arm circumference, *TSF* triceps skinfold thickness, *AMA* arm muscle area, *BMI* body mass index, *MNA-SF* Mini-Nutritional Assessment short form

20.8 ± 9.4 kPa. There was a gender difference in TSF (men; 9.1 ± 5.3, women; 12.5 ± 7.3, $p = 0.016$) and AMA (men; 35.2 ± 9.2, women; 30.1 ± 8.0, $p = 0.004$). TSF was significantly higher in women, while AMA was higher in men. Although the average BMI value was in the normal range, the nutritional index such as serum albumin concentration, MNA-SF, and CONUT showed the risk of malnutrition. The median BI, used as an index of ADL or disuse syndrome, was 50 points, revealing that several subjects required care.

Table 2 shows a simple correlation analyses for parameters shown in Table 1. MTP was positively correlated with BI, MNA-SF, albumin, BMI, AMA, TSF, and AC, and was negatively correlated with CONUT. Tongue pressure was associated with both ADL and nutritional status.

One of the aims of this study was to clarify the relationship between tongue pressure and sarcopenia. The number of subjects diagnosed as having sarcopenia was 15 (14.4 %), and 9 of them were men. Then, a multivariate regression analysis was performed to investigate if sarcopenia was an independent explanatory factor for decreased tongue pressure. Table 3 shows the results of the multivariate regression models used to examine the relationship between MTP and other factors such as age, albumin concentration, MNA-SF, BI, sex, denture usage, and presence of sarcopenia. As it is known, anthropometric parameters such as AC, TSF, AMA, and BMI differ according to gender; these parameters were not used as explanatory variables. However, the evaluation of muscle volume represented by those parameters was included in the presence of sarcopenia. The definitive criteria of sarcopenia used in this study mainly depended on the AMA data of the Japanese population according to sex. As CONUT represents albumin concentration with its method of calculation partially, and its correlation with MTP was weaker than that of albumin concentration, we did not consider CONUT as a factor in this regression analysis. MTP was significantly associated with age (beta = −0.205, $p = 0.022$), albumin concentration (beta = 0.215, $p = 0.032$), degree of BI (beta = 0.208, $p = 0.041$), and presence of sarcopenia (beta = −0.207, $p = 0.043$).

In this study, 42.3 % of the subjects had dysphagia. To evaluate the differences and relationship between dysphagia and ADL or nutritional parameters, we analyzed parameters in 2 groups (Table 4). The mean age, denture usage, and sex ratio were not significantly different between the dysphagia group and non-dysphagia group. MTP was significantly lower in the dysphagia group than the non-dysphagia group ($p < 0.001$), and ADL or nutritional parameters were also worse in the dysphagia group than the non-dysphagia group. Logistic regression analysis shows the independent explanatory factors for the presence of dysphagia (Table 5). The parameters considered in this model were the presence of sarcopenia, sex, denture usage, and a logit-transformed propensity score (PS) for dysphagia by age, albumin, BMI, MNA-SF, CONUT, and BI. The parameters generated into a PS were considered a causal factor of primary or secondary sarcopenia. Sex difference and denture usage were selected as confounders for sarcopenia and dysphagia. The PS (beta = 2.298, $p < 0.001$) and the presence of sarcopenia (beta = 10.386, $p = 0.040$) were independently and significantly associated with dysphagia.

Discussion

In this study of elderly subjects (excluding individuals with a past history of stroke or neurodegenerative disease), tongue pressure was related to general nutritional status, skeletal muscle mass, and ADL. In addition, multivariate analysis demonstrated that albumin, BI, age, and presence of sarcopenia were all independent explanatory variables for tongue pressure. We also found that the causal factors of primary or secondary sarcopenia and the presence of sarcopenia were related to dysphagia, independently. These results suggest that a decreased skeletal muscle volume and power is associated with a decrease in the ability to swallow. The reason for these results may be that this study only included very elderly (age 75 or older) subjects and excluded patients with some diseases (stroke or neurodegenerative disease) known to be associated with swallowing muscle function.

Malnutrition and low activity are causes of secondary sarcopenia, while tongue thickness is correlated with arm

Table 2 Bivariate simple correlation analyses of each parameter

	Barthel index	CONUT	MNA-SF	Albumin	BMI	AMA	TSF	AC	Age	MTP
MTP	0.39*	−0.32*	0.39*	0.42*	0.42*	0.53*	0.33*	0.56*	−0.21	1
Age	−0.07	0.11	−0.01	−0.1	−0.08	−0.13	−0.13	−0.15	1	
AC	0.29*	−0.40*	0.60*	0.45*	0.86*	0.83*	0.72*	1		
TSF	0.1	−0.28	0.48*	0.28	0.70*	0.22	1			
AMA	0.31*	0.11	0.47*	0.42*	0.65*	1				
BMI	0.25	−0.32*	0.59*	0.38*	1					
Albumin	0.28	−0.88*	0.37*	1						
MNA-SF	0.51*	−0.29*	1							
CONUT	−0.16	1								
Barthel-index	1									

Coefficients of correlation were calculated with Pearson's product-moment correlation coefficient for parametric values or Spearman's rank-correlation coefficient for non-parametric values

MTP maximum voluntary tongue pressure against the palate, *AC* mid-upper arm circumference, *TSF* triceps skinfold thickness, *AMA* arm muscle area, *BMI* body mass index, *MNA-SF* Mini-Nutritional Assessment short form

* p value <0.05

muscle circumference and BMI [14]. Based on these findings, it can be inferred that elderly people with reduced skeletal muscle mass and decreased skeletal muscle power due to sarcopenia also present with decreased tongue pressure and swallowing function. By excluding elderly subjects with diseases that can directly affect motor function of the tongue, such as stroke, Parkinson's disease, and ALS, it may have become possible to demonstrate the relationship between tongue pressure and nutritional status, ADL, swallowing function, and sarcopenia. These diseases may have a direct influence on tongue function.

Many studies have reported that age is correlated with maximum tongue pressure against the palate [7–11] and tongue pressure during swallowing [12]. The present study measured tongue pressure only in the very elderly. Considering that there was a negative correlation between age and tongue pressure among these very elderly subjects, primary sarcopenia due to aging may also be a significant risk factor for decreased tongue pressure.

Based on the reported correlation between tongue pressure and BMI [30], it is inferred that a correlation exists between malnutrition and decreased tongue pressure; however, there are few studies on tongue pressure and nutritional status. In a study involving 145 elderly individuals, there was a relationship between decreased MTP and choking during eating [30]. This relationship indicates that, assuming that elderly people with sarcopenia presenting with decreased skeletal muscle mass and power were included in the study, the results are in line with those of our study. Among studies of tongue pressure and muscles, Buehring et al. [31] reported that tongue pressure is positively correlated with grip strength and jumping power, thus suggesting that tongue power is correlated with skeletal muscle power. However, there was no correlation between tongue pressure and appendicular skeletal muscle index [31]. The subjects in the study by Buehring et al. [31] were elderly individuals who were independent in their ADL, whereas our subjects had a BI score of 50 points; therefore, the difference in results may have been due to the marked difference in the subjects' characteristics.

Our results showed no relationship between dentures and tongue pressure. Kodaira et al. [32] placed experimental palatal plates on the tongues of adults with a mean age of 25 years and measured changes in MTP against the palate with and without the palatal plate. They found that the palatal plate had no effect on MTP, similar to the results of the present study.

The present study had some limitations. First, we were unable to include multiple explanatory variables because of the small number of subjects. For example, we were unable to include BMI in the multivariate analysis because of the inclusion of BMI in MNA-SF criteria and its strong correlation with AC and other anthropometric measurements. CONUT includes in its criteria not only albumin as an indicator of protein metabolism, but also lipid metabolism and lymphocyte count; however, since albumin is more strongly correlated with tongue pressure, only albumin was taken into account. Second, although a few studies have reported an association between tongue pressure and cognitive function, we excluded the assessment of cognitive function in the present study because we did not perform it for all cases. However, considering that dementia has been frequently reported to be correlated with malnutrition [33–35] and low ADL [36–39], even if a decline in cognitive function has an effect on tongue pressure, precise measurements would be impossible because of difficulty in

Table 3 Multivariate linear regression analysis for MTP

	Exp (B)	95 % Confidence interval	*p* value
Age	−0.205	−0.713 to −0.058	0.022
Albumin	0.215	0.256 to 5.442	0.032
MNA-SF	0.114	−0.271 to 0.953	0.272
Barthel index	0.208	0.002 to 0.101	0.041
Sex	0.068	−2.051 to 4.719	0.436
Dentures	−0.068	−4.521 to 1.941	0.430
Sarcopenia	−0.207	−10.834 to −0.174	0.043

MTP was significantly associated with age, serum albumin concentration, degree of Barthel index, and presence of sarcopenia

MTP maximum voluntary tongue pressure against the palate, *MNA-SF* Mini-Nutritional Assessment short form

following instructions. Furthermore, malnutrition and ADL could be confounding factors. Third, as this is a cross-sectional study, the present study did not examine causal relationships. Because dysphagia leads to decreased nutrient intake, dysphagia appears to cause malnutrition. However, Hudson et al. [40] reported that the relationship between decreased swallowing function and malnutrition is more of an interdependency than a causal relationship, while another review [41] stated that protein energy malnutrition is the cause of dysphagia. Based on these reports, rather than dysphagia causing malnutrition in a unidirectional relationship, the two may have a bidirectional relationship. The fact that a functional disorder results from the frailty cycle [42], a negative cycle that primarily comprises malnutrition, low activity, and sarcopenia also supports the above concept of a bilateral relationship. The concept of sarcopenic dysphagia can perhaps be partially explained by the following view: systemic sarcopenia is caused by aging, malnutrition, and low ADL; simultaneously, dysphagia is caused by the attenuation and decreased power of muscles involved in dietary intake (oral cavity, pharynx). Although it is often difficult to measure the mass and power of muscles involved in dietary intake, measurement of the muscle mass and power of the tongue are considered to be the easiest measurements. The future development of quantitative measurement methods is anticipated to result in the establishment of a method for diagnosing sarcopenic dysphagia. Fourth, the morbidity of sarcopenia may be underestimated because of the use of anthropometric measurements in diagnosing reduced skeletal muscle mass. The EWGSOP consensus [18] indicates that, although anthropometric measurements can be used easily in clinical settings, measurement errors frequently occur. In addition, in elderly individuals with decreased ADL, an increase in fat volume in muscle fiber [43] is inferred to result in a calculation of AMA, which is larger than the actual muscle area. Thus, the morbidity of sarcopenia in the present study was low. When possible, sarcopenia is better assessed with methods such as dual X-ray absorptiometry or computed tomography [18]. However, this underestimation, in which only extreme decreases in skeletal muscle mass and power were examined, may have shown the relationship between sarcopenia and dysphagia.

Table 4 Univariate analyses show differences in parameters between the non-dysphagia group and dysphagia group

Variable	Dysphagia ($n = 44$)	Non-dysphagia ($n = 60$)	*p* value
MTP (kPa)	14.7 ± 8.0	25.3 ± 7.7	<0.001
Age (years)	84.8 ± 4.1	84.2 ± 5.6	0.502
AC (cm)	20.8 ± 3.1	25.3 ± 3.3	<0.001
TSF (mm)	8.3 ± 5.2	13.5 ± 7.1	<0.001
AMA (cm^2)	26.7 ± 6.8	35.7 ± 8.0	<0.001
BMI (kg/m^2)	18.4 ± 3.6	21.8 ± 4.0	<0.001
Albumin (g/dL)	2.8 ± 0.6	3.4 ± 0.6	<0.001
MNA-SF (points)	7.1 ± 2.9	9.9 ± 2.8	<0.001
CONUT (points)	5.8 ± 2.9	3.8 ± 2.7	<0.001
Barthel index (points)	36.8 ± 34.1	56.4 ± 38.9	0.015
Sex (men, %)	31.8	36.7	0.679
Dentures (%)	59.1	60.0	1.000
Sarcopenia (%)	1.7	31.8	<0.001

MTP maximum voluntary tongue pressure against the palate, *AC* mid-upper arm circumference, *TSF* triceps skinfold thickness, *AMA* arm muscle area, *BMI* body mass index, *MNA-SF* Mini-Nutritional Assessment short form

Table 5 Logistic regression analysis for interpretation parameters of presenting dysphagia

	Exp (B)	95 % CI	*p* value
Sex	0.481	0.157–1.473	0.200
Dentures	1.436	0.528–3.908	0.479
PS	2.298	1.470–3.593	<0.001
Sarcopenia	10.386	1.115–96.718	0.040

PS (logit transformed propensity score) was calculated from logit transformation of a propensity score for age, albumin, *BMI* body mass index, *MNA-SF* Mini-Nutritional Assessment short form, CONUT, and Barthel index for the presence of dysphagia

Finally, only a few studies have reported that ADL and nutritional status are associated with dysphagia [13, 14, 40, 41, 44]. Furthermore, only a handful of reports have mentioned the relationship between secondary sarcopenia and dysphagia [15, 44]. Here, we have demonstrated that decreased tongue pressure, which can cause dysphagia, is correlated with malnutrition and low ADL, which can cause secondary sarcopenia. Thus, we feel that we have succeeded in partially explaining the pathology of sarcopenic dysphagia.

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