Relationship between Generalized Sarcopenia and the Severity of Dysphagia after a Stroke

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Objective: Patients who have suffered a stroke may experience dysphagia, which could raise the risk of aspiration pneumonia and death. This is also a complication prevalent in older adults with various comorbidities. This study aimed at investigating the association between head lifting strength and dysphagia, particularly in each of the two phases of dysphagia, namely the oral and the pharyngeal phase, in stroke patients.

Methods: We prospectively recruited 64 patients within six months of their first-ever stroke. Head lifting strength, handgrip strength, and calf circumference were measured. The severity of dysphagia was evaluated using the video-fluoroscopic dysphagia scale (VDS). Partial correlation and multiple linear regression analyses were applied to examine the association between head lifting strength and dysphagia.

Results: The subjects were comprised of 31 men and 33 women with a mean age of 63 years. The median National Institute of Health Stroke Scale (NIHSS) score was 5.5 (interquartile range 4.0-8.0). Based on the penetration-aspiration scale, 46 participants had dysphagia without aspiration and 18 had dysphagia with aspiration. The head lifting strength in the non-aspiration group was higher compared with the aspiration group. The head lifting strength was significantly correlated with the VDS-pharyngeal phase ($r=-0.715$) and the penetration-aspiration scale ($r=-0.662$). In the multiple linear regression analysis, head lifting strength was independently associated with pharyngeal-phase dysphagia ($P<0.001$).

Conclusion: Head lifting strength is significantly associated with the severity of dysphagia in the pharyngeal phase. (JKDS 2022;12:24-34)

Keywords: Dysphagia, Stroke, Sarcopenia, Videofluoroscopic swallowing study, Head lifting strength

INTRODUCTION

Dysphagia is a clinical condition in which a neurological or structural disorder causes problems in the transfer of food from the mouth to the stomach¹. Reportedly, dysphagia is a disease that occurs in 25-81% of stroke patients, 35-82% of

Parkinson's patients, 19-84% of those diagnosed with dementia², and 38-65% of those with traumatic brain injury³. It is a common problem with high prevalence observed in 11-34% of healthy and independent seniors². If left untreated, dysphagia can lead to dehydration, malnutrition, aspiration pneumonia, and poor quality of life. It is a leading cause of

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mortality and morbidity from complications prevalent in older adults with various clinical conditions⁴.

In 1997, The term “sarcopenia” was first proposed by Rosenberg to describe age-related decrease in muscle mass⁵. Sarcopenia is a syndrome of progressive and general loss of muscle mass and strength⁶. In 2005, Robbins et al. used the term “dysphagia due to sarcopenia” in their research⁷. Since then, there has been a dramatic increase in studies of dysphagia associated with sarcopenia. The term “sarcopenic dysphagia” was first used by Kuroda in 2012⁸. The definition of sarcopenic dysphagia is a swallowing disorder caused by sarcopenia of the swallowing muscles, including the general skeletal muscle². Recently, in the field of geriatrics, several studies have been actively conducted on the relationship between sarcopenia, swallowing muscle and dysphagia.

There are various studies on the relationship between swallowing muscles and dysphagia. Previous studies demonstrated the relationship between suprahyoid muscle mass and swallowing function, and indicated the importance of measuring the geniohyoid muscle, one of the suprahyoid muscles, when evaluating the mass of the muscles involved in swallowing function^{9,10}. Shimizu et al. reported that the atrophy of the geniohyoid muscle was significantly prominent in patients who could not regain their preoperative level of oral intake within 2 weeks after surgery¹¹. In other words, the degree of geniohyoid muscle atrophy was significantly correlated with dysphagia. Among the studies investigating other swallowing muscles, the lower cross-sectional area of the tongue muscle and higher area of ultrasonographic brightness of the tongue muscle were independent risk factors for sarcopenic dysphagia according to a regression analysis conducted by Ogawa et al¹².

Although there are not many methods to evaluate swallowing muscle strength, tongue pressure and jaw-opening force can be measured as assessment tools. It has been reported that tongue pressure weakens with aging and is associated with symptoms of dysphagia¹³. Jaw-opening force is associated with

pharyngeal residue¹⁴. However, both methods require special measurement equipment such as a tongue pressure measurement device or a sphenometer, so it is not a method that can be used conveniently in daily clinical settings.

On the other hand, head lifting strength (HLS) is a simple assessment tool that can be easily used in the clinic to evaluate the strength of the suprahyoid muscles, a group of four swallowing muscles. In a systemic review of the beneficial effects of head lift exercise on swallowing function, it has been reported that the exercise improves dysphagic symptoms by widening the diameter of the upper esophageal sphincter opening¹⁵. Another study also reported that the severity of dysphagia was associated with the HLS measured by the Medical Research Council (MRC) scale¹⁶.

Previous studies examining the effects of HLS on dysphagia did not investigate which phases HLS was more associated with, because they did not divide the swallowing process into oral and pharyngeal phases. Also, HLS was not quantified. In previous studies, HLS was measured by dividing it into several categories, such as genio-sternum distance grade (GS grade) of 4 categories¹⁷ or MRC score of 6 categories¹⁶. Without quantification, differences between HLS within the same category could not be distinguished. Furthermore, among the studies examining the relationship between HLS and dysphagia, there were no studies evaluated by videofluoroscopic swallowing study (VFSS). Also, no studies have adjusted for generalized sarcopenia factors such as grip strength (HGS) or calf circumference (CC). These two factors should be included as variables because they are significantly associated with sarcopenic dysphagia as indicators of muscle strength and muscle mass, respectively¹⁸.

The present study aims to investigate the association between quantified HLS and VFSS assessed dysphagia, particularly each two phases of dysphagia, the oral or pharyngeal phase, in stroke patients. In this study, generalized sarcopenia factors such as HGS and CC were also included and considered.

MATERIALS AND METHODS

1. Participants

This observational, quantitative, and cross-sectional study included stroke patients referred to the rehabilitation department at a general hospital in South Korea for neurorehabilitation between August 2018 and June 2020. The diagnosis of stroke was limited to cases in which cerebral infarction or hemorrhage was confirmed using computed tomography or magnetic resonance imaging. The inclusion criteria were as follows: (1) first-ever hemiplegic stroke; (2) inpatient transferred to rehabilitation department within 3 months after stroke onset during subacute phase; (3) ability to lift head in supine position with maximum effort; (4) medical and neurological stability; and (5) cognitive ability to follow instructions for proper positions, and defined as a score greater than 12 according to the Korean version of the Mini-Mental State Examination (K-MMSE). The exclusion criteria were as follows: (1) history of a recent oropharyngeal or cervical surgical procedure; (2) other medical conditions that may affect VFSS, such as oropharyngeal cancer, achalasia, parkinsonism, Guillain-Barre syndrome, or aspiration pneumonia; (3) dental problems including dentures and tooth loss and (4) tracheostomy status. The participants were divided into two groups according to the Penetration-

Aspiration Scale (PAS) in the flow chart.(Fig. 1) Anthropometric measurements and HLS were assessed on the same day following VFSS. This study was approved by the general hospital's institutional review board, and informed consent was obtained from all patients.

2. Assessment

1) Anthropometry

All anthropometric measurements were carried out in the morning after an overnight fast of at least 10 h, based on a previous study¹⁹. A physiatrist accurately carried out all the anthropometric measurements. Height and bodyweight were measured in units of 0.1 cm and 0.1 kg, respectively. Body mass index (BMI) was calculated as the bodyweight divided by the square of the height (kg/m^2).

(1) Hand grip strength (HGS)

Muscle strength was assessed after evaluating the HGS which was measured using a digital grip strength dynamometer (Takei 5401, Takei Scientific Instruments, Tokyo, Japan) to the nearest 0.1 kg. Participants were instructed to apply the maximum grip strength to each hand three times consecutively, alternating between the left and right, in a sitting position with the elbow at 90 degrees, the wrist at a neutral position, and the interphalangeal joint of index finger at 90 degrees. Resting intervals of at least 30 seconds

Fig. 1. Study flow chart.

were allowed between each measurement. The maximal measured grip strength was regarded as the HGS value²⁰.

(2) Calf circumference (CC)

CC was measured by using a millimeter-graded, non-stretchable plastic tape measure to the nearest 0.1 cm. It was measured with the participants placed in the supine position, with both knees raised, and the calf placed at a right angle to the thigh²¹. The tape measure was placed around the calf at the point of greatest girth without compressing the subcutaneous tissue and was moved along the length of the calf to obtain the maximal circumference. CC values were recorded as the average of the measurements from two trials for each leg, and the maximal measured CC was regarded as the CC value.

(3) Head Lifting Strength (HLS)

HLS was assessed as the percentage value of the actively measured range of motion of neck flexion (AROM) to the passively measured range of motion of neck flexion (PROM) in the supine position. AROM and PROM were measured by angle between the transverse line and the line from the mid-tragus to the C7 spinous process in each position status²². To measure PROM, the patient was placed in the supine position with the neck passively and fully flexed, and was directed to maintain this position with the chin down. The support was withdrawn from the top of the motion and AROM was measured at the level to which the head dropped with the neck flexor muscles maintaining the isometric contraction. (Fig. 2) To obtain the target head-lift position, patients were instructed to raise their head high and forward enough to be able to observe their toes without raising their shoulders off the ground. This head lifting posture was based on the posture of a previous study¹⁶.

2) Videofluoroscopic swallowing study (VFSS)

VFSS was conducted by three experienced rehabilitation physicians, assisted by a radiologic technician in the fluoroscopic laboratory immediately after a patient was assigned to the high-risk dysphagia group. A modified version of the protocol used in Logemann's study was used²³. While sitting upright in

a chair, swallowing images of the lateral projection were obtained from patients. The patients underwent swallowing trials with varying viscosities, including puree, semisolids, solids, and thin liquids (2 cc, 5 cc and cup). For the puree trial, a thick, curd-type yogurt was given to the patient. For the semisolid trial, soft and moist rice porridge was prepared. For the solid trial, regular textured rice was prepared. All trials were coated or mixed with an undiluted liquid barium solution, barium sulfate; Solotop sol 140 (Taejoon Pharm, Seoul, Korea). The physiatrists started with a puree trial, followed by semisolid, solid, and thin liquid trials. Following our institution's VFSS protocol, a thin liquid 2 cubic centimeter (cc) trial preceded the 5 cc trial. If the 2 cc trial indicated aspiration and the evaluator determined there was a high risk for further aspiration, the 5 cc trial could be skipped and the VFSS discontinued. If there was a large amount of aspiration, the study was aborted, and the patients were encouraged to expectorate the food material. The number of trials administered per viscosity was decided by the physiatrist and determined by the patient's swallowing function results

Fig. 2. Head lifting strength was assessed as the percentage value of the AROM to the PROM in the supine position. AROM and PROM were measured by angle between the transverse line and the line from the mid-tragus to the C7 spinous process in each position status. To measure PROM, the patient was placed in the supine position with the neck passively and fully flexed, and was directed to maintain this position with the chin down. The support was withdrawn from the top of the motion and AROM was measured at the level to which the head dropped with the neck flexor muscles maintaining the isometric contraction.

from prior clinical assessments and by the risk of aspiration determined by VFSS findings. All of the study procedures were recorded on MP4 video files (30 frames/second).

(1) Videofluoroscopic dysphagia scale (VDS)

In this study, VDS was used to assess dysphagia severity. VDS is a comprehensive swallowing assessment based on VFSS results, which can be divided into oral and pharyngeal phases to assess scores. The oral phase consists of 7 items (lip closure, bolus formation, tongue-to-palate contact, mastication, apraxia, premature bolus loss, and oral transit time). The pharyngeal phase also consists of 7 items (pharyngeal triggering, vallecular residues, pyriform sinus residues, laryngeal elevation, pharyngeal wall coating, pharyngeal transit time, and aspiration). Scores range from 0 to 100, with a maximum score of 40 for oral function and 60 for pharyngeal function. The higher the score, the greater the level of dysphagia severity²⁴.

(2) Penetration-Aspiration Scale (PAS)

PAS was also used to assess dysphagia severity. PAS is an 8-point observation scale used to measure the degree of airway aspiration. Higher scores indicate more severe aspiration. It is determined by the depth at which the material reaches the airway and whether the material entering the airway is expelled again. Penetration is defined as the material passing in the larynx but not passing below the vocal folds. On the other hand, aspiration is defined as the action of a material penetrating the larynx and entering into the airway under true vocal folds²⁵.

3) Other parameters

Serum albumin level, time from stroke onset and stroke severity score (the National Institute of Health Stroke Scale [NIHSS]) were assessed.

3. Statistical analysis

Results are reported as mean (standard deviation; SD) for parametric data, and as median and 25th to 75th percentiles (interquartile range; IQR) for nonparametric data. Patients were divided into two groups, one with aspiration and one without aspira-

tion. The χ^2 -test, t-test and the Mann-Whitney U-test were used to analyze the differences between two groups stratified by the PAS score (1-5 and 6-8). A multivariable logistic regression model was used to identify factors that were independently associated with aspiration. The participants with non-aspiration group served as a reference. Relationships between each variable were analyzed using partial correlation analysis, adjusted for gender, age, BMI, NIHSS, MMSE-K and albumin. Coefficients of correlation were calculated with Pearson's correlation coefficient for parametric values or Spearman's correlation coefficient for non-parametric values. Multiple linear regression analyses were used to determine which variables were independently associated with VDS-O, VDS-P or PAS adjusted for gender, age, BMI, NIHSS, MMSE-K and albumin. Statistical Package for the Social Sciences (Statistics for Windows, Version 21.0; IBM, Armonk, NY) was used for the statistical analyses. Statistical significance was defined as a P value of less than 0.05.

RESULTS

The demographic and clinical features as well as anthropometric data of the 64 patients (31 male, 33 female) are presented in Table 1. Multivariable logistic regression analyses were conducted to determine the factor most associated with occurrence of aspiration in Table 2. The results of the partial linear correlation analyses between each independent variable and dysphagia assessment are presented in Table 3. Multiple linear regression analyses with the stepwise method were conducted to determine the factor most associated with dysphagia in Table 4. Age, gender, BMI, NIHSS, MMSE-K, Albumin, AROM, HLS, HGS, CC differed significantly between two groups classified by the PAS scores (1-5 and 6-8). (Table 1) Multivariable logistic regression analysis showed that occurrence of aspiration was independently associated with HLS (OR=0.771; 95% CI=0.628-0.946; P=0.013) and HGS (OR=0.850; 95% CI=0.731-0.988; P=0.034). (Table 2) The HLS, HGS, CC and dysphagia

Table 1. Demographic characteristics and anthropometric data.

Characterics	Total (n=64)	Non-Aspiration (PAS 1-5) (n=46)	Aspiration (PAS 6-8) (n=18)	P value
Age, years, mean (SD)	62.57 (15.4)	61.28 (16.8)	65.43 (11.1)	0.021*
Gender, male:female	31:33	21:25	10:8	0.204
Height, cm, mean (SD)	161.61 (9.41)	160.26 (9.5)	164.94 (8.5)	0.073
Weight, kg, mean (SD)	60.43 (10.8)	61.24 (11.1)	58.38 (10.1)	0.328
BMI, kg/m ² , mean (SD)	23.12 (2.6)	23.69 (2.5)	21.31 (2.1)	0.001**
Subtype, ischemic:hemorrhagic	28:36	21:25	7:11	0.624
Lesion side, right:left:bilateral	32:24:8	26:14:6	6:10:2	0.165
Specific location of stroke, ACA:MCA:PCA:both	5:45:11:3	4:33:8:1	1:12:3:2	0.490
NIHSS, score, median [IQR]	5.5 [4.0-8.0]	4.0 [4.0-7.5]	7.0 [4.0-11.75]	0.029*
MMSE-K, score, median [IQR]	21.0 [16.5-25.0]	22.0 [17.0-26.5]	19.0 [14.75-21.25]	0.026*
Albumin, g/dL, mean (SD)	3.71 (0.28)	3.74 (0.27)	3.61 (0.31)	0.042*
Time from onset, days, mean (SD)	20.1 (5.1)	18.7 (4.7)	21.5 (6.2)	0.391
PROM, degree, mean (SD)	65.42 (4.94)	65.17 (4.85)	65.89 (5.18)	0.602
AROM, degree, mean (SD)	56.48 (7.28)	58.17 (7.02)	51.72 (5.89)	0.001**
HLS, %, mean(SD)	86.13 (7.92)	89.07 (6.61)	78.44 (5.51)	<0.001**
HGS, kg, mean (SD)	24.47 (7.46)	25.79 (7.42)	20.93 (6.21)	0.011*
CC, cm, mean (SD)	32.82 (2.51)	33.26 (2.53)	31.54 (2.16)	0.014*
Dysphagia Assessment, score, median [IQR]				
VDS-O	4.5 [3.0-7.5]	3.0 [2.5-4.0]	5.0 [3.5-13.0]	0.037*
VDS-P	15.5 [8.5-23.5]	10.5 [6.5-16.0]	23.5 [20.5-28.5]	<0.001**
PAS	3.5 [2.0-6.0]	2.5 [2.0-3.5]	7.0 [6.0-8.0]	<0.001**

*P<0.05, **P<0.01.

BMI: Body mass index, NIHSS: National Institute of Health Stroke Scale, MMSE-K: Korean version of the mini-mental state examination, PROM: Passive range of motion, AROM: Active range of motion, HLS: Head lifting strength, HGS: Hand grip strength, CC: Calf circumference, VDS-O: Videofluoroscopic dysphagia scale-oral phase, VDS-P: Videofluoroscopic dysphagia scale-pharyngeal phase, PAS: Penetration-Aspiration scale.

Table 2. Multivariable logistic regression analysis for the occurrence of aspiration.

Variables	OR	95% CI	P
Age	0.965	0.878-1.060	0.458
Gender (female)	0.220	0.032-1.493	0.121
BMI	0.988	0.866-1.144	0.328
NIHSS	1.136	0.952-1.355	0.158
MMSE-K	0.993	0.839-1.176	0.935
Albumin	0.209	0.009-4.794	0.327
HLS	0.771	0.628-0.946	0.013*
HGS	0.850	0.731-0.988	0.034*
CC	0.861	0.526-1.409	0.552

*P<0.05.

OR: Odds ratio, CI: Confidence interval, BMI: Body mass index, NIHSS: National Institute of Health Stroke Scale, MMSE-K: Korean version of the mini-mental state examination, HLS: Head lifting strength, HGS: Hand grip strength, CC: Calf circumference.

assessment score showed significant correlations (Table 3); among these, the HLS and the VDS-P score ($r = -0.715$) were most highly correlated. In the multiple linear regression analysis of the dysphagia assessment, HLS, HGS and CC were independently associated with the dysphagia assessment. (Table 4) Results

indicated that only the HGS (standardized $\beta = -.623$, $P < .01$) was independently associated with the VDS-O. The HLS (standardized $\beta = -.696$, $P < .001$) was the most significant predictor of VDS-P, followed by the HGS (standardized $\beta = -.405$, $P < .05$). The HLS (standardized $\beta = -.626$, $P < .001$) was also the most significant

Table 3. Partial correlation coefficient (r) adjusted for gender, age, BMI, NIHSS, MMSE-K and albumin.

Variables	VDS-O		VDS-P		PAS	
	r	P	r	P	r	P
Total (n=64)						
HLS	-.205	.103	-.715	<.001**	-.662	<.001**
HGS	-.517	<.001**	-.437	<.001**	-.431	<.001**
CC	-.315	.013*	-.224	.091	-.239	.071
Non-aspiration (PAS 1-5) (n=46)						
HLS	-.226	.113	-.494	<.001**	-.406	.007**
HGS	-.421	.005**	-.337	.021*	-.322	.033*
CC	-.315	.048*	-.203	.127	-.254	.096
Aspiration (PAS 6-8) (n=18)						
HLS	-.272	.151	-.508	.019*	-.435	.043*
HGS	-.485	.023	-.395	.059	-.354	.065
CC	-.449	.041*	-.265	.156	-.324	.133

*P<0.05, **P<0.01.

BMI: Body mass index, NIHSS: National Institute of Health Stroke Scale, MMSE-K: Korean version of the mini-mental state examination, VDS-O: Videofluoroscopic dysphagia scale-oral phase, VDS-P: Videofluoroscopic dysphagia scale-pharyngeal phase, PAS: Penetration-Aspiration scale, HLS: Head lifting strength, HGS: Hand grip strength, CC: Calf circumference.

Table 4. Multiple linear regression analyses for dysphagia assessment adjusted for gender, age, BMI, NIHSS, MMSE-K and albumin.

Variables	VDS-O		VDS-P		PAS	
	β	P	β	P	β	P
Total (n=64)						
HLS	-.158	.256	-.696	<.001**	-.626	<.001**
HGS	-.623	.004**	-.405	.011*	-.384	.017*
CC	-.305	.115	-.235	.067	-.065	.649
Non-aspiration (PAS 1-5) (n=46)						
HLS	-.136	.315	-.534	.005**	-.481	.011*
HGS	-.385	.037*	-.332	.055	-.313	.065
CC	-.264	.176	-.238	.124	-.093	.572
Aspiration (PAS 6-8) (n=18)						
HLS	-.201	.233	-.376	.045*	-.251	.088
HGS	-.308	.061	-.233	.092	-.279	.081
CC	-.185	.264	-.129	.351	-.102	.434

*P<0.05, **P<0.01.

β : standardized regression coefficient, BMI: Body mass index, NIHSS: National Institute of Health Stroke Scale, MMSE-K: Korean version of the mini-mental state examination, VDS-O: Videofluoroscopic dysphagia scale-oral phase, VDS-P: Videofluoroscopic dysphagia scale-pharyngeal phase, PAS: Penetration-Aspiration scale, HLS: Head lifting strength, HGS: Hand grip strength, CC: Calf circumference.

predictor of PAS, followed by the HGS (standardized β = -.384, P<.05). Total predictive value for the multiple regression analysis was approximately 43% (VDS-O, adj. R^2 =.431), 64% (VDS-P, adj. R^2 =.639), 60% (PAS, adj. R^2 =.602), respectively.

DISCUSSION

This study aimed to investigate the role of HLS as a simple useful tool for assessing the severity of dysphagia in stroke patients. Partial correlation and multiple regression analysis was performed to evaluate the relationship between HLS and severity of dysphagia. We confirmed that HLS can be an effective

tool for assessing the severity of dysphagia, especially pharyngeal phase of dysphagia.

There were factors that showed a significant difference between the two groups divided according to PAS, but only HLS and HGS were independently associated after regression. These results are consistent with previous studies that HLS is associated with aspiration¹⁶, and that lower HGS is a risk factor for aspiration pneumonia²⁶. Several factors lost significance after regression analysis. The reason may be that the difference between the two groups may not be large enough for other factors, or the tendency may not be sufficiently expressed due to the small number of aspiration groups compared to the non-aspiration group.

HLS was associated with VDS-P and PAS as severity of dysphagia in the pharyngeal phase, but not with VDS-O as severity of dysphagia in the oral phase. HLS indicates the strength of submental suprahyoid muscles such as the digastric, geniohyoid and mylohyoid. These muscles facilitate opening of the UES by pulling the hyoid bone anteriorly and superiorly, preventing aspiration caused by incomplete pharyngeal clearance^{27,28}. Previous studies reported that the head lift exercise (HLE), also called Shaker exercise, had a significant effect on hyolaryngeal excursion, UES opening width and bolus clearance time in healthy older adults²⁹. Specifically for each muscle, geniohyoid, one of the suprahyoid muscle, is reportedly smaller in patients who underwent dysphagia with aspiration³⁰. In addition, Baba et al. reported that geniohyoid muscle significantly affected the duration of swallowing sounds¹⁰. Swallowing sound is a measure for evaluating dysphagia, and longer duration has been reported in patients with aspiration or laryngeal penetration³¹. Considering the mechanism of action and function of the suprahyoid muscles, HLS might have a significant effect on vallecular residues, pyriform sinus residues, and laryngeal elevation among the sub-items of VDS-P. HLS was also significant associated with PAS as a method of evaluating the pharyngeal phase by the same way. However, HLS was not associated with VDS-O

because oral phase dysphagia could progress without suprahyoid muscle weakness. Wakabayashi et al. also reported that head lifting strength assessed by MRC score was independently associated with dysphagia with aspiration, but not the presence of dysphagia¹⁶. These results are compatible with the findings of our study.

HGS was significantly associated with all three dysphagia assessment scales, VDS-O, VDS-P and PAS. In particular, as mentioned in the paragraph above, HLS was not associated with oral-phase dysphagia, but HGS was also associated with VDS-O, not only with VDS-P. Maeda et al. reported that low hand-grip strength was associated with sarcopenic dysphagia³². However, whether HGS has a more significant association with which phase in the oral phase or pharyngeal phase has not been separately studied. Previous studies have investigated the association between HGS and tongue strength^{33,34}. An association between decreased tongue pressure and grip strength was found in community-dwelling older individuals³³ and in older inpatients of a rehabilitation hospital³⁴. As tongue strength has been reported as a good predictor of the presence of oral-phase dysphagia^{35,36}, HGS, which is associated with tongue strength, may also affect oral-phase dysphagia. HGS correlates not only with tongue pressure as oral-phase dysphagia predictor, but also with cross-sectional area of the geniohyoid muscle as pharyngeal-phase dysphagia indicator³⁷. These results is consistent with our study about the significant association of HGS with both VDS-O and VDS-P. In Table 3, HGS was not significant for VDS-P and PAS in the aspiration group. The reason may be that the tendency may not be sufficiently expressed due to the small number of aspiration group compared to the non-aspiration group.

Matsuo and Yoshimura previously reported that CC was independently associated with dysphagia among older people in acute-care inpatients³⁸. Additionally, Kurosawa et al. reported that CC was significantly correlated with dysphagia severity scale (DSS) and functional oral intake scale (FOIS) as a scale for

severity of dysphagia and the presence of dysphagia was independently associated with CC, after adjusting for age and sex³⁹. They presented CC is a useful index for assessing dysphagia among community dwelling individuals who require long-term care.

However, in the current study, CC was correlated with oral-phase dysphagia in partial correlation analysis, but not after regression analysis. The possible explanation for this discrepancy is that the patients in our study had lost systemic skeletal muscle mass including calf muscles due to immobilization by bed-ridden state in the intensive care unit for a certain period immediately after stroke. Disuse is a common cause of muscle atrophy and a period of disuse ranging between 10 and 42 days generally leads to a rate of muscle loss of approximately 0.5-0.6% of total muscle mass per day although there is considerable variation between people⁴⁰. The first muscles to atrophy and weaken in the bed-ridden state are those in the lower limbs rather than the upper limbs as these are anti-gravity muscles that resist gravitational forces in the upright position⁴¹. In addition, muscles atrophy with a loss in size and mass generally occur around 30% to 40% in spastic paralysis of stroke⁴². Another possible explanation for this discrepancy is that the oral phase, which is predominately under volitional control, is greatly affected by lingual discoordination that occurs in stroke patients⁴³. In stroke patients, there are many sensorimotor factors that affect oral-phase dysphagia in addition to the muscle mass component²⁴. Oral-phase dysphagia includes difficulties in bolus formation due to buccofacial apraxia and deterioration of lip sealing, tongue movement and mastication, as well as problems with residual oral remnants due to lack of oral sensory awareness. Robbins et al.⁴⁴ noted increased disturbances in lingual, labial, and mandibular coordination in patients with left hemispheric damage (LHD) and suggested that the oral phase of swallowing is predominately a function of the left hemisphere. Irie and Lu⁴⁵ also noted that oral stage dysfunction was more evident after LHD, although the dysmotility patterns were not explicitly described.

There are some limitations to this study. First, this study was carried out at a single rehabilitation hospital, possibly limiting the generalization of the results. Therefore, a multicenter large-scale research is necessary to verify the results of the present study. Second, a causal relationship between HLS, HGS, CC and dysphagia was unclear due to the cross-sectional study design. Accordingly, more elucidations on the causal relationship need to be determined through longitudinal research and intervention research in the future. Third, we used CC instead of dual-energy X-ray absorptiometry or bioelectrical impedance analysis to measure muscle mass, which lacks diagnostic accuracy. In addition, physical function such as gait speed was not included as an additional factor because many patients could not walk independently. Finally, we did not measure muscle quality. Muscle tissue is replaced as a contractile tissue by fat and fiber in older people. There is also a study showing changes in increased muscle fibers and adipose tissue using echo-intensity of ultrasound¹². In conclusion, HLS was significantly associated with severity of pharyngeal-phase dysphagia and can be a convenient tool for assessing the pharyngeal-phase dysphagia in daily clinical settings.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ETHICS APPROVAL

This study was approved by the general hospital's institutional review board, and informed consent was obtained from all patients.

AUTHORS' CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: Hyun Im Moon; data collection: Jeong A Ham, Min Kyeong Ma; analysis and interpretation of results: Gyu Seong Kim;

draft manuscript preparation: Gyu Seong Kim, Hyun Im Moon. All authors reviewed the results and approved the final version of the manuscript.

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