

*Original Article***The effect of tongue pressure strengthening exercise for dysphagic patients**

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ABSTRACT

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Objective: The purpose of this study was to investigate the efficacy and the effect of tongue pressure strengthening exercise for dysphagic patients by quasi-randomized controlled trial.

Methods: Thirty-four dysphagic patients were randomly assigned to either an intervention group that received rehabilitation including tongue pressure strengthening exercise or a control group that received conventional rehabilitation. Both groups participated in a 40-minute rehabilitation program five times a week for three weeks, and the intervention group also participated in tongue pressure strengthening exercise for ten minutes. We evaluated the Maximum Tongue Pressure (MTP), Swallowing Tongue Pressure (STP), Dysphagia Severity Scale (DSS), Eating Status Scale (ESS), Functional Oral Intake Scale (FOIS), and Mann Assessment of Swallowing Ability (MASA) before and after the intervention.

Results: Both groups demonstrated a significant improvement in the DSS, ESS, FOIS and MASA scores ($p < 0.01$). Only the intervention group showed

a significant improvement in the MTP and STP scores. A comparison of the degree of change between the two groups showed a significant improvement in the MTP, STP and MASA of the intervention group. The intervention group also showed five improvements in the oral and the pharyngeal function in the MASA items.

Conclusion: The tongue pressure strengthening exercise promoted the improvement of dysphagia. Furthermore, this finding suggests that the exercise led to the improvement of not only the oral phase but also the pharyngeal phase of the swallowing function.

Key words: tongue pressure, dysphagia, rehabilitation, quasi-randomized controlled trial

Introduction

Tongue movement in the swallowing function is related to the oral preparatory stage and the oral propulsive stage such as bolus formation and lingual bolus propulsion [1]. Furthermore, the possibility that tongue exercise influences pharyngeal function has been reported [2, 3].

In dysphagia rehabilitation, a commonly used indirect approach is tongue movement training. However, the training method and intensity are not clear, and there is little supporting data available [4]. Recently, tongue function has been studied by examining tongue pressure [5, 6]. In the United States, research on tongue pressure is based on measurements taken by the Iowa Oral Performance Instrument (IOPI) [7–11]. In Japan, a tongue pressure measuring instrument manufactured by JMS and released in 2011 is widely used [12, 13].

The contact between the tip of the tongue and the hard palate plays an important role as an anchor when the tongue holds the bolus in the oral cavity and propels it to the pharynx [14]. It has been reported that

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the anchor function of the tongue is important for the improvement of swallowing pressure [9]. To quantitatively evaluate tongue movement, we decided to measure the pressure that the tip of the tongue exerts on the anterior hard palate when squeezing back during lingual bolus propulsion, and defined the tongue pressure as this value [12]. Tongue pressure has been measured by various methods in previous studies [5, 7–9], and the pressure of the tip of the tongue evaluated by the JMS tongue pressure measuring instrument corresponds to the tongue pressure. We investigated the relationship between tongue pressure and videofluoroscopic examination of swallowing (VF) findings. We reported the possibility that strengthening the maximum tongue pressure and swallowing tongue pressure could improve the swallowing function of dysphagic patients. Although there are some reports of case studies and before-after studies [15], there are no reports on randomized controlled trials.

The purpose of this quasi-randomized controlled trial study was to investigate whether tongue pressure strengthening exercise for dysphagic patients facilitates the improvement of dysphagia and to clarify its effect in the oral and pharyngeal phases.

Methods

1. Subjects

The study subjects were thirty-four dysphagic patients (21 men, 13 women, average age 72.3 ± 10.9 years) during hospitalization in our hospital. Inclusion criteria were the following: 1) patients diagnosed with dysphagia by a rehabilitation doctor and receiving dysphagia rehabilitation; 2) patients with the ability to understand the guidance related to this study; and 3) patients consenting to this study. Exclusion criteria were the following: 1) patients with a morphological abnormality related to the oral cavity and tongue; 2) patients with dementia scoring less than 20 points in the revised Hasegawa's dementia scale (HDS-R) [16]; and 3) patients with an unstable medical status. We selected dysphagic patients who met all inclusion criteria, and did not meet any of the exclusion criteria. The subjects comprised twenty-three cerebrovascular disease patients, four disuse syndrome patients, three postoperative thoracotomy patients, one traumatic brain injury patient, and three pneumonia patients.

At the start of the study, written informed consent was obtained from all the subjects. The subjects were informed that the data provided would not be used for any purpose other than for the study, that personal identifiable information would be masked, and that they could withdraw from the study at any time.

2. Study design

The design of this study adopted a quasi-randomized controlled trial of a prospective intervention study. The subjects were randomly and alternately divided

into two groups: the intervention group that received rehabilitation including tongue pressure strengthening exercise, and the control group that received conventional rehabilitation. This was a single-blind study where the therapists know which group each subject is in, but the subjects do not know, and the evaluators and therapists are separated. The evaluation was carried out by rehabilitation doctors and licensed occupational therapists registered with the Japanese Society of Dysphagia Rehabilitation. Rehabilitation was performed by occupational therapists.

3. Intervention

A JMS tongue pressure measuring instrument was used in the evaluation and the exercise. Two types of exercise were applied for tongue pressure strengthening (Fig. 1). One was an isometric contraction exercise; the other was a tongue pressure pattern exercise.

In the isometric contraction exercise, the subjects placed a probe in their oral cavity, and pushed the tip of their tongue against the hard palate using 80% of the maximum tongue pressure [6–11, 17]. This exercise was repeated more than fifty times.

In the tongue pressure pattern exercise, subjects pushed the tip of their tongue against the hard palate using 60% of the maximum tongue pressure while swallowing saliva for reference to the “effortful” swallow [18] and the “swallow with stress on anchor function” [19]. This exercise was repeated more than twenty times. In addition, the exercise was performed while being given visual feedback. Furthermore, ice massage for the pharynx [20] was performed if subjects felt that the probe was a foreign object and the swallowing reflex was hard to achieve.

The intervention group performed the two tongue pressure strengthening exercises for five minutes each. In between the exercises, the ice massage for the pharynx and the head raising exercise [21] were carried out. The training programs such as the tongue movement, the ice massage for the pharynx and the head raising exercise were selected and performed individually as the exercise for the control group. The exercise for both groups was unified for forty minutes, five days a week for three weeks.

4. Evaluation

Rehabilitation outcomes were evaluated between before and after the intervention using the Dysphagia Severity Scale (DSS) [22], Eating Status Scale (ESS) [23], Functional Oral Intake Scale (FOIS) [24] and Mann Assessment of Swallowing Ability (MASA) [25].

Outcome items

(1) Tongue pressure

1) Maximum Tongue Pressure (MTP)

The MTP was measured using the JMS tongue pressure measuring instrument. Evaluators inserted an

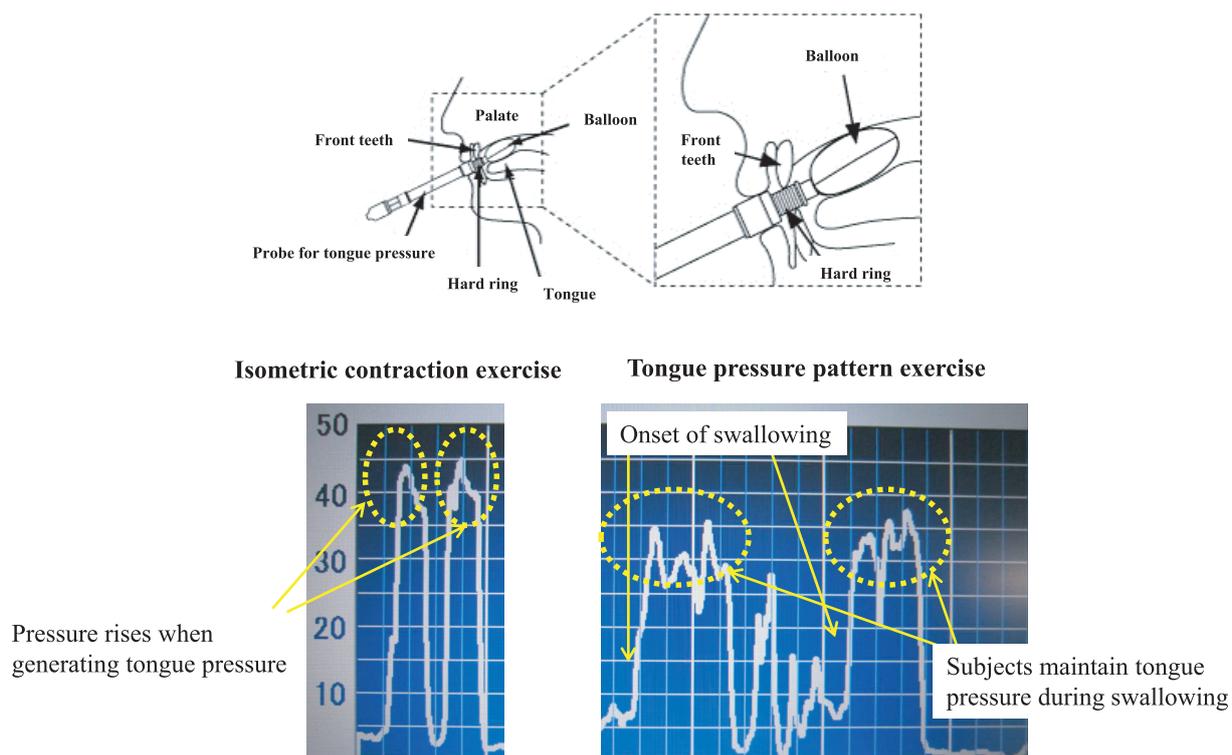


Figure 1. Method for measuring tongue pressure and the transition of tongue pressure during tongue pressure strengthening exercise.

automatically precharged tongue pressure probe in the subjects' oral cavity, and instructed the subjects to use the tip of their tongue and push the balloon of the probe against the hard palate using the maximum power. The subjects did this three times while measurements were taken and visual feedback was given. The mean value of the three measurements was defined as the "the MTP value". The measurement position was determined based on a stable posture such as that at the time of the daily oral intake. Evaluators considered risk management while checking the vital signs at the measurement time.

2) Swallowing Tongue Pressure (STP)

Evaluators placed a balloon in the subjects' oral cavity between the tip of their tongue and the hard palate, similar to the MTP measurement, and the STP was measured during swallowing of saliva. Evaluators checked the elevation of the larynx for an accurate measurement. The mean value of the three measurements was defined as the "the STP value".

(2) Dysphagia Severity Scale (DSS)

The severity of swallowing dysfunction was evaluated using the Dysphagia Severity Scale (DSS) [22]. The DSS is a 7-point ordinal scale, where the lower scores indicate more severe dysphagia. The DSS was comprehensively determined by various evaluation results.

(3) Eating Status Scale (ESS)

Eating status was evaluated using the Eating Status Scale (ESS) [23]. The ESS indicates nutritional status

using a 5-point ordinal scale to score the ratio of oral feeding and tube feeding. Accordingly, the lower the ratio of oral feeding, the lower the score.

(4) Functional Oral Intake Scale (FOIS)

The FOIS [24] is a 7-point ordinal scale, where nothing by mouth is 1 point and regular diet is 7 points. The FOIS is a global assessment scale used to evaluate modified diets and nutritional status.

(5) Mann Assessment of Swallowing Ability (MASA)

The MASA [25] test has a total score of 200 points. It is generally understood that a low number of evaluation points indicates severe dysphagia. The MASA is a global assessment scale that can provide a quick clinical evaluation of dysphagia.

5. Study method and statistical analysis

Subjects' demographic characteristics and the values of evaluation items of both groups were compared before the intervention. Additionally, the values of evaluation items in each group were compared between before and after the intervention (comparison within the group). Furthermore, the degree of change calculated by subtracting the value before the intervention from that after the intervention was compared in both groups (comparison between groups). Evaluation values of the MTP and STP with an increase of more than 10% were defined as an effective improvement.

Statistical analysis was performed using the *t*-test,

chi-square test and Mann-Whitney *U* test in the comparison of both groups before the intervention. In addition, comparison between before and after the intervention in both groups was analyzed using the paired *t*-test and Wilcoxon signed-rank test. Furthermore, the comparison between both groups in which the degree of change was calculated by subtraction was analyzed using the *t*-test and Mann-Whitney *U* test. The statistical significance level was set at less than 5%.

Results

1. Subjects' progress (Fig. 2)

The flow diagram of the subjects' progress is shown

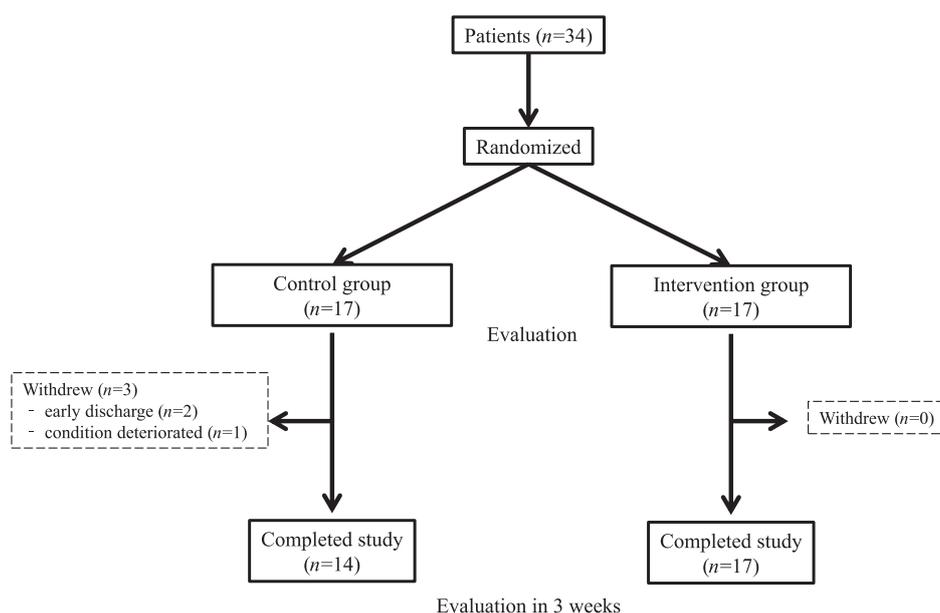


Figure 2. Flow diagram of the subjects' progress.

Table 1. Comparison of characteristics of subjects and each evaluation item before the intervention.

	Control group (n=14)	Intervention group (n=17)	<i>p</i> Value
Age (years)	74.7±10.9	69.9±11.5	0.25 ^a
Gender (male/female)	10/4	10/7	0.72 ^b
Disease (CVD/other)	9/5	12/5	0.99 ^b
Dysphagia type (bulbar/pseudo bulbar/others)	1/4/9	3/6/8	0.55 ^b
Time since CVD (day)	15 (14–20)	20 (17.75–58)	0.095 ^c
MTP (kPa)	26.1±10.7	18.4±11.5	0.066 ^a
STP (kPa)	5.6±2.5	4.0±1.8	0.063 ^a
DSS	3 (3–4)	3 (2–3)	0.056 ^d
ESS	3.5 (2–4)	2 (1–4)	0.35 ^d
FOIS	3.5 (2–4)	2 (1–4)	0.35 ^d
MASA	160.3±25.6	143.5±28.8	0.10 ^a

CVD, cerebrovascular disease; MTP, maximum tongue pressure; STP, swallowing tongue pressure. Mean±SD Median (IQR). ^a: Student's *t*-test. ^b: Chi-square test. ^c: Welch's *t*-test. ^d: Mann-Whitney *U*-test. There were no significant differences in subjects' demographic characteristics between the two groups.

in Fig. 2. Of the thirty-four subjects, thirty-one completed all the exercise programs. The three dropouts comprised two subjects who were discharged from the hospital and one subject whose condition deteriorated during the study.

2. Comparison of characteristics of subjects and each evaluation item before the intervention (Table 1)

There were no significant differences in subjects' demographic characteristics between the two groups.

3. Comparison between before and after the intervention in each group (Table 2)

Each evaluation item of the control group and the

intervention group was compared between before and after the intervention. Significant differences were found in the MTP, STP, DSS, ESS, FOIS and MASA of the intervention group ($p < 0.01$). Although there were significant differences in the DSS, ESS, FOIS, MASA of the control group ($p < 0.01$), neither the MTP nor STP showed a significant difference ($p = 0.25$, $p = 0.51$).

4. Comparison between before and after the intervention between the two groups (Table 3)

There were significant changes in the MTP and STP of the intervention group ($p < 0.05$). Although the DSS, ESS and FOIS of the intervention group had a larger degree of change than that of the control group, significant changes were not found. On the other hand, there was a significant change in the MASA of the intervention group ($p < 0.05$).

Next, we performed a detailed examination of each evaluation item of MASA where a significant degree of change was found in the intervention group (Table 4). As a result, significant differences were observed in the tongue movement ($p < 0.05$), tongue strength ($p < 0.05$), bolus clearance ($p < 0.05$), oral transit ($p < 0.01$) and pharynx response ($p < 0.05$).

Discussion

1. With respect to the effect of tongue pressure strengthening exercise

This quasi-randomized controlled trial study examined whether dysphagia rehabilitation including tongue pressure strengthening exercise for dysphagic patients was more effective than conventional dysphagia rehabilitation.

The tongue pressure has an important role to control

Table 2. Comparison between before and after the intervention in the two groups.

	Control group (n=14)				Intervention group (n=17)			
	Pre	Post	p Value	Mean difference (95% CI)	Pre	Post	p Value	Mean difference (95% CI)
MTP (kPa)	26.1±10.7	27.7±11.9	0.25 ^a	1.6 (-1.3 to 4.6)	18.4±11.5	23.5±12.5	0.000 ^{***a}	5.0 (3.3 to 6.8)
STP (kPa)	5.6±2.5	5.9±2.8	0.51 ^a	0.3 (-0.6 to 1.1)	4.0±1.8	6.2±3.3	0.002 ^{**a}	2.2 (0.9 to 3.5)
DSS	3 (3-4)	4 (3.25-5.5)	0.005 ^{***b}	-	3 (2-3)	3 (3-4)	0.000 ^{***b}	-
ESS	3.5 (2-4)	4(4-4)	0.004 ^{***b}	-	2 (1-4)	4 (3-4)	0.002 ^{**b}	-
FOIS	3.5 (2-4)	5 (4-6)	0.001 ^{***b}	-	2 (1-4)	5 (3-6)	0.000 ^{***b}	-
MASA	160.3±25.6	172.9±25.5	0.000 ^{***a}	12.6 (8.8 to 16.4)	143.5±28.8	163.5±25.8	0.000 ^{***a}	20 (14.3 to 25.7)

Mean±SD Median (IQR). ^a: Paired *t*-test. ^b: Wilcoxon's signed-rank test. ^{**} $p < 0.01$ ^{***} $p < 0.001$
There were no significant changes in the amount of change of MTP and STP of the control group.

Table 3. Comparison of degree of change between before and after the intervention between the two groups.

	Control group (n=14)	Intervention group (n=17)	p Value	Mean difference (95% CI)
MTP (kPa)	1.6±5.1	5.1±3.4	0.03 ^a	3.5 (0.3 to 6.6)
STP (kPa)	0.3±1.5	2.2±2.5	0.014 ^a	1.9 (0.4 to 3.5)
DSS	1 (0-1)	1 (1-1)	0.57 ^b	-
ESS	1 (0.25-1)	1 (0-2)	0.71 ^b	-
FOIS	1.5 (1-2)	2 (1-3)	0.74 ^b	-
MASA	12.6±11.0	20.0±11.0	0.04 ^a	7.4 (0.5 to 14.2)

Mean±SD Median (IQR). ^a: Student's *t*-test. ^b: Mann-Whitney *U*-test. ^{*} $p < 0.05$

The degree of change was obtained by subtracting the measured value before the intervention from that after the intervention. There were significant changes in the amount of change of MTP, STP and MASA of the intervention group ($p < 0.05$).

Table 4. Detailed examination of each evaluation item of MASA in the intervention group.

	The Mann Assessment of Swallowing Ability (MASA)						
	Control group	Intervention group	<i>p</i> Value		Control group	Intervention group	<i>p</i> Value
Alertness	0.15±0.55	0.50±0.89	0.21 ^b	Tongue coordination	0.15±0.55	0.81±1.28	0.14 ^b
Cooperation	0.15±0.56	0.13±0.50	0.89 ^a	Oral preparation	0.46±0.88	1.13±1.02	0.10 ^a
Auditory comprehension	0.15±0.55	0	0.28 ^a	Gag reflex	0.23±0.83	0.06±0.25	0.49 ^b
Respiration	2.61±1.26	2.12±1.86	0.41 ^b	Palatal movement	0.46±0.88	0.63±0.96	0.63 ^a
Respiration rate after swallow	0.92±1.04	0.63±1.20	0.31 ^a	Bolus clearance	0	0.94±1.29	0.01 ^{*a}
Aphasia	0.08±0.28	0	0.34 ^b	Oral transit	0	1.13±1.26	0.003 ^{**a}
Apraxia	0	0	No Change	Cough reflex	0.31±0.75	0.13±0.50	0.47 ^b
Dysarthria	0.46±0.52	0.25±0.45	0.27 ^a	Voluntary cough	1.00±1.15	1.06±1.43	0.88 ^a
Saliva management	0.23±0.44	0.69±0.79	0.08 ^b	Voice	1.54±1.45	1.50±1.55	0.98 ^a
Lip seal	0.15±0.38	0.38±0.5	0.41 ^a	Tracheostomy	0	0	No Change
Tongue movement	0.62±0.96	1.38±1.20	0.04 ^{*a}	Pharyngeal phase	1.62±1.39	2.13±1.15	0.14 ^a
Tongue strength	0.38±0.96	1.75±1.81	0.02 ^{*a}	Pharyngeal response	1.38±2.18	3.25±1.98	0.01 ^{*a}

Mean±SD. ^a: Student's *t*-test. ^b: Welch's *t*-test. **p*<0.05 ***p*<0.01

Significant differences were observed in tongue movement (*p*<0.05), tongue strength (*p*<0.05), bolus clearance (*p*<0.05), oral transit (*p*<0.01) and pharynx response (*p*<0.05).

the flow of bolus passing through the oral cavity and pharynx [26]. If tongue pressure generation is affected, pharyngeal residue caused by poor laryngeal penetration and bolus clearance will create a risk of aspiration [14]. Robbins demonstrated that tongue strengthening exercise by isometric contraction for dysphagic patients improves tongue pressure and dysphagia [9], the MTP decreases with aging, and the STP remains constant with aging [7]. Steele reported that a tongue pressure training program improves tongue pressure and aspiration [27]. The standard value of the MTP in elderly people over 70 years was found to be 31.9 ± 8.9 kPa [6], and the repeatability and reliability of the measurement were assessed [13]. In this study, the MTP value before the intervention was lower than the standard value. The value of the control group was 26.1 ± 10.7 kPa, and the value of the intervention group was 18.4 ± 11.5 kPa. Thus, there are many patients whose tongue pressure decreases so as not to be able to generate effective tongue pressure for swallowing due to diseases in clinical practice.

We considered that strengthening of both the MTP and STP is necessary to improve the swallowing function. For this purpose, each training under the principle of specificity in muscle strengthening [17] was considered effective for strengthening both of the tongue pressures, and we devised and carried out two types of tongue pressure strengthening exercises. The first one was an isometric contraction exercise to strengthen the MTP which has been reported in previous literature. The second one was a tongue pressure pattern exercise to strengthen the STP.

In the comparison of before and after the intervention

in each groups of this study, significant improvement was observed in the items of the DSS, ESS, FOIS, and MASA in both groups. Regardless of whether or not the tongue pressure strengthening exercise was included in the rehabilitation program, it was possible to show the effectiveness of dysphagia rehabilitation. However, a significant improvement was found with only the MTP and STP in the intervention group, which was considered to show the importance of tongue pressure strengthening exercise.

Furthermore, comparing the change before and after the intervention in order to show the efficacy and effect of the tongue pressure strengthening exercise, a significant improvement in not only the MTP and STP but also the MASA was observed in the intervention group compared to the control group. It was considered that the training including the tongue pressure strengthening exercise shows a greater possibility of improving swallowing disorders compared to the conventional training. On the other hand, the reason why there was no significant difference in the DSS, ESS, and FOIS other than the MASA, was the lack of evaluation categories and the narrowness of the range of each category. Also, a significant change was observed in the five items related to the oral and pharyngeal phases of the MASA in the intervention group. As the tongue is composed of intrinsic and extrinsic tongue muscles, strengthening of tongue pressure may be directly related to the oral phase of swallowing. Significantly improved items of the MASA, "tongue movement," "tongue strength," "bolus clearance," and "oral transit," had an influence on the intervention effect on the oral phase of the

tongue pressure strengthening exercise.

Furthermore, Palmer reported that the muscle involved in tongue pressure generation is the mylohyoid of the suprahyoid muscles, the anterior belly of the digastric and the intrinsic tongue muscles [2]. Fukuoka examined the muscle activity of various training and the suprahyoid muscles, and reported that the maximum tongue pressure movement was the highest muscle activity in all of them [3]. Tongue pressure generation may lead to not only the strengthening of tongue muscles but also the strengthening of the suprahyoid muscles. We thought that the tongue pressure pattern exercise promoted the transfer of motor learning by repeating the swallowing movement as the “effortful swallow”, the “hard swallow” [18] and the “swallow with stress on anchor function” [19], which is effective for pharyngeal residue by pressing the tongue to the hard palate during the swallowing reflex. Therefore, it may lead to the improvement of tongue pressure during the act of swallowing. The tongue movement of pressing and licking the probe that is placed in the mouth before the swallowing reflex appears was confirmed during the training, and the movement was part of bolus formation or bolus propulsion of the oral phase. Significant improvement was obtained in ‘Pharyngeal response’ of the MASA in the intervention group. “Pharyngeal response” was evaluated by coughing or talking after swallowing, and was determined by the reaction in the case of bolus passing through the pharynx and pharyngeal residue [25]. Robbins reported the improvement of the Penetration-Aspiration Scale (PAS) by the strengthening of the tongue pressure [9]. We also reported that tongue pressure has a significant correlation with oral function and vallecular residue in VF findings [12], where tongue pressure was related to the pharyngeal phase. Tongue pressure strengthening exercise prompted not only oral phase such as the muscle strength of tongue and bolus clearance, but also the muscle activity of the suprahyoid muscles. This study suggested the possibility of facilitating the improvement of swallowing disorders of the pharyngeal phase.

2. Clinical application of tongue pressure measurement and exercise

Texture modified foods and thickened fluids are often provided to reduce the risk of aspiration when patients suffer from dysphagia caused by disease. Although thickened fluids are safe for dysphagic patients, problems with taste lead to inadequate fluid intake and dehydration [28, 29]. Many patients disregard the advice of doctors and therapists, and drink thin liquids despite the documented risk of aspiration [30]. The establishment of strategies and training methods to maximally improve the swallowing function is considered important to improve this vicious circle. Therefore, for more effective training and programs for enhancing tongue pressure,

conditions such as the intensity and frequency of exercise should be considered, and it is important to gradually increase the intensity based on the principle of overload. Conventional resistance training using a tongue depressor has problems due to the unclear setting of the loading by therapists and no assessment of quantitative effects. In addition, the adjustment of exercise loads for the head raising exercise and the Mendelsohn maneuver [18] is not easy. On the other hand, establishing the training load and target value in consideration of the theory of motor learning and muscle strengthening can be carried out by evaluating the MTP and the STP of subjects using a tongue pressure measuring instrument before the training, and it is possible to observe the progress of the training. Currently, the way to confirm whether various swallowing methods such as the effortful swallow are actually acquired could be determined only by VF findings. Furthermore, the tongue pressure measuring instrument can be used for visual feedback to promote motor learning of the subjects, and it is simple to confirm whether or not the subjects can actually perform the movement aimed at by the therapist.

Although we are unable to determine that the training program with the tongue pressure strengthening exercise in this study is the best one, we consider it important to continue exploring more effective ways to improve the swallowing function and quality of life (QOL) regarding eating by patients.

3. Limitations of the study

There are limitations to this study: it was not separated by diagnostic type in the subject selection criteria, and the number of subjects was insufficient. If stroke or sarcopenia is found to have an effect on dysphagia, then the training will need to be adapted. In addition, the period to commencement of training of stroke patients is short, and so natural recovery may have an influence. Furthermore, the evaluation scales except the MASA are narrow in terms of the range of the rating scale, and are assessed by the ordinal scale. To clarify the training effect, it will be necessary to analyze the motion by VF and to measure the distance moved by the hyoid bone before and after the intervention.

Conclusion

The effect of tongue pressure strengthening exercise for dysphagic patients in this study was demonstrated by the quasi-randomized controlled trial.

In dysphagia rehabilitation, the tongue pressure strengthening exercise using a simplified tongue pressure measuring instrument is an effective training method to improve dysphagia. In addition, it is suggested to contribute to the improvement of dysphagia of the pharyngeal phase as well as the oral phase.

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