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Tongue-to-palate resistance training improves tongue strength and oropharyngeal swallowing function in subacute stroke survivors with dysphagia

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SUMMARY **Tongue function can affect both the oral and pharyngeal stages of the swallowing process, and proper tongue strength is vital for safe oropharyngeal swallowing. This trial investigated the effect of tongue-to-palate resistance training (TPRT) on tongue strength and oropharyngeal swallowing function in stroke with dysphagia patients. This trial was performed using a 4-week, two-group, pre–post-design. Participants were allocated to the experimental group (n = 18) or the control group (n = 17). The experimental group performed TPRT for 4 weeks (5 days per week) and traditional dysphagia therapy, whereas the control group performed traditional dysphagia therapy on the same schedule. Tongue strength was measured using the Iowa Oral Performance Instrument. Swallowing function was measured using the videofluoroscopic dysphagia scale (VDS) and penetration–aspiration scale (PAS) based on a videofluoroscopic swallowing study. Experimental group showed more improved in the tongue strength (both anterior and posterior regions, P = 0·009, 0·015). In addition, the experimental group showed more improved scores on the oral and pharyngeal phase of VDS (P = 0·029, 0·007), but not on the PAS (P = 0·471), compared with the control group. This study demonstrated the effectiveness of TPRT in increasing tongue muscle strength and improving swallowing function in patients with post-stroke dysphagia. Therefore, we recommend TPRT as an easy and simple rehabilitation strategy for improving swallowing in patients with dysphagia.**

KEYWORDS: tongue, stroke, dysphagia, aspiration, swallowing

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Introduction

The role of the tongue in oropharyngeal swallowing is extensive and essential to normal swallowing function. The tongue is a structure in the stomatognathic system and serves such primary functions as mastication, formation, manipulation and propulsion of bolus into the pharynx (1, 2). It also contributes to respiration and speech (3). During the swallowing process, in the oral stage, the front of the tongue squeezes food against the hard palate to transport it to the base of the tongue. Subsequently, in the pharyngeal stage, the swallowing reflex and contraction of the suprahyoid muscles occur.

However, neurogenic disorders, such as stroke, may weaken the tongue (4–6), resulting in reduced mastication, poor bolus formation, disturbed food transport into the pharynx, remaining residue in the oral cavity, leakage from the lips and aspiration (7, 8). In other words, impaired tongue function can affect both the oral and pharyngeal stages, and proper tongue strength and endurance are vital for safe swallowing (9).

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According to previous studies, tongue pressure reflects clinical signs of dysphagic symptoms during swallowing in acute stroke survivors (10). In addition, improved isometric tongue strength in stroke survivors with dysphagia is associated with increased pressure generation during swallowing as well as improvements in swallowing function and dysphagia-specific quality-of-life measures (7). Therefore, maintaining tongue pressure is important for safe swallowing in patients with oropharyngeal dysphagia.

Tongue-to-palate resistance training (TPRT) is a common remedial approach for swallowing rehabilitation, and its effectiveness has been verified in several studies. Several previous studies have reported increased tongue muscle strength and mass following TPRT in healthy or elderly adults (11, 12). Similarly, Robbins *et al.* (7) reported increased tongue muscle strength as well as decreased aspiration and enhanced quality of life related to swallowing function following TPRT in patients with neurologic disease.

Most previous studies on TPRT have used special tongue resistance training tools, which have useful functions, including adjustment of the degree of resistance and biofeedback (11, 12). However, such tools are costly and difficult to manipulate, which hinders their use by individuals at the hospital or at home. Therefore, in this study, we investigated the effectiveness of an easy TPRT method involving pressing the tongue strongly against the palate. The objective was to examine the effect of TPRT on tongue muscle strength and swallowing function in patients with post-stroke dysphagia. We hypothesised that TPRT would improve tongue muscle strength as well as oral and pharyngeal functions.

Methods

Participants

This study recruited stroke survivors with dysphagia from two university hospitals in the Republic of Korea. This study was conducted from July 2015 to March 2016. Inclusion criteria were as follows: (i) post-stroke oropharyngeal dysphagia confirmed by a videofluoroscopic swallowing study (VFSS), (ii) tongue muscle strength <10 kPa, (iii) Mini-Mental Status Examination score >20, (iv) able to swallow voluntarily and (v) cortex damage only. Exclusion criteria were as follows: (i) secondary stroke, (ii) trigeminal neuropathy, (iii) significant malocclusion, (iv) facial asymmetry, (v) parafunctional habits (clenching, bruxing, tongue thrusting) and (vi) measurement and exercise not possible because tongue muscle strength was 0 kPa.

This study was performed using a 4-week, two-group, pre–post-design. Participants were randomly allocated to the experimental group ($n = 21$) or the control group ($n = 20$) using a random allocation software program. The subjects' characteristics and all outcome measures were assessed before and after the intervention by an experienced physician and occupational therapist.

Intervention

The experimental group was treated with TPRT. The tongue was divided into anterior and posterior regions to determine the position and number of sets for each exercise, as described by Robbins *et al.* (7). The anterior tongue was positioned longitudinally along the hard palate, just posterior to the alveolar ridge. Posterior tongue was positioned with the posterior border of the hard palate (Fig. 1).

The experimental group performed 30 exercise repetitions for the anterior and posterior regions. The exercises were conducted in a random sequence. The exercise repetition number was determined based on findings from our pilot study as well as previous studies (7). The patient's lower chin was palpated during the exercise to verify contraction of the tongue muscles. Patients were allowed to rest for a few seconds

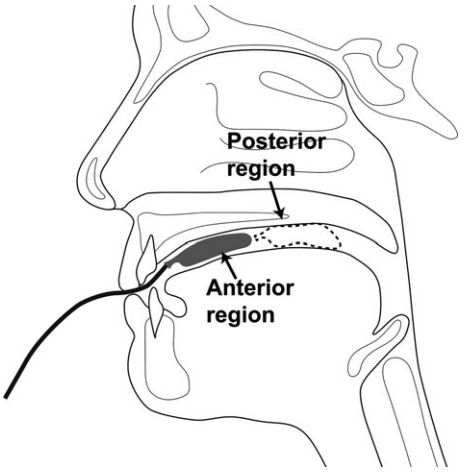

Fig. 1. Measurement of tongue muscles.

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when desired, to prevent excessive muscle fatigue. Both groups also received conventional dysphagia therapy including thermal tactile stimulation, facial massage and various manoeuvres. The intervention was conducted five times a week for 4 weeks by two experienced occupational therapists.

Outcome measures

Anterior tongue strength (ATS) and posterior tongue strength (PTS) were measured using the Iowa Oral Performance Instrument*. The IOPI includes a tongue bulb, connecting tube and main body. The bulb, which is made of soft rubber and is approximately 3·5 cm in length and 4·5 cm in diameter, is filled with approximately 2·8 mL of air. The bulb is connected to the main body by an 11·5-cm flexible tube. Tongue strength value was expressed in kilopascals (kPa) (13). To ensure measurement accuracy, calibration was checked once a week, as recommended in the IOPI manual.

Swallowing function was measured using the videofluoroscopic dysphagia scale (VDS) and penetration–aspiration scale (PAS) based on a VFSS. The VDS is a functional evaluation scale that comprehensively reflects overall swallowing function in stroke survivors based on VFSS findings. The 14 items in the VDS represent the oral phase (lip closure, bolus formation, mastication, apraxia, premature bolus loss and oral transit time) and pharyngeal phase (pharyngeal triggering, vallecular residue, pyriform sinus residue, laryngeal elevation, epiglottic closure, pharyngeal wall coating, pharyngeal transit time and aspiration). The score ranges from 0 to 100, with higher scores indicating higher dysphagia severity (14).

The PAS is a standard tool that reflects laryngeal penetration and aspiration. Laryngeal penetration is defined as passage of material into the larynx, which does not pass below the vocal folds, while aspiration refers to the action of material penetrating the larynx and entering the airway below the true vocal folds. The scale is broken down into eight different levels based on the depth of material invasion into the airway and whether or not the material is expelled, with higher levels indicating higher aspiration severity (15).

Table 1. Characteristics of participants

Characteristics	Experimental group (n = 18)	Control group (n = 17)
Age (year), mean ± SD	62·17 ± 11·01	59·29 ± 10·19
Gender (male/female)	11/7	8/9
Type of stroke (Haemorrhage/infarction)	7/11	7/10
Side of stroke (right/left)	9/9	11/6
Time since onset of stroke months, mean ± SD	4·94 ± 5·52	5·29 ± 5·62

SD, standard deviation.

Data analysis

The normality of the variables was assessed using the Shapiro–Wilk test. To evaluate the intervention effects, the paired t-test was used to compare the outcome measures before and after the intervention in each group. The independent t-test was used to compare the changes in the outcome measures between groups. All statistical analyses were performed using SPSS version 15.0†, with the level of significance set at $P < 0·05$.

Results

Thirty-five of 41 subjects included in this trial, and six participants (experimental group [n = 3] and control group [n = 3]) dropped out before the post-test due to transferring to another hospital. Therefore, total 35 participants completed this trial. A summary of the clinical and demographic characteristics of the subjects is shown in Table 1. There were no significant differences in the baseline characteristics between groups ($P > 0·05$).

Tongue strength

The experimental group showed significant increases in ATS and PTS ($P < 0·000$ for both). The control group also showed significant increases in ATS and PTS ($P = 0·003$ and 0·004, respectively). After the intervention, statistical analysis showed significant differences in ATS and PTS between groups ($P = 0·009$ and 0·015, respectively) (Table 2).

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Table 2. Comparison of pre–post in tongue muscle strength of the experimental and control group

	Experimental group				Control group				Between groups
	Before treatment	After treatment	Mean difference	*P*-value	Before treatment	After treatment	Mean difference	*P*-value	*P*-values
Tongue strength									
Anterior region	32·67 (10·78)	41·89 (9·54)	9·22 (6·73)	<0·000**	29·65 (10·41)	32·53 (10·17)	2·88 (3·38)	0·003*	0·009***
Posterior region	28·06 (7·56)	39·11 (7·80)	11·06 (4·37)	<0·000**	26·59 (9·13)	31·41 (9·74)	4·82 (5·97)	0·004*	0·015***

The values are mean ± standard deviation, *$P < 0·05$, **$P < 0·00$ by paired *t*-test, ***$P < 0·05$ by independent *t*-test.

Table 3. Comparison of pre–post in swallowing function of the experimental and control group

	Experimental group				Control group				Between groups
	Before treatment	After treatment	Mean difference	*P*-value	Before treatment	After treatment	Mean difference	*P*-value	*P*-values
VDS									
Oral phase	10·36 (6·79)	4·19 (4·26)	−6·22 (5·07)	<0·000**	12·64 (6·04)	8·02 (5·54)	−4·67 (4·12)	<0·000**	0·029***
Pharyngeal phase	37·36 (11·09)	25·75 (13·71)	−11·61 (8·22)	<0·000**	42·67 (13·71)	37·02 (9·03)	−5·64 (3·44)	<0·000**	0·007***
PAS	6·00 (1·02)	3·56 (1·04)	−2·44 (0·85)	<0·000**	5·88 (1·16)	3·82 (1·22)	−2·06 (1·14)	<0·000**	0·471

The values are mean ± standard deviation. VDS, videofluoroscopy dysphagia scale; PAS, penetration–aspiration scale.
**$P < 0·00$ by paired *t*-test, ***$P < 0·05$ by independent *t*-test.

Oropharyngeal swallowing function

The experimental group showed significant improvements in both the oral and pharyngeal phases of the VDS ($P < 0·000$ for both). The control group also showed significant improvements in both the oral and pharyngeal phases ($P < 0·000$ for both). After the intervention, statistical analysis showed significant differences in both the oral and pharyngeal phases between groups ($P = 0·029$ and 0·007, respectively) (Table 3).

Both groups showed a significant decrease in PAS score ($P < 0·000$ for both). After the intervention, statistical analysis showed no significant difference in PAS score between groups ($P = 0·471$) (Table 3).

Discussion

Previous studies have demonstrated that tongue resistance training can effectively treat swallowing impairments, such as aspiration. The present study sought to examine an easier and free tongue exercise to validate its clinical application.

This study demonstrated that TPRT is an effective method for improving tongue muscle strength. The experimental group showed improvements of 9·2 kPa for the anterior tongue (a 28% increase) and 11 kPa for the posterior tongue (a 39% increase). In comparison, the control group showed improvements of 2·8 kPa for the anterior tongue (a 10% increase) and 4·8 kPa for the posterior tongue (a 18% increase). The tongue is a skeletal muscle, which responds to physiologic changes brought on by repeated resistance exercises in a manner similar to the muscles in the extremities. In a similar study, Robbins *et al.* (7) conducted a study of tongue resistance training using the IOPI exercise in patients with post-stroke dysphagia. They found significant improvements of 9·7 kPa for the anterior tongue (a 28% increase) and 16·9 kPa for the posterior tongue (a 56% increase). These results are in line with our study, providing evidence of the therapeutic effects of TPRT.

Resistance training has been reported to be an effective means of increasing muscle strength. Numerous studies have conducted resistance training over different durations, including 4–8 weeks. However, the neural factor theory states that at least 4 weeks of repeated resistance training is required to increase skeletal muscle mass and strength (16). Therefore, in the present study, we conducted TPRT for 4 weeks,

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which showed a positive impact on tongue muscle strength.

This study also confirmed that TPRT improved the oral and pharyngeal phases of swallowing. This may be attributed to the following: first, the improvement in tongue muscle strength may have directly affected the oral phase of swallowing. The tongue is an essential organ responsible for chewing, manipulating and transferring food to the pharynx, and it requires adequate muscle strength to perform these functions. Hence, we believe that improving tongue muscle strength through TPRT can considerably improve oral function, including bolus formation, mastication and tongue-to-palate contact. Second, the improvement in the oral phase via increased tongue muscle strength may have indirectly influenced the pharyngeal phase. Because swallowing is a series of processes transferring a bolus from the oral phase to the pharyngeal phase, improvement in the oral phase would have a positive effect on the pharyngeal phase. If maximum strength of the tongue is increased, it can push against the palate with more force while swallowing a bolus. The resulting intra-oral pressure helps the bolus to be quickly and safely moved to the pharynx, which has a positive effect on removing pharyngeal residue and aspiration in the pharyngeal phase. Robbins *et al.* (7) reported that tongue resistance training using the IOPI exercise significantly increased maximum muscle strength and decreased aspiration due to strength improvement of the tongue muscles used for swallowing. This report supports the findings of the present study.

Changes in the central nervous system via resistance training could partially account for the improvement in the pharyngeal phase of swallowing. Previous studies have reported that oral exercise resulted in activation of the brain, including the cerebellum, precentral gyrus, postcentral gyrus and lentiform nucleus (17). They also have suggested that repeated exercise can positively influence brain plasticity. It is known that brain plasticity induced by resistance training can occur within a few weeks of training (18, 19). In other words, the improvement in the pharyngeal phase through TPRT is thought to have resulted from peripheral effects, such as increased tongue muscle strength, combined with brain plasticity.

This study confirmed that TPRT improves tongue muscle strength and swallowing function in patients with post-stroke dysphagia. We expect future studies to improve TPRT with different types and intensity of exercises to determine more effective and efficient exercise protocol.

This study has some limitations. First, the small sample size may have influenced the results; therefore, the results cannot be generalised. Second, the absence of follow-up after the intervention did not allow for determination of the durability of the effects. Third, our findings do not reflect a pure TPRT effect because we conducted TPRT together with conventional dysphagia therapy. Further studies including a larger sample size and longer follow-up are required to evaluate the long-term effects of TPRT.

Conclusion

This study demonstrated the effectiveness of TPRT in increasing tongue muscle strength and improving swallowing function in patients with post-stroke dysphagia. Based on these findings, we recommend TPRT as a relatively easy and simple rehabilitation strategy for improving swallowing in patients with dysphagia.

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