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Effects of Tongue-Strengthening Exercise on Tongue Strength and Effortful Swallowing Pressure in Young Healthy Adults: A Pilot Study

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ABSTRACT

Purpose: The purpose of this study was to investigate the effects of tongue-strengthening exercise (TSE) on tongue strength and effortful swallowing pressure in young healthy adults.
Method: Thirteen young healthy volunteers (six men, seven women; M_{age} = 20.5 ± 0.5 years) performed 8 weeks of isometric TSE 3 days per week. A tongue pressure measurement device was used to measure maximum isometric tongue pressure (MITP) and conduct the TSE, and a tactile sensor system attached to the hard palate was used to measure effortful swallowing pressure. MITP and effortful swallowing pressure were measured at baseline, after 4 and 8 weeks of training, and at 4 and 8 weeks after the last training session to examine the detraining effects.
Results: The results indicated that both MITP and effortful swallowing pressure increased significantly from baseline to 8 weeks after training. Although the improved MITP significantly decreased at 4 and 8 weeks after training cessation, no detraining effect was observed for effortful swallowing pressure.
Conclusions: TSE is an effective method for increasing tongue pressure in wide tongue–palate contact areas during effortful swallow. The effortful swallowing pressure gained with TSE appears to be maintained for at least eight nontraining weeks.

Among the oral structures, the tongue plays an essential role in mastication, bolus formation, control, and transport for the swallowing process. Tongue strength is a major driving force in propelling a bolus from the oral cavity into the pharynx during the oral phase of swallowing (Pouderoux & Kahrilas, 1995). It has been reported that tongue strength significantly declines in patients after stroke (Hirota et al., 2010; Robbins et al., 2007), in those with Parkinson's disease (O'Day et al., 2005; Solomon et al., 2000) and head and neck cancer (Lazarus et al., 2000, 2007), and during healthy aging (Nicosia et al., 2000; Utanohara et al., 2008; Youmans et al., 2009). Decreased tongue strength is associated with bolus residue in the oral cavity and the pharynx, longer meal times, nutritional deficits, and a risk of aspiration (Butler et al., 2011; Carrión et al., 2015; Namasivayam et al., 2016; Ono et al., 2007). Decreased tongue strength has also been reported to have a negative impact on oral intake ability and swallowing-related quality of life (Pitts et al., 2019; Robbins et al., 2007).

Tongue-strengthening exercise (TSE) is a common therapeutic approach for patients with decreased tongue strength, and its effectiveness has been confirmed. TSE is widely used in Japan as a training method for swallowing rehabilitation. Several studies have described increased maximum isometric tongue pressure (MITP), reduced pharyngeal residue, decreased aspiration, and improved quality of life related to swallowing function following TSE

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(Kim et al., 2017; Robbins et al., 2005, 2007; Rogus-Pulia et al., 2016; Steele et al., 2013, 2016). A systematic review on the assessment of swallowing function based on videofluoroscopic swallowing studies reported mixed results for swallowing safety and efficiency, but the evidence regarding tongue pressure was positive (Smaoui et al., 2020). In particular, increased MITP, which is measured by pushing the tongue against the palate with voluntary contraction, has been reported in a number of studies. MITP is thought to indicate tongue strength, but not tongue pressure produced during swallowing. Although various effects of TSE have been reported, few studies have focused on tongue pressure during swallowing. The maximum pushing pressure of the tongue and tongue–palate contact pressure during swallowing are produced by different movements of the tongue. How TSE affects tongue movement during swallowing, the force of which can also be voluntarily adjusted, remains unclear, as does how it modulates swallowing with effort. Effortful swallow is a rehabilitation method for oropharyngeal dysphagia and has been shown to produce significantly greater muscle activity and tongue pressure compared with normal swallow (Fukuoka et al., 2013; Hind et al., 2001; Huckabee et al., 2005; Yeates et al., 2010). Pouderoux and Kahrilas (1995) reported that hard volitional swallowing resulted in significantly higher swallowing pressures in the oral and pharyngeal cavities, and voluntarily increased tongue–palate contact has been shown to increase effortful swallowing pressure (Huckabee et al., 2005). Therefore, effortful swallow is considered to represent the ability of individuals to exert tongue pressure during swallowing. However, whether TSE improves tongue pressure during effortful swallow remains unclear. If it becomes clear that TSE strengthens not only tongue strength but also tongue pressure during swallowing with voluntary effort, this would provide new insights into the regulation of tongue pressure output.

Given this background, the aim of this study was to determine the effects of TSE on tongue strength and pressure during effortful swallow. Tongue pressure during effortful swallow was measured using a tongue sensor sheet system consisting of a thin tongue pressure sensor sheet that can measure tongue–palate contact at 5 points on the tongue and palate in detail (Fukuoka et al., 2013, 2019; Hirota et al., 2010; Hori et al., 2009, 2013; Ono et al., 2010). To our knowledge, there are no previous studies that have examined the training effects of TSE using a tongue sensor sheet system.

This study also aimed to determine how long both the tongue strength and effortful swallowing pressure gained from TSE could be maintained. Gaining a better understanding of the detraining (training cessation period) effects of TSE could be important for planning a maintenance training program. Although several studies have examined the detraining effects on TSE, no consensus has been reached and many points remain unclear (Clark et al., 2009; Oh, 2015). In addition, few studies have examined the detraining effects on tongue pressure during swallowing. We hypothesized that a TSE program would improve both MITP and effortful swallow pressure and that detraining effects would be observed in both MITP and effortful swallow pressure.

Method

Participants

Thirteen young healthy volunteers (six men, seven women; $M_{\text{age}} = 20.5 \pm 0.5$ years; age range = 20–21 years) participated in this study. All participants were speech-language pathology students enrolled at Hiroshima International University. The participants were recruited through a posting on the university bulletin board. To determine the effects of TSE accurately, we selected young healthy adults who could comply with the training load. Data from these young healthy volunteers could be expected to be useful in comparison with healthy older people and patients with dysphagia in future research. The inclusion criteria were age of 20 years or greater, no abnormalities in oropharyngeal function, and able to participate in an 8-week training program. The exclusion criterion was the presence of self-reported abnormalities. None of the participants had any disturbances of mastication or swallowing, neurological disorders, or abnormalities in the number of teeth except for the third molar, a history of temporomandibular disorders, or occlusion abnormalities. All participants reported not taking any medications that could affect their swallowing function. Written informed consent was obtained from all participants after receiving a full explanation of the study purpose and methods. Participation was on a volunteer basis, and no class credits or incentives were offered. All procedures involving human participants in this study were performed in accordance with the ethical standards of the institutional and national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The study protocol was approved by the ethics review board of Hiroshima International University (Approval No. 19-030).

Study Design and Training Protocol

This study was conducted in a university laboratory. All participants completed an 8-week isometric TSE program. The TSE consisted of compressing an air-filled balloon between the tongue and anterior section of the palate using a tongue strength measurement device (TPM-02;

JMS Co.), which consists of a disposable probe with an air-filled balloon (diameter: 18 mm), a connection tube, and a digital presentation device (Utanohara et al., 2008; Yano et al., 2019a; Yoshida et al., 2006; Yoshikawa et al., 2011; see Figure 1). The participants were instructed to hold a hard ring lightly between the upper and lower incisors to stabilize the air-filled balloon within their oral cavity and then to close their mouth. The participants held the oral probe with their incisors such that the air-filled balloon could be placed between the anterior part of the tongue and the hard palate. In this study, TSE was performed only for the anterior part of the tongue. The TSE program involved following the protocol in accordance with the method of Robbins et al. (2007). The one-repetition maximum (1RM) was measured for all participants before training to determine their baseline training level. Training values were set at 60% of the baseline 1RM in each session for the first week and at 80% of the 1RM in the 8 weeks after the second week. The participants adjusted their training values by referring to the tongue pressure values displayed in real time on the measuring device. To adjust the loading dose through the training period, the tongue strength of each participant was remeasured every 2 weeks, and training levels were recalculated according to the overload principle. The training was performed for 10 repetitions in six sets with a 1-min rest period after each set. The total number of repetitions was 60, and they were performed consecutively throughout the day. The number of repetitions above is higher than that set by Robbins et al. (2007), because it was set with reference to previous studies that trained only the anterior part of the tongue (Yano et al., 2019a, 2019b). The participants performed a total of 24 training sessions 3 days a week on nonconsecutive days. They were instructed to record each session on their self-checklist. Although each participant conducted self-training in the laboratory, the participant's target performance was monitored by the trainer (the first author T. F.). Training target performance was defined as the ability to press the anterior tongue against the hard palate to the set load intensity (60% or 80% of 1RM).

Measurements

MITP and effortful swallowing pressure were measured at baseline, at 4 and 8 weeks after the training had started, and at 4 and 8 weeks after the final training session to examine the detraining effects. All measurements were performed by the trainer (the author).

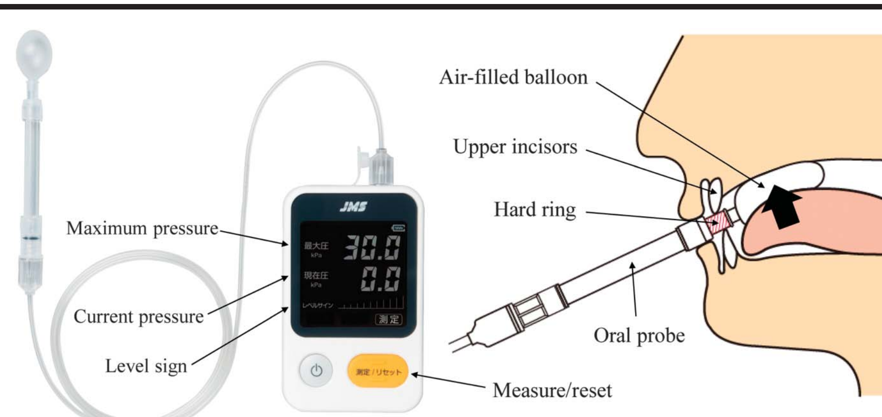
MITP

MITP was measured using the same device as that for the TSE. The value of the anterior tongue pressure as measured by the JMS device has been reported to be correlated with the Iowa Oral Performance Instrument (IOPI PRO; 0.64 for males and 0.74 for females; Yoshikawa et al., 2021). The participants were instructed to compress a balloon onto the anterior section of their palate for a few seconds using maximum voluntary effort. For each participant, the values were recorded 3 times at 1-min intervals; the average value of the three trials was calculated and defined as MITP (Utanohara et al., 2008).

Effortful Swallowing Pressure

The participants were instructed to swallow their saliva while pushing hard with the tongue on the palate and squeezing hard with their swallowing muscles (Hind et al., 2001; Witte et al., 2008). Tongue pressure during effortful swallow was measured using a tactile sensor

Figure 1. The tongue pressure measurement device used in this study. This device consists of a disposable oral probe with an air-filled balloon, connection tube, and digital device.



system (Swallow-Scan Version 1.037) attached to the hard palate (Fukuoka et al., 2019; Hirota et al., 2010; Hori et al., 2009; Ono et al., 2010). An ultra-thin sensor sheet (0.1-mm thick; OSA09A08) with five pressure-sensing parts was used, and measurements were made for Channel 1 (Ch.1) at the anterior-median part of the hard palate, Ch.2 at the mid-median part, Ch.3 at the posterior-median part, Ch.R at the right circumferential part, and Ch.L at the left circumferential part (see Figure 2). This sensor sheet is T-shaped to fit the curve of the palate and disposable but can be used repetitively on the same participant. For each participant, a sensor sheet of suitable size to fit the hard palate was chosen from three available sizes (small, medium, and large). The sensor sheet was attached using a sheet-type denture adhesive (Touch Correct 2) that has an excellent sealing effect and very little effect on swallowing. It was confirmed by the analysis of timing, direction, and range of tongue movement in videofluorographic images during swallowing study with and without the sensor sheet (Hori et al., 2013). Tongue pressure as measured by the sensor sheet was recorded at a sampling rate of 100 Hz and displayed on a personal computer in real time using a dedicated analysis software (Swallow-Scan). The accuracy of the sensors to tongue pressure was reported as 0.27 kPa in previous studies (Hori et al., 2013). Before recording the data, an effortful swallowing pressure trial was confirmed by tongue pressure waveforms. Based on the tongue pressure contour recorded for effortful swallow, the maximal magnitude (kPa), duration (s), and integrated value (kPa·s) were identified and obtained (see Figures 3a and 3b). These items were automatically calculated using Swallow-Scan. The maximal magnitude and integrated value are defined as the peak and total activities of tongue pressure during swallowing, respectively.

Data Analysis

Statistical analyses were performed using SPSS 26.0 J (IBM Japan). Data are reported as mean ± standard deviation. An analysis of variance with repeated measures (13 subjects × 5 points in time) and effect sizes (η_p^2) was performed to examine differences among the 5 points in time throughout the training and detraining periods. Post hoc comparisons with the Bonferroni–Dunn test were used to determine any differences at all time points during the training. The level of significance was set at $p < .05$.

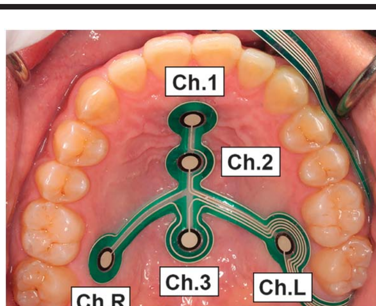


Figure 2. The tongue pressure sensor sheet on the hard palate with five pressure-sensing parts. Ch.1 = anterior-median part; Ch.2 = mid-median part; Ch.3 = posterior-median part; Ch.R = right circumferential part; Ch.L = left circumferential part; Ch = Channel.

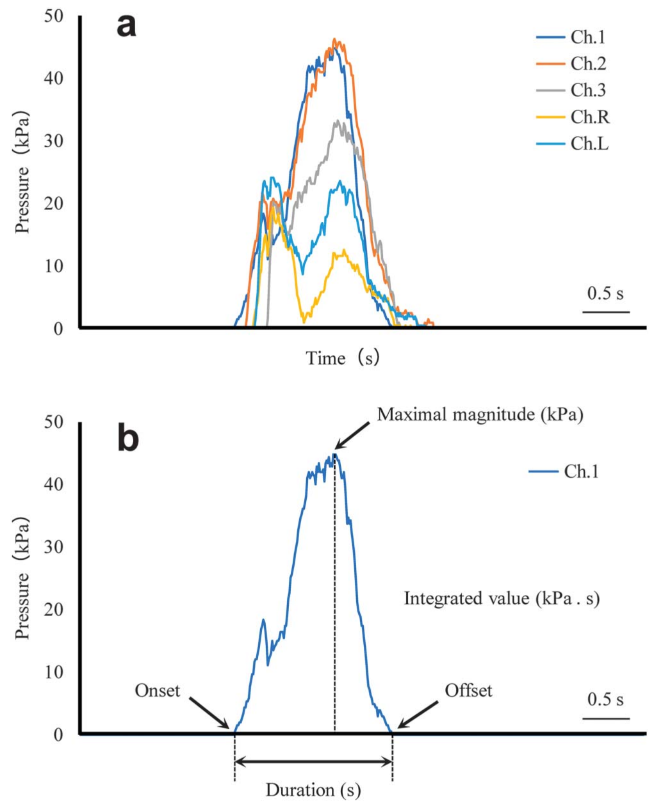


Figure 3. Representative waves of a participant and items for measuring effortful swallowing pressure on all channels (a) and a single channel (b) Ch. = Channel..

Results

There were no attrition/missing data since all participants were able to complete the training. Regarding adherence based on the self-checklist, the training implementation rate was 94.4% ± 3.6% using the following formula:

$$\text{Training implementation rate (\%)} = \text{Number of times implemented (set number of times} - \text{number of times not implemented)} \times 100/\text{set number of times.} \quad (1)$$

Table 1. Effects of tongue-strengthening exercise (TSE) on maximum isometric tongue pressure (MITP).

Variable	Baseline	TSE 4 weeks	TSE 8 weeks	DT 4 weeks	DT 8 weeks			
	M ± *SD*	*M* ± *SD*	*M* ± *SD*	*M* ± *SD*	*M* ± *SD*	*F*	*p*	η_p^2
MITP (kPa)	43.19 ± 6.07	51.12 ± 5.75*	55.23 ± 5.63*	51.82 ± 5.74*†	52.15 ± 6.10*†	42.366	.000	.779

Note. DT = detraining.
*Significant difference versus baseline. †Significant difference versus 8 weeks of training.

MITP

After the fourth week of TSE, MITP was significantly increased throughout the training and detraining periods compared with baseline, $F(4, 48) = 42.366$, $p < .001$, $\eta_p^2 = .779$ (see Table 1 and Figure 4). The post hoc comparisons revealed that MITP increased significantly for both the 4- and 8-week training and detraining periods compared with baseline and that MITP decreased significantly for both the 4- and 8-week detraining period compared with the 8-week training period.

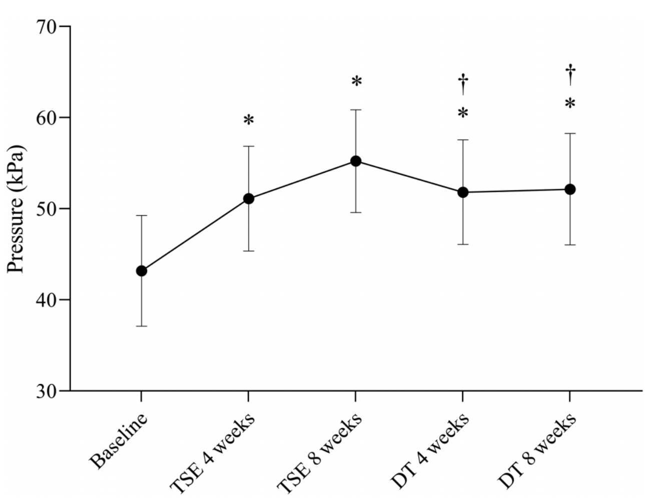
Effortful Swallowing Pressure

Significant increases in the maximum magnitude of effortful swallowing pressure were observed at Ch.1, $F(4, 48) = 9.855$, $p < .001$, $\eta_p^2 = .451$; Ch.2, $F(4, 48) = 13.179$, $p < .001$, $\eta_p^2 = .523$; Ch.R, $F(4, 48) = 9.811$, $p < .001$, $\eta_p^2 = .450$; and Ch.L, $F(4, 48) = 9.861$, $p < .001$, $\eta_p^2 = .451$, after 8 weeks of training compared with baseline (see Table 2 and Figure 5). No significant changes at Ch.3 were observed throughout the training period. No significant detraining effects in the maximum magnitude were observed at Ch.1, Ch.2, Ch.R, or Ch.L after 4 and 8 weeks of training.

The duration of tongue pressure at Ch.R was significantly longer at 4 weeks than at baseline, $F(4, 48) = 3.827$, $p = .009$, $\eta_p^2 = .242$; however, no significant differences in duration were found in the other measurement parts (see Table 3 and Figure 6). Overall, no differences were observed in the duration of tongue pressure during swallowing.

Regarding the integrated value of tongue pressure, a trend similar to the results of the maximal magnitude of tongue pressure was observed. Significant increases were found at Ch.1, $F(4, 48) = 5.743$, $p = .001$, $\eta_p^2 = .324$; Ch.2, $F(4, 48) = 7.192$, $p < .001$, $\eta_p^2 = .375$; Ch.R, $F(4, 48) = 10.463$, $p < .001$, $\eta_p^2 = .466$; and Ch.L, $F(4, 48) = 4.621$, $p = .003$, $\eta_p^2 = .278$, after 8 weeks of training compared with baseline (see Table 4 and Figure 7). No significant changes were observed at Ch.3 throughout the training period. In addition, no significant detraining effects were found in the integrated value of tongue pressure at Ch.1, Ch.2, Ch.R, or Ch.L.

Figure 4. Line graph showing changes in maximum isometric tongue pressure. DT = detraining; TSE = tongue-strengthening exercise. *Significant difference versus baseline. †Significant difference versus 8 weeks of training.



Discussion

The aim of this study was to investigate the effects of TSE on tongue strength and effortful swallowing pressure. The results indicated that MITP increased significantly from baseline to 8 weeks after training; this finding is similar to previous studies reporting that TSE improves tongue strength in young healthy adults (Lazarus et al., 2003; Oh, 2015; Park et al., 2020; Yano et al., 2019b). Based on the overload principle and motor learning, TSE is a well-accepted and effective method to improve tongue strength. Numerous studies have reported that a higher intensity load for the tongue muscle leads to higher tongue strength. The training implementation rate indicated high adherence, with an average of 94.4%, which could be attributed to the fact that the participants were speech-language pathology students and the training was easily controlled. In this study, we also investigated the possible detraining (training cessation period) effects of TSE on tongue strength. Gaining a better understanding of the detraining

Table 2. Effects of tongue-strengthening exercise (TSE) on the maximal magnitude of effortful swallowing pressure.

	Maximal magnitude of tongue pressure (kPa)							
	Baseline	TSE 4 weeks	TSE 8 weeks	DT 4 weeks	DT 8 weeks			
Measurement parts	*M* ± *SD*	*M* ± *SD*	*M* ± *SD*	*M* ± *SD*	*M* ± *SD*	*F*	*p*	η_p^2
Channel 1	20.72 ± 10.18	34.35 ± 12.60*	39.86 ± 13.60*	35.28 ± 12.99*	36.57 ± 12.68*	9.855	.000	.451
Channel 2	14.65 ± 11.90	24.75 ± 9.17*	33.18 ± 10.32*	32.57 ± 11.68*	30.85 ± 12.85*	13.179	.000	.523
Channel 3	17.88 ± 8.03	21.48 ± 7.51	20.12 ± 12.14	22.37 ± 11.50	23.76 ± 13.00	.960	.438	.074
Channel R	16.34 ± 10.48	36.61 ± 16.85*	37.83 ± 15.94*	35.95 ± 14.33*	33.76 ± 12.25*	9.811	.000	.450
Channel L	21.87 ± 11.21	34.45 ± 13.46*	40.85 ± 13.83*	36.95 ± 10.39*	34.61 ± 15.19	9.861	.000	.451

Note. DT = detraining.

*Significant difference versus baseline.

effects of TSE could be important for planning a maintenance training program. Our data indicated that the tongue strength gained with TSE significantly decreased at both 4 and 8 weeks. Clark et al. (2009) investigated the detraining effects of TSE after 9 weeks of training. They found that tongue strength significantly decreased at 4 weeks after training (M = 23.2 days). These findings suggested that the lingual musculature is susceptible to detraining effects. By contrast, Oh (2015) and Van den Steen et al. (2018) reported no significant decrease in tongue strength at 8 weeks in the detraining period, and these values were still greater than those at baseline (Van den Steen et al., 2018). The reason for these differences may be due to the training methods. In the training protocols, participants performed tongue-pushing exercises 120 times or for approximately 30 min per session, which was more frequent than the protocol in this study. The tongue muscle differs from other skeletal muscles in that it consists solely of muscles without joints (Oh, 2015). The internal tongue muscle, which is the main body of the tongue, has a high ratio of fast-twitch fibers anteriorly and slow-twitch fibers posteriorly, and unlike limb muscles, it has a unique muscle fiber type (Burkhead et al., 2007). Therefore, the detraining effect on the tongue may be different from that of the limb muscles. It is also generally reported that detraining effects may differ depending on the intensity, number of sessions, frequency, and duration of training (Mujika & Padilla, 2001). Therefore, it is important to investigate the detraining effects associated with TSE considering these conditional differences. Clarifying the detraining effects by TSE under various conditions could be expected to be useful for setting optimal training conditions in clinical practice.

The effects of TSE on effortful swallowing pressure were also previously investigated by Robbins et al. (2007), Van den Steen et al. (2020), and Oh (2015). Those studies reported that tongue pressure significantly increased during effortful swallow. Oh concluded that recruited muscles during tongue press activity are essential to the initiation

Figure 5. Bar graph showing changes in the maximal magnitude of effortful swallowing pressure. DT = detraining; TSE = tongue-strengthening exercise; Ch = Channel.

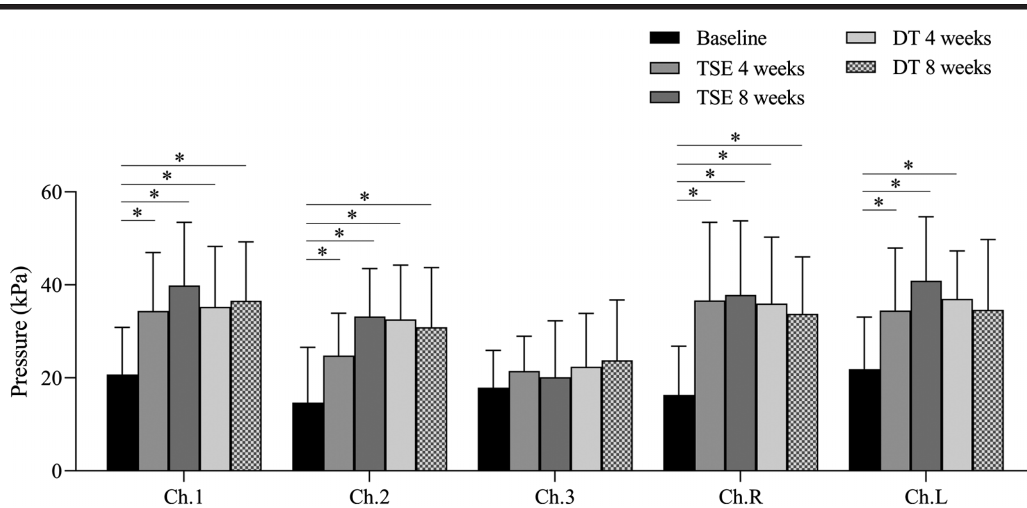


Table 3. Effects of tongue-strengthening exercise (TSE) on the duration of effortful swallowing pressure.

	Duration of tongue pressure (s)							
	Baseline	TSE 4 weeks	TSE 8 weeks	DT 4 weeks	DT 8 weeks			
Measurement parts	*M* ± *SD*	*M* ± *SD*	*M* ± *SD*	*M* ± *SD*	*M* ± *SD*	*F*	*p*	η_p^2
Channel 1	1.17 ± 0.59	1.40 ± 0.44	1.46 ± 0.37	1.46 ± 0.43	1.38 ± 0.45	1.355	.263	.101
Channel 2	1.15 ± 0.66	1.54 ± 0.58	1.55 ± 0.54	1.53 ± 0.44	1.48 ± 0.70	2.311	.071	.161
Channel 3	.98 ± 0.46	1.07 ± 0.33	.91 ± 0.42	.90 ± 0.40	.97 ± 0.51	.475	.754	.038
Channel R	1.09 ± 0.59	1.72 ± 0.54*	1.61 ± 0.51	1.56 ± 0.49	1.55 ± 0.60	3.827	.009	.242
Channel L	1.59 ± 0.67	1.69 ± 0.61	1.85 ± 0.57	1.68 ± 0.52	1.70 ± 0.72	.548	.701	.044

Note. DT = detraining.

*Significant difference versus baseline.

of swallowing, and greater activities result in a more vigorous swallow. In our study, effortful swallowing pressure was measured using a sensor sheet attached to the hard palate to examine the effects of TSE. The sensor sheet used in this study can measure the median and posterior-circumferential parts of the hard palate with five measurement points. Therefore, this sensor sheet made it possible to evaluate tongue–palate contact pressure during effortful swallow in greater detail. Although our participants did not perform specific exercises for effortful swallow, the maximal magnitude and integrated value of tongue pressure during effortful swallow were significantly increased after 8 weeks of training. In the measurement items, the maximal magnitude and integrated value are defined as the peak and the activities of tongue pressure during swallowing, respectively. Our results suggest that TSE increases the peak and total activities of effortful swallowing pressure. TSE increased not only tongue strength but also tongue pressure during effortful swallowing. The reason for this may be that the TSE was similar to the exercise of pushing the tongue up strongly during effortful swallowing. On the other hand, no significant change in the duration of effortful swallowing pressure was found. With regard to age-related changes in tongue pressure during swallowing, it has been reported that the duration of tongue pressure in older adults is prolonged compared with younger adults (Tamine et al., 2010). In future studies, the effect of TSE on the duration of tongue pressure during swallowing in older adults should be investigated.

The findings of this study also suggest that TSE is an effective method for increasing tongue pressure in wide tongue–palate contact areas during swallowing. However, in the measured tongue–palate contact parts during effortful swallow, different effects of TSE were observed. According to the results in Tables 2 and 4, the maximal tongue pressure magnitude and integrated values increased at Ch.1 (anterior-median part), Ch.2 (mid-median part), Ch.R (right circumferential part), and Ch.L (left circumferential part), whereas no significant changes were observed at Ch.3 (posterior-median part). As a possible explanation for this, the participants trained only the anterior tongue. It has been reported that training both the anterior and posterior portions of the tongue increases

Figure 6. Bar graph showing changes in the duration of effortful swallowing pressure. DT = detraining; TSE = tongue-strengthening exercise; Ch = Channel.

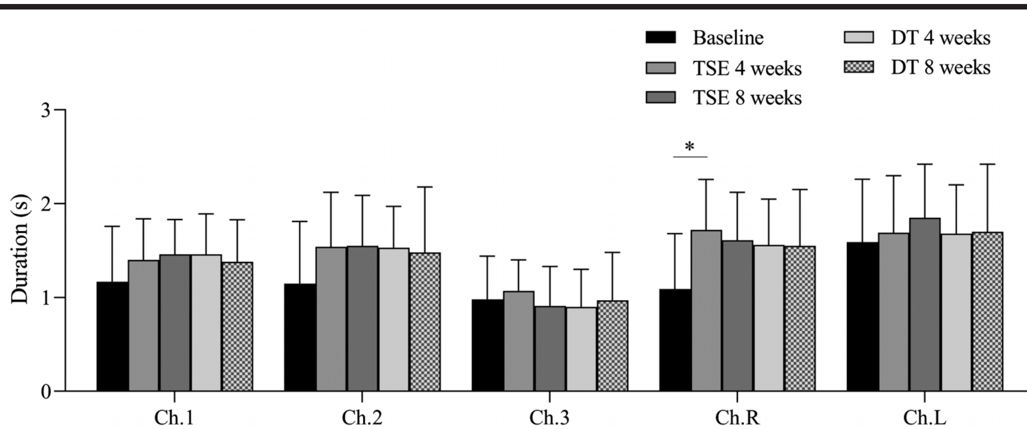


Table 4. Effects of tongue-strengthening exercise (TSE) on the integrated value of effortful swallowing pressure.

	Integrated value of tongue pressure (kPa•s)							
	Baseline	TSE 4 weeks	TSE 8 weeks	DT 4 weeks	DT 8 weeks			
Measurement parts	*M* ± SD	*M* ± SD	*M* ± SD	*M* ± SD	*M* ± SD	*F*	*p*	η_p^2
Channel 1	11.41 ± 9.49	21.09 ± 10.84*	28.29 ± 15.55*	22.19 ± 10.77	22.21 ± 13.18	5.743	.001	.324
Channel 2	8.43 ± 7.50	16.06 ± 8.69	21.82 ± 10.61*	21.41 ± 12.76*	19.49 ± 15.76	7.192	.000	.375
Channel 3	8.34 ± 7.76	8.14 ± 5.21	8.71 ± 10.47	9.49 ± 10.52	10.63 ± 11.69	.323	.861	.026
Channel R	8.14 ± 7.20	23.12 ± 13.41*	24.24 ± 13.58*	21.75 ± 10.96*	18.91 ± 11.52*	10.463	.000	.466
Channel L	13.35 ± 9.49	21.65 ± 12.67*	26.06 ± 12.45*	22.71 ± 10.18	20.21 ± 12.11	4.621	.003	.278

Note. DT = detraining.

*Significant difference versus baseline.

tongue pressure in the posterior and anterior portions of the tongue during swallowing (Rogus-Pulia et al., 2016). TSE for both the anterior and posterior tongue may lead to different results in tongue pressure production during effortful swallow.

The finding in relation to detraining was that the participants maintained their increased effortful swallowing pressure after 8 weeks of TSE. Despite the decreased tongue strength, no other detraining effects were observed in effortful swallowing pressure. Van den Steen et al. (2020) performed 8 weeks of TSE in healthy older adults and reported no detraining effects on effortful swallow pressure. These results suggest that TSE increases effortful swallowing pressure in both young and older adults and is not associated with any detraining effects.

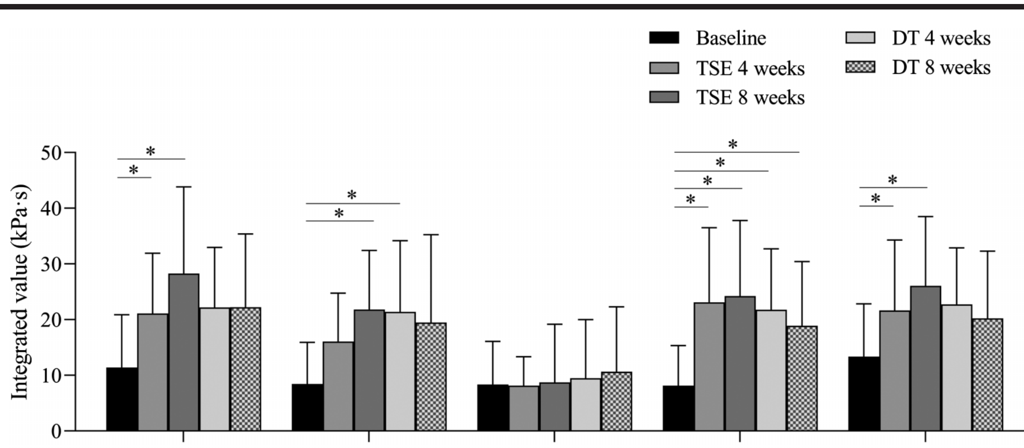
The difference between tongue strength and tongue pressure during swallowing was termed *functional reserve* (Steele et al., 2013). With respect to functional reserve, previous studies have shown that tongue pressure appears to be preserved during swallowing, despite declines in tongue strength with age (Nicosia et al., 2000; Robbins et al., 1995). Accordingly, the swallow pressure gained with TSE appears to be maintained compared with tongue strength. The results of this study suggest that TSE may improve the ability to regulate tongue pressure during swallowing and maintain it for a period of time.

Although this study was a pilot study involving young healthy adults, it may provide useful data on the effects of TSE on tongue muscle strength and effortful swallowing pressure. In the future, it will be necessary to examine data from other age groups. In addition, the detraining effects of different training conditions (e.g., training intensity, number of sessions, frequency, and duration) on tongue strength and pressure during swallowing need to be investigated.

Study Limitations

This study had several important limitations. The participants were limited to young healthy adults with a narrow age range, and the sample size was small. Since this

Figure 7. Bar graph showing changes in the integrated value of effortful swallowing pressure. DT = detraining; TSE = tongue-strengthening exercise; Ch = Channel.



was a pilot study, we did not use a control group. Because the participants were speech-language pathology students, they had some knowledge of TSE and effortful swallowing techniques. It cannot be denied that such knowledge and techniques may have influenced the results of this study. Although TSE clearly resulted in improved effortful swallowing pressure, it is unclear whether it would have had a similar effect on other age groups or patients with dysphagia. Therefore, caution is required when adapting the results of this study to a wider range of ages and patients with dysphagia. In future studies, more appropriate sample sizes will be required, and older adults and patients with dysphagia should be included. In this study, TSE was carried out only for the anterior tongue, and posterior isometric tongue pressure was not measured. Therefore, the effects of training for both the anterior and posterior tongue on effortful swallowing pressure remain unclear.

Conclusions

The findings of this study indicated that TSE increased tongue strength and effortful swallowing pressure. TSE is therefore considered to be an effective method for increasing tongue pressure in wide tongue–palate contact areas during effortful swallow. Although the improved tongue strength significantly decreased at 4 and 8 weeks after training cessation, no detraining effect was observed for effortful swallowing pressure. The effortful swallowing pressure gained with TSE appears to be maintained for at least eight nontraining weeks.

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