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ORIGINAL ARTICLE

Effects of Tongue Strength Training and Detraining on Tongue Pressures in Healthy Adults

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Abstract This study examined the effect of tongue strengthening training and long-term detraining on tongue tip pressure, tongue base pressure, and tongue pressure during effortful swallowing. Ten young healthy volunteers (21–35 years) were participated in this study. Participants received 8-week tongue strengthening exercise 3 days a week with each session lasting 30 min. Measurement of tongue pressure and tongue strengthening exercise were administrated using Iowa Oral Performance Instrument (IOPI). Training intensity was applied at 60 and 80 % of maximal tongue pressure for the first week and the remainder, respectively. Following completion of 8-week training, 28 weeks of detraining period was continued. Training increased tongue tip pressure, tongue base pressure, and tongue pressure during effortful swallowing above pre-training values ($p < 0.05$). After 28-week detraining, all tongue variables were significantly lower than after 8-week training ($p < 0.05$) but remained significantly higher than pre-training levels ($p < 0.05$). These findings demonstrate that high-intensity tongue strengthening exercise can improve tongue pressures. However, training effects were diminished gradually during detraining period. Thus, maintenance programs after strengthening exercise would be required for prolonging training effects.

Keywords Deglutition · Deglutition disorders · Exercise · Tongue · Training

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Introduction

The tongue's role in oropharyngeal swallowing is extensive and essential to normal swallowing. The tongue performs significant functions in the oral preparatory, oral transit, and pharyngeal phase of swallowing, including major contributions to bolus manipulation and transport [1]. The tongue has an entirely muscular composition and plays a critical role as the major propulsive force in moving food, liquid, secretions, and medications through the oropharynx and into the esophagus during swallowing [2]. In the oral transit phase and pharyngeal phase, strong tongue to palatal contact is very important. In a functional system, pressing the tongue to the palate is achieved not only through the activation of tongue muscles, but also through the floor-of-mouth muscles and jaw closing muscles. Thus, pressing on an intraoral bulb mimics to some degree the action of the oral structures on a bolus. The strength of the contraction of the floor-of-mouth muscles can determine the extent of the upward laryngeal trajectory, which is an important physiologic event in swallowing [3].

There are lots of studies about tongue strengthening. Most of them are about training effects of tongue strengthening exercises. 4–30 weeks of tongue strengthening exercise using Iowa Oral Performance Instrument (IOPI) showed improvements of tongue pressure and swallowing function [2, 4–6]. Tongue directional exercise using tongue depressor as a resistance instead of IOPI for 9 weeks showed significantly increased isometric tongue pressure, too [7]. Also, tongue is known to show task-specific training effects, i.e., strength, endurance, and power according to the training methods [8].

For individuals who exercise, regardless of age, periods of training cessation (detraining) or inactivity may be anticipated [9]. In limb muscles, the strengthening effects

decline as time passes during detraining period. Reductions in maximal voluntary muscle strength, muscle cross-sectional area, and neural drive to the muscle have been reported [10, 11]. However, the effects of detraining periods on muscle strength remain unclear. While some studies reported full loss of the training-induced strength gains after 2, 3, 6, 8, and 12 months of detraining [12–16], other reports suggest that strength gains are partially maintained after 3, 4, 5, and even 12 months of detraining in limb muscles [17–21].

Tongue is differ from other skeletal muscle groups in that the moveable structure is composed almost entirely of muscle and does not move around a joint. Instead, movement is accomplished through a complex pattern of contractions of fibers aligned in intersecting planes [8]. Also, unlike most limb muscles, tongue is composed of mixed muscle fibers. The majority of muscle fibers in the anterior human tongue are Type 2, and Type 1 in the posterior tongue [22]. Therefore, detraining effects of the tongue may differ from that of major limb muscles. Only few studies have reported detraining evidence based on a strengthening exercise of swallowing-related musculature. To the best of our knowledge, there is only one study relevant to detraining effect of tongue strengthening exercise. Clark et al. [7] studied the effects of tongue directional exercise using tongue depressor on lingual strength of healthy adults. In that study, lingual strength significantly increased after 9-week training. But, baseline and detraining measures did not differ significantly after an average of 23.2 days (range = 18–31 days).

Despite evidence of physiological decline during detraining, there is not enough data suggesting how long the beneficial effects of training of swallowing-related muscle are maintained following the cessation of a strengthening training in human. Therefore, the present study was designed to determine the effect of strengthening exercise of the tongue in human following 8 weeks of training and 7 months of long-term detraining.

Materials and Methods

Subjects and Experimental Design

Ten healthy volunteers (7 women and 3 men) without reported history of speech or swallowing deficits participated in the experiment between March 2013 and December 2013. The mean age of the participants was 25.8 years with a range of 21–35 years. All participants reported no drug use that could affect swallowing and neurological function and they did not engage in any type of strength training program for at least 1 year prior to this study. The participants received 8-week tongue strengthening exercise 3 days a week in non-consecutive days with each session lasting approximately 30 min. All subjects were tested for tongue tip pressure, tongue base pressure, and tongue pressure during effortful swallowing on 12 occasions (at baseline, after 2, 4, 6, 8 weeks of training and after 4, 8, 12, 16, 20, 24, 28 weeks of detraining). Before conducting the study, all participants received a complete explanation of the purpose, risks, and procedures of the investigation, and provided written informed consent. Procedures were in accordance with the ethical standards of the committee on human experimentation at the institution at which the work was conducted and this study was approved by the Institutional Review Board.

Measurements

All measurements were performed using IOPI by the same evaluator on 12 occasions. The same conditions were maintained for each test at all testing periods. All participants attended two familiarization trials before the start of the study to reduce the risk of injury and muscle soreness after the testing. During training, assessments were conducted during the last session of the week, biweekly. During detraining, assessments were conducted 4-week interval.

Tongue Tip Pressure

Anterior lingual elevation strength was assessed with the tongue bulb positioned longitudinally 10 mm posterior to the tongue tip [5]. Participants were instructed to push the tongue up against the bulb with maximum effort. Three trials were elicited, with the maximum pressure (kPa) across the three trials recorded as tongue tip strength [23].

Tongue Base Pressure

Posterior lingual elevation strength was assessed with the tongue bulb positioned 10 mm anterior to the most posterior circumvallate papilla [5]. Participants were instructed to push the tongue up against the bulb with maximum effort. Three trials were elicited, with the maximum pressure (kPa) across the three trials recorded as tongue base strength [23].

Effortful Swallowing Tongue Pressure

Maximum tongue pressure during effortful swallowing was assessed with the tongue bulb positioned 10 mm anterior to the most posterior circumvallate papilla. Participants were instructed to squeeze all of mouth and throat muscles as hard as possible and swallow. Three trials were elicited, with the maximum pressure (kPa) across the three trials recorded as effortful swallowing tongue pressure.

The order of measures was consistent across assessment sessions. Tongue tip strength measure was obtained first. Tongue base strength was assessed next, followed by effortful swallowing strength assessment. Rest period of 2 min was provided between measures to avoid fatigue.

Training Protocol

The 8-week training protocol was held thrice per week and each session lasted for 30 min, in the same place. Each participant was trained individually by the author. Participants exercised the anterior (ditto as measurements) and posterior (ditto as measurement) portions of the tongue one after the other. Training intensity at 60 % of maximal tongue pressure (1-RM) was selected for the first week of training to maximize participant safety and compliance [5]. Training intensity was increased to 80 % of maximal tongue pressure in the second week of training and training continued at this intensity until the 8th week of training. Published recommendations on strengthening training in the healthy adults state that about 80–100 % 1RM should be used to maximize strength [24]. Based on the results from the weekly repeated measurements, absolute increments in the training load were added during the 8 weeks to maintain the participants' training intensity at 80 % of maximal tongue pressure. The IOPI light display was set so that the first (highest) green light was illuminated when the target pressure was reached. The participant was instructed, "Push as hard as you can against the bulb, holding it for 2 s. You should push hard enough to light up the top green light." After taking a rest for 10 s, the participant repeated the procedure. Each exercise session was completed in approximately 30 min. No more than one training session was conducted per day.

Detraining

Following completion of the 8-week strengthening training, participants were instructed to carry on their normal lifestyles and avoid any type of strengthening exercise for 28 weeks. During detraining, subjects were contacted systematically to ensure that they were not engaged in regular exercise.

Statistical Analysis

All data were analyzed with SPSS (version 18.0) for windows. Data are reported as mean ± SD. Descriptive statistics and tests for normality (Shapiro–Wilks test) were performed for all outcome variables. Repeated-measures multivariate analysis of variance was used to examine differences within subjects over time. When F value was significant, post hoc mean comparisons were analyzed with the least significant difference multiple comparisons test. The significant level was set at $p < 0.05$.

Results

Of the 10 participants who underwent initial assessment, none dropped out of the program and completed 8-week tongue strengthening training and 28-week follow-up.

Training Effects

After 8-week training period, there were significant improvements ($p < 0.05$) in tongue tip pressure and tongue base pressure as well as effortful swallowing pressure. Tongue tip pressure, tongue base pressure, and effortful swallowing pressure were significantly increased at 4th, 2nd, and 4th week, respectively, compared with baseline ($p < 0.05$). And these pressures were steadily increased to 8th week. Table 1 shows the training effects according to the flow of time.

Detraining Effects

After 28 weeks of detraining, there were significant decreases in tongue tip pressure and tongue base pressure as well as effortful swallowing pressure. Tongue tip pressure, tongue base pressure, and effortful swallowing pressure were significantly decreased at 8th, 20th, and 20th week, respectively, compared with 8-week training. However, these reduced tongue tip pressures were still greater than pre-training values ($p < 0.05$). Table 2 shows the detraining effects according to the flow of time.

Discussion

The aim of this study was to examine the change in tongue tip pressure, tongue base pressure, and tongue pressure during effortful swallowing of young adults in response to 8 weeks of tongue strength training followed by 28 weeks of detraining.

The results of this study revealed significant increases in tongue tip pressure and tongue base pressure as well as effortful swallowing pressure at the end of the training. As seen in Table 1, participants demonstrated steadily increasing tongue pressures during the entire 8 weeks of training. The present study used high-intensity training and was able to increase tongue tip pressure, tongue base pressure, and effortful swallowing tongue pressure by 25, 26, 35 %, respectively, after 8-week training. The results of the present study demonstrated that normal subjects were able to gain significant tongue strength after 8 weeks of

Table 1 Training effects of tongue strength exercise

	Tongue tip pressure (kPa)		Tongue base pressure (kPa)		Effortful swallowing pressure (kPa)	
	Mean ± SD	*p*	Mean ± SD	*p*	Mean ± SD	*p*
Baseline	64.5 ± 13.05		60.8 ± 11.85		53.2 ± 9.81	
TR 2 week	71.1 ± 11.53	0.065	67.9 ± 11.49*	0.001	57.7 ± 9.76	0.183
TR 4 week	74.5 ± 10.79*	0.008	72.2 ± 10.33*	0.000	60.4 ± 11.46*	0.045
TR 6 week	77.7 ± 11.66*	0.000	74.4 ± 10.66*	0.000	68.6 ± 12.18*	0.000
TR 8 week	80.5 ± 12.23*	0.000	76.4 ± 11.11*	0.000	71.6 ± 12.59*	0.000

TR training

* Significant difference versus baseline ($p < 0.05$)

Table 2 Detraining effects of tongue strength exercise

	Tongue tip pressure (kPa)		Tongue base pressure (kPa)		Effortful swallowing pressure (kPa)	
	Mean ± SD	*p*	Mean ± SD	*p*	Mean ± SD	*p*
TR TM	80.5 ± 12.23		76.4 ± 11.11		71.6 ± 12.59	
DT 4 week	79.5 ± 12.19	0.419	77.0 ± 11.02	1.000	69.6 ± 11.88	0.419
DT 8 week	77.1 ± 12.12*	0.013	77.0 ± 11.12	1.000	69.1 ± 11.63	0.132
DT 12 week	76.6 ± 11.42*	0.018	76.6 ± 11.19	1.000	68.6 ± 11.39	0.106
DT 16 week	76.1 ± 11.73*	0.008	75.4 ± 10.74	1.000	68.5 ± 11.07	0.471
DT 20 week	75.4 ± 11.35*	0.002	73.5 ± 10.27*	0.022	64.4 ± 10.37*	0.003
DT 24 week	75.3 ± 11.36*	0.005	71.3 ± 10.34*	0.006	63.9 ± 10.46*	0.001
DT 28 week	74.3 ± 11.18*	0.004	69.6 ± 10.42*	0.001	62.0 ± 10.46*	0.000

TR training, *TM* termination, *DT* detraining

* Significant difference versus 8-week training ($p < 0.05$)

intensive training. Our results are similar to those studies that reported improved strength after tongue strengthening exercise [2, 4–6].

Although our participants did not train effortful swallowing, their tongue pressures during effortful swallowing were increased significantly together after 8-week tongue strengthening exercise ($p < 0.05$). Probably, effortful swallowing pressure improvements might be related to increased tongue muscular strength observed during the training period. Because muscles that are essential to the initiation of the swallow are recruited during a tongue-press activity and greater activity results in a more vigorous swallow, when a swallow is weak, a tongue-press exercise may improve swallowing [3]. The current study supports the efficacy of tongue strengthening exercise in increasing tongue muscle strength and oral pressure during swallowing in healthy individuals.

The major finding of this study was that after 28 weeks of detraining, normal subjects were able to maintain the increases achieved after 8 weeks of tongue strengthening exercise. Regarding the effects of detraining in tongue strength, the results of this study demonstrated that functional gains observed during the training period significantly decreased after 2–5 months of detraining. As seen in Table 2, participants demonstrated steadily decreasing tongue pressures during the entire 28 weeks of detraining. After 28 weeks of detraining, tongue tip pressure, tongue base pressure, and tongue pressure during effortful swallowing were significantly lower compared to tongue pressure values measured after 8 weeks of training but remained higher than pre-training values. The present selected 28 weeks of long-term detraining in an attempt to determine the consequences of withdrawing the strength training stimulus. Participants in the present study retained 61, 56, 48 % of the gains in tongue tip pressure, tongue base pressure, and tongue pressure during effortful swallowing, respectively, after 28 weeks of detraining.

A critical issue in rehabilitation is the retention of skills and abilities gained as a result of intervention. This is of particular concern for strength training, where gains result specifically from requiring muscle groups to exert forces beyond what is necessary for everyday movements [7].

Clark et al. [7] investigated the detraining effect of the tongue muscle after 9 weeks of strengthening training and found that training effects significantly decreased in lingual strength in the weeks following the discontinuation of training (average of 23.2 days). But, our participants maintained the strengthening effect even after 28 weeks during detraining period. Although the strengthening effects attained at 8 weeks were significantly decreased during detraining period (8–20 weeks), tongue pressures did not reduce to the baseline level. One possible explanation for the discrepancy between two experiments is the difference of exercise method and intensity. In major limb muscles, the detraining effects of strengthening exercises are known as intensity- or training volume-dependent [19, 20]. Fatouros et al. [19] reported that exercising at a higher intensity results in a lower rate of strength loss during detraining, and strength gains are maintained for a longer period of time. On the other hand, Harris et al. [20] reported that it is not intensity, but rather training volume over a given training period that effects the detraining outcomes. In Clark's study [7], participants pressed the tongue against the hard palate or tongue depressor with maximum effort for 1 s. So the exertion subject exhibited could be subjective. But, in our study participants pressed the tongue against the IOPI bulb for 2 s according to the target value and the exertion subject exhibited was monitored in real time. And the time of training lasted approximately 30 min per session in our study compared with approximately 3 min per session in Clark's study.

This study was based on normal subjects without swallowing problem. In general, the elderly are more vulnerable to detraining effects [15, 16]. Therefore, maintenance programs after strengthening exercises would be more important for prolonging training effects in the elderly or oropharyngeal dysphagia patients [25]. With regard to the detraining effect of tongue strengthening exercise, there might be about two strategies to counteract the detraining effect. The first is continued maintenance exercise. Trappe et al. [26] reported that with continued exercise of once per week, older individuals have been shown to maintain both strength and muscle size after completing an initial strength training regimen. The second strategy is retraining exercise. It is reported that 12–21 weeks retraining after 3–24 weeks detraining period restored the gained strength [14, 27, 28]. Applying those methods to the tongue strengthening exercise would lessen burden of detraining periods to maintain the needed tongue strength.

Caution must be taken with regard to the participants in this study who were young healthy people aged 21–35 years, free from swallowing problem, and not taking any medication that would interfere with the study. They may not be a true representation of general population and the finding of the present study must be treated with caution as the results may not be applicable to other person with healthy problem. Thus, additional study is required concerning detraining effects after strengthening exercise of the tongue muscle of elderly or dysphagia patients.

Conclusion

In summary, the results of the present study highlight that a period of 28 weeks of detraining following 8 weeks of tongue strength exercise significantly impairs the major part of the favorable functional changes obtained after training although the gain maintained above the baseline. Therefore, our data reinforce the idea that periodic exercise or retraining is needed after prolonged tongue strengthening exercise in order to improve or maintain the exercise effect.

Conflict of interest The author has no conflict of interest to report.

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