Clinical Trial/Experimental Study

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Tongue strengthening exercise is effective in improving the oropharyngeal muscles associated with swallowing in community-dwelling older adults in South Korea

A randomized trial

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Abstract

Background Tongue strengthening exercise (TSE) is a remedial method for the training of swallowing-related muscles in the oropharyngeal phase. However, clinical evidence of its effectiveness is insufficient.

Methods To investigate the effect of TSE on the oropharyngeal muscles associated with swallowing in older adults, in this study, 40 elder adults living in the community were recruited and assigned to 2 groups. The experimental group performed a TSE with a 1-repetition maximum resistance level of 70%. The exercise was divided into an isometric and isotonic part. The control group did not perform an exercise. We measured the muscle strength and thickness of the tongue and suprahyoid muscles using an Iowa Oral Performance Instrument and ultrasonography.

Results The experimental group showed a statistically significant increase in tongue muscle strength and thickness in the oral phase ($P = .001$ and $< .001$, respectively). In the pharyngeal phase, the experimental group showed a statistically significant increase in the mylohyoid and digastric muscles (suprahyoid muscles) ($P = .045$ and .019, respectively). The control group showed no statistically significant changes.

Conclusion TSE is effective in increasing the strength and thickness of the oropharyngeal muscles of elder adults and is recommended for those who are vulnerable to swallowing difficulties.

Abbreviations: 1-RM = 1-repetition maximum, TSE = tongue strengthening exercise.

Keywords: older, sarcopenia, strength, swallowing, tongue

1. Introduction

Sarcopenia occurs during the normal aging process, results in a reduction of muscular volume and size, and leads to muscle weakness.[1] The elderly may undergo physiological changes of skeletal muscle, which reduce physical activity and result in negative impacts, such as falls; these changes may also affect the muscles associated with swallowing and cause swallowing difficulty in the elderly, which is called presbyphagia.[2–4] Therefore, exercise of the muscles related to swallowing in elderly people who are vulnerable to sarcopenia is important.

The tongue is a skeletal muscle and a representative soft-tissue structure of the stomatognathic system of the oral cavity.[5] The role of the tongue in oropharyngeal swallowing is extensive and essential to normal swallowing function. The tongue is involved in mastication, manipulation, and formation and transport of the food bolus to the tongue base during the oral phase of the swallowing process.[6] However, the strength and endurance of the tongue muscles are significantly reduced in the elderly compared to younger adults, because these muscles are affected by sarcopenia.[7,8] As a result, various problems can occur, such as lateral sulcus residue, poor bolus formation and mastication during the oral phase, and vallecular residue and aspiration during the pharyngeal phase.[6,9]

Tongue strengthening exercise (TSE) is a therapeutic exercise aimed at enhancing the swallowing function by improving tongue

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Table 1

Characteristics of participants.

Characteristics	Experimental group (n = 20)	Control group (n = 20)
Age (y) mean ± SD	69.5 ± .4.3	68.4 ± 3.9
Gender, male/female	10/10	11/9
Height, cm	159.7 ± 7.6	158.9 ± 9.8
Weight, kg	59.8 ± 9.5	60.6 ± 9.7
Body mass index	23.3 ± 2.3	24.1 ± 3.8

SD = standard deviation.

muscle strength. Several previous studies have demonstrated the efficacy of TSE.[10–13] Robbins et al[14] demonstrated an increased tongue strength in 10 elder adults who performed TSE for 8 weeks; the increase in tongue thickness was measured by magnetic resonance imaging. However, the Robbins et al[14] study had a very small number of subjects and no control group. Recently, Van den Steen et al[10] reported a significant increase in tongue muscle strength after TSE application for 8 weeks in a healthy older adult; however, the effect of TSE on the thickness of the tongue and other muscles associated with swallowing was not determined, because only tongue muscle strength was measured. Studies related to TSE are lacking and the effects remain unclear. Therefore, this study investigated the effect of TSE on the oropharyngeal muscles of elder adults living in the community.

2. Methods

2.1. Participants

A total of 40 community-dwelling elder adults living in 2 senior citizen's centers in the Busan territory of South Korea were enrolled in this study. This study was conducted from September 2018 to December 2018. The inclusion criteria were as follows: age > 65 years, able to independently perform activities of daily living, > 24 point score on the Mini-Mental Status Examination-Korean version, tongue pressure >30 kilopascal (kPa), and normal range of tongue motility (e.g., protrusion, lateralization). The exclusion criteria were as follows: history of speech or swallowing deficits, severe visual impairment, parafunctional sucking and biting habits (finger sucking, lip, cheek, and object biting, bruxism, and nail biting), smoker, and person with a specific hobby (e.g., wind instrument player). The subjects' general characteristics are shown in Table 1. Ethical approval was obtained from the Inje University Institutional Review Board before conducting the experiment (INJE 2018-09-002-001).

2.2. Tongue strengthening instrument

This study employed a TPS system for the TSE (TPS 100, Cybermedic Inc, Iksan, South Korea). The TPS system is a tongue muscle exercise device designed for resistance training. The TPS system consists of a pressure sensor, air-bulb, and display (e.g., tablet PC, smartphone) for the resistance training, and the pressure sensor and tablet PC are connected by a Bluetooth interface. The external force applied to the pressure sensor is automatically displayed on the Tablet PC screen in kPa (Fig. 1).

2.3. Intervention

A total of 40 older adults were divided between an experimental group (n = 20) and a control group (n = 20). The experimental group performed TSE using the TPS system. The 1-repetition maximum (1-RM) was measured for all subjects before training to determine their baseline resistance value. To measure the 1-RM, a pressure sensor was placed between the tongue and the palate of each subject in both groups, and they were asked to press their tongue as strongly as possible against the sensor. The experimental group then performed TSE by applying70% of their 1-RM baseline measurement.

The exercise performed by the experimental group was divided into an isotonic and isometric type. The isotonic type was performed by repeating the contraction and relaxation of the

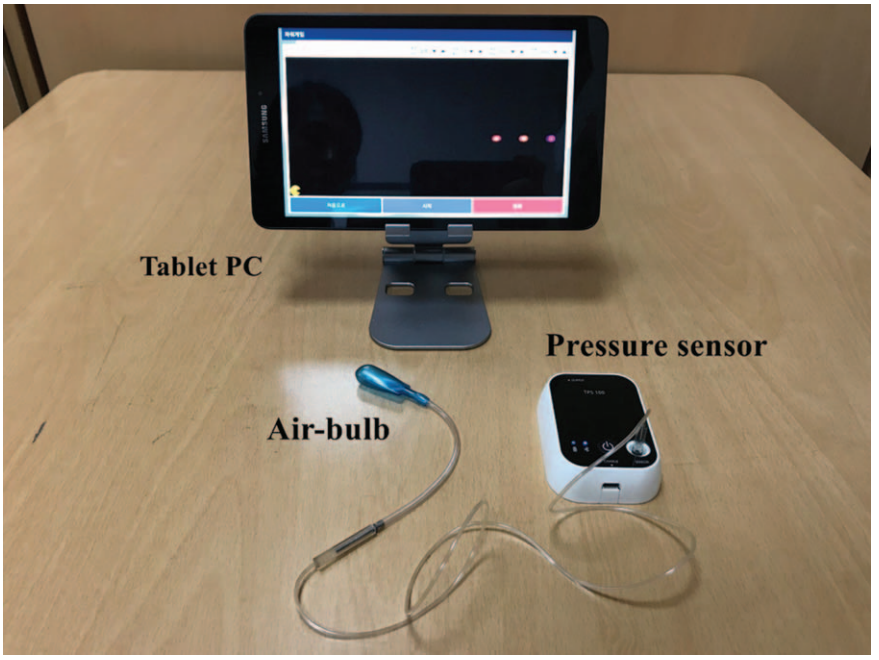

Figure 1. Constituents of the TPS system.

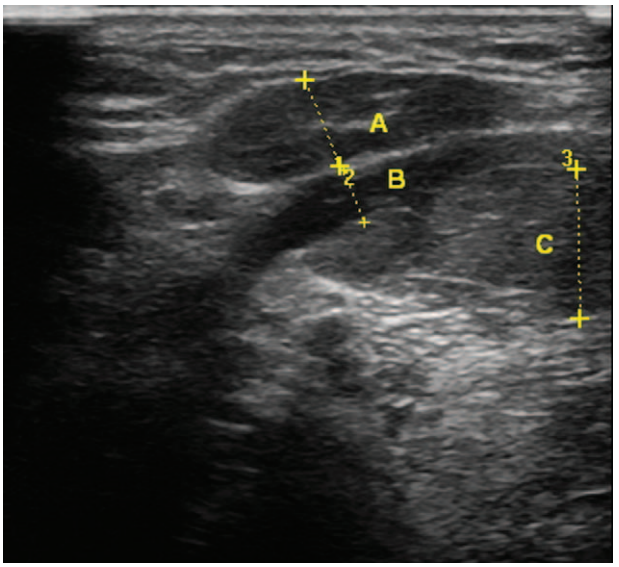

Figure 2. Thickness measure of the suprahyoid muscles. (A: anterior belly of digastric muscle, B: mylohyoid muscle, C: geniohyoid muscle).

tongue muscle 30 times at 3 sets per day. The isometric type was a state of contraction of the tongue muscle maintained for 30 seconds for a total of 3 sets. The control group did not perform an exercise.

2.4. Outcome measurement

Tongue strength was measured using the TPS system. The measurement was performed by placing the air-bulb between the tongue and the palate and then pressing the bulb firmly with the tongue. The average value of 3 consecutive measurements was recorded.

The thickness of the tongue and suprahyoid muscle was measured using a portable ultrasonography device (SONON300L, Healcerion, Seoul, Korea) with a 10 MHz and linear- and convex-array transducer. Tongue thickness was determined by measuring the distance between the upper and lower surfaces of the tongue muscles in the center of the plane perpendicular to the Frankfort horizontal plane of the frontal session. The vertical distance was measured from the surface of the mylohyoid muscle to the dorsum of the tongue. Suprahyoid muscle measurements were performed by positioning the transducer between the hyoid bone and the chin and visualizing the image on a tablet PC. The suprahyoid muscle measurements included the measurements of the anterior bellies of the digastric and the mylohyoid muscles. The digastric muscle measurements were obtained from the upper to the lower boundary of the fascia covering the muscle at the broadest point perpendicular to the mylohyoid muscle. The mylohyoid muscle measurements were recorded below the measurement point of the digastric muscle, from the upper to the lower boundary of the fascia covering the muscle (Fig. 2). Ultrasonographic measurement of muscle thickness was performed by an experienced rehabilitation physician.

2.5. Data analysis

Participant characteristics were analyzed using the statistical software program SPSS Statistics 20 (IBM Corporation, US). Descriptive statistics were presented as means with standard deviations. The Shapiro–Wilk test was used to check normality of the outcome variables. 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. The effect sizes (Cohen d) of changed scores between the experimental and control groups were calculated. An effect size of 0.2, 0.5, and 0.8 represented a small, moderate, and large effect, respectively.

3. Results

3.1. General characteristics of subjects

Data from a total of 40 patients were analyzed. No significant differences in the baseline characteristics were observed between the 2 groups ($P > .05$). The flowchart of the study is shown in Figure 3. The general characteristics of the subjects are shown in Table 1.

3.2. Tongue muscle strength

The experimental group showed a statistically significant increase of tongue muscle strength from 37.08 ± 3.50 kPa to 43.92 ± 4.88 kPa ($P = .002$); the increase was approximately 6.8 kPa (18%). The control group showed an increase from 36.55 ± 3.29 kPa to 37.09 ± 3.36 kPa ($P = .196$), which was not statistically significant; the increase was approximately 0.5 kPa (1.5%). A statistically significant difference between the 2 groups was observed after the intervention ($P = .001$) (Table 2).

3.3. Tongue muscle thickness

The experimental group showed a statistically significant increase of tongue muscle thickness from 42.58 ± 2.53 mm to 44.75 ± 2.98 mm ($P = .005$); the increase was approximately 2.17 mm (5%). The control group showed an increase from 39.00 ± 1.84 mm to 39.09 ± 2.11 mm ($P = .102$), which was not statistically significant; the increase was approximately 0.36 mm (0.9%). A statistically significant difference was observed between the two groups after the intervention ($P < .000$) (Table 2).

3.4. Thickness of the mylohyoid muscles

The experimental group showed a statistically significant increase of mylohyoid muscle thickness from 0.75 ± 0.19 mm to 1.85 ± 0.32 mm ($P = .008$); the increase was approximately 0.09 mm (12%). The control group showed an increase from 0.70 ± 0.06 mm to 0.70 ± 0.11 mm ($P = .792$), which was not statistically significant; the increase was approximately 0.01 mm (1.4%). A statistically significant difference was observed between the two groups after the intervention ($P = .045$) (Table 3).

3.5. Thickness of the digastric muscles

The experimental group showed a statistically significant increase of digastric muscle thickness from 6.57 ± 0.51 mm to 6.88 ± 0.49 mm ($P = .002$); the increase was approximately 0.31 mm (4.7%). The control group showed an increase from 6.29 ± 0.44 mm to 6.30 ± 0.49 mm ($P = .414$), which was not statistically significant; the increase was approximately 0.01 mm (0.15%). A statistically significant difference was observed between the 2 groups after the intervention ($P = .019$) (Table 3).

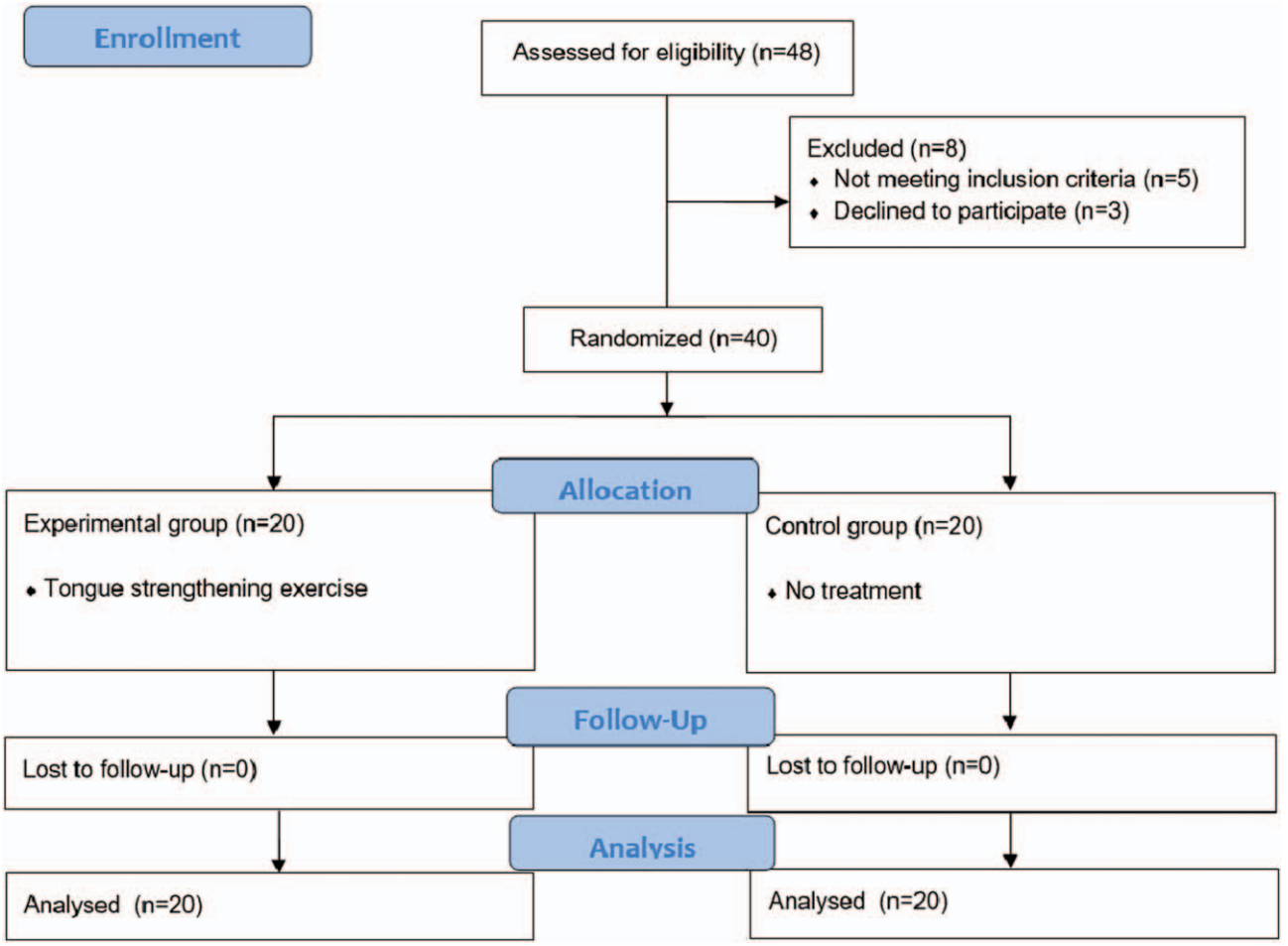

Figure 3. Flow chart.

Table 2

Changes of tongue muscles in parameters before and after treatment.

	Experimental group				Control group					
***P* values size**	**Before**	**After**	**Change**	***P* value**	**Before**	**After**	**Change**	***P* value**	**Intergroup *P* values**	**Effect size**
Muscle strength, kPa	37.08 (3.50)	43.92 (4.88)	6.83 (4.42)	.002*	36.55 (3.29)	37.09 (3.36)	0.55 (1.36)	.196	0.001†	1.54
Muscle thickness, mm	42.58 (2.53)	44.75 (2.98)	2.17 (1.50)	.005*	39.00 (1.84)	39.09 (2.11)	0.36 (0.67)	.102	<0.000†	0.72

Mean (standard deviation).
* $P < .05$ by paired *t* test.
† $P < .05$ by independent *t* test.

Table 3

Changes of submental muscles in parameters before and after treatment.

	Experimental group				Control group					
	Before	**After**	**Change**	***P* value**	**Before**	**After**	**Change**	***P* value**	**Intergroup *P* values**	**Effect size**
MHM thickness, mm	0.75 (0.19)	0.85 (0.32)	0.09 (0.10)	.008*	0.70 (0.06)	0.70 (0.11)	0.01 (0.11)	.792	.045†	0.34
DM thickness, mm	6.57 (0.51)	6.88 (0.49)	0.31 (0.13)	.002*	6.29 (0.44)	6.30 (0.49)	0.01 (0.07)	.414	.019†	0.63

Mean (standard deviation).
DM = digastric muscle, MHM = mylohyoid muscle.
* $P < .05$ by paired *t* test.
† $P < .05$ by independent *t* test.

4. Discussion

Maintaining and improving the strength of the oropharyngeal muscles is important for safe swallowing in the elderly. Therefore, we investigated the effect of TSE on the oropharyngeal muscles of elder adults living in the community. We measured the tongue strength and thickness in the oral phase using the Iowa Oral Performance Instrument and ultrasonography. The tongue muscle strength and thickness of the elder adults in the experimental group significantly increased by 18% and 5%, respectively; however, no significant changes were observed in the control group. Therefore, TSE is an effective method to increase the tongue strength and thickness of the elderly.

A reasonable loading value is one of the important factors in resistance training. Recently, Van den Steen et al[10] conducted a study using TSE at 60%, 80%, and 100% of the 1-RM value in a group of healthy elder adults; all groups showed a significant increase in tongue muscle strength, but100% 1-RM was the most effective. TSE at 100% of the 1-RM is likely to result insubstantial muscle fatigue and noncompliance, because the exercise must be performed with a constant maximum effort. Therefore, this study was performed at 70% of the range that is generally accepted as optimal for resistance training.[15] As a result, we were able to confirm that the range we chose increased tongue muscle strength as well as the range in previous studies.[10–13] This study also measured the change in tongue thickness, which was not reported in previous studies. We confirmed by using ultrasonography that TSE induces physiological changes, including tongue thickness and muscle strength. Resistance exercise of skeletal muscle increases the number of myofibers and results in increased muscle hypertrophy and cross-sectional area.[16–19] The results of our study confirm that the tongue muscle is responsive to resistance training.

Interestingly, this study confirms that TSE is an effective method to increase suprahyoid muscle thickness in the pharyngeal phase. The experimental group demonstrated a significant increase in both the digastric and mylohyoid muscle thickness. Yoshida et al[20] in the sEMG study demonstrated that tongue press exercise induces activation of the suprahyoid muscles. Muscle activation is a recruitment of motor units by peripheral nerves. High amplitudes on the sEMG value represent an increase in the number of recruited motor units or an increased discharge rate of motor units.[21] Therefore, the induction of muscle activation most likely induces muscle physiology changes, such as muscle strength and muscle thickness, and the results of our study support this concept. The tongue muscles and suprahyoid muscles are attached to the hyoid bone below the chin and are partially integrated.[22] Therefore, contraction of the tongue muscles, such as the genioglossus and hyoglossus muscles, and the suprahyoid muscles, such as the digastric muscle and the myolyoid muscle, during TSE may be associated.[23] For this reason, TSE is thought to positively influence changes in both the suprahyoid and tongue muscles.

5. Conclusion

In conclusion, TSE is an effective method to increase the thickness of the suprahyoid and tongue muscles and increase tongue muscle strength in the elderly. We propose TSE for elder adults who are vulnerable to swallowing difficulties.

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