Effects of Two Types of Tongue Strengthening Exercises in Young Normals

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Abstract
This pilot study examines the effects of two
types of tongue strengthening exercises on
tongue function measures of strength and
endurance in a group of 31 healthy young
subjects. Subjects underwent baseline and 1
month post-baseline assessments of tongue
function and were randomized to one of
three groups, including: (1) no exercise;
(2) exercise group receiving standard tongue
strength exercises using a tongue depressor,
and (3) exercise group receiving tongue
strengthening exercises using the Iowa Oral
Performance Instrument. Results revealed a
significantly greater change in maximum
tongue strength in the group that received
any treatment compared with the group re-
ceiving no treatment (p = 0.04). Results pro-
vide support for the theory that tongue
strengthening exercises improve tongue
strength in healthy young subjects.

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Introduction

The tongue plays a major role in propul-
sion of the bolus of food or liquid through
the oral cavity into the pharynx and through
the pharynx into the esophagus [1]. Tongue
strength has been found to play a role in oral
stage swallow functioning [2–4], with signifi-

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cant correlations between strength and temporal measures of the oral phase of swallowing, specifically, oral transit times. In addition, tongue strength has been correlated with ability to effectively clear a bolus through the oral cavity (i.e., percentage oral residue) [4].

In the limbs, muscle strength training is known to increase muscle bulk (i.e., enlargement of muscle fiber area and increase in the number of fibers in humans), as well as to increase neural activation of muscles [5–8]. In addition, muscle strength training has been found to increase maximal isometric muscle force in young (ages 20–30) and elderly (age 68+) normal subjects [5, 8, 9]. Researchers have advocated muscle strengthening exercises to improve limb muscle strength in patients with neuromuscular disease. Improvement in muscle strength has been found following strength exercise programs in these same patients [10–13]. Although tongue strengthening exercises have been advocated to improve tongue function for speech and swallowing in dysarthric and dysphagic populations [14–16], few studies to date have examined the effects of tongue strengthening exercises on tongue strength in disordered populations [17], and no study to date has been done in healthy subjects.

Subjects and Methods

This study examined the effects of tongue strengthening exercises in a group of 31 healthy subjects, ages 20–29 years. Twenty-three females and 8 males participated in this study, with a mean age of 26 years. Male and female subjects were examined together, as studies have found no sex difference in tongue strength [18, 19]. The study protocol was approved by the Institutional Review Board of Northwestern University and the Lakeside VA Medical Center Office of Research. Written informed consent was obtained for all subjects. An in-depth interview revealed that no subject demonstrated any history of a neurologic disease or head and neck surgery or injury that might affect

tongue function. An oral-motor examination was performed on all subjects and intraoral inspection confirmed that no subject had undergone tongue piercing nor was wearing a tongue stud. Subjects were randomized to one of three groups: (1) no exercise group; (2) exercise group receiving standard tongue strength exercises using a tongue depressor, and (3) exercise group receiving tongue strengthening exercises using the Iowa Oral Performance Instrument (IOPI), a device that provides biofeedback on the amount of tongue strength generated by the subject.

Subjects underwent assessments of tongue function at two points in time: (1) baseline and (2) 1 month post-baseline. During data collection for the tongue function measures, subjects were seated with the tongue pressure bulb placed against the hard palate, just behind the upper alveolar ridge. A bite block was not used in this study [20]. Tongue function testing included: (1) maximal isometric pressure generation (P_{max} = strength) and (2) submaximal pressure generation (50% of P_{max} = endurance) [20]. Tongue function was measured with the IOPI, a device designed to measure pressure applied with the tongue on an air-filled bulb [20, 21]. The air-filled bulb is attached to a pressure transducer connected to an amplifier, signal conditioning conduit, and digital voltmeter. The light display is calibrated to indicate the pressure exerted relative to a maximum value. Also, the light display provides visual feedback for the subject to control and maintain a submaximal tongue strength response during endurance testing. The device has a built-in timer with an on/off switch so that tongue endurance can be recorded in seconds.

For the tongue strength (P_{max}) task, the subjects were instructed as follows: 'Press up on the bulb with your tongue and squeeze the bulb against the roof of your mouth. Squeeze as hard as you can for three seconds'. Subjects performed three trials, with 2 min rest between trials [22]. Maximum tongue strength was measured in kilopascals (kPa). Three trials of maximum pressure were obtained for each subject at each time point, using the maximum pressure as the subject's maximal tongue strength [20].

During data collection for the tongue endurance task (50% P_{max}), the subject was trained to exert sufficient pressure with the tongue on the bulb to maintain the light-emitting diodes (LED) at 50% P_{max}. Subjects were asked to sustain 50% P_{max} for as long as possible and were timed. The middle LED was set to represent 50–60% of P_{max} [23]. The experimenter provided verbal encouragement during each trial of tongue endurance. Trials were terminated when the subjects could no longer maintain adequate pressure on the bulb to

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keep the lights within the green (i.e., 50% P_{max}) zone. Subjects were allowed a range of one light (40% of P_{max}) above or below the target green zone that they could briefly (i.e., 1–2 s) enter during this task [23]. Subjects underwent three trials of tongue endurance testing and were given 2 min rest between trials. Tongue endurance was assessed by measuring the time the subject could maintain 50% of maximum pressure. Three trials of endurance testing were performed for each subject at each evaluation point, using the maximum endurance (in seconds) as the subject's maximal tongue endurance [20].

Subjects randomized to receive tongue strengthening exercises were asked to perform the exercises 5 days a week [6] for 1 month, practicing 5 times per day, 10 repetitions per practice session. During practice sessions, subjects were instructed to press against a tongue depressor or the IOPI tongue bulb with their tongue in four directions: (1) left; (2) right; (3) on protrusion, and (4) on elevation. Subjects were instructed to push as hard as they could with the tongue for 2 s on each repetition for each direction. Subjects were not given instruction in nor asked to practice the tongue endurance task (50% P_{max}). Subjects using the tongue depressor manually resisted against the tongue with the tongue depressor. Subjects using the IOPI were instructed to press as hard as they could against the tongue bulb while viewing the numeric pressure reading on the IOPI as feedback for how hard they were pushing. Subjects underwent practice of maximum tongue strength and tongue endurance tasks with the examiner to ensure understanding of the tasks. Subjects randomized to either of the two exercise groups were given written instructions and completed a form documenting each practice session. Subjects were instructed to bring the completed form to the 1-month post-baseline testing session and were asked to verify accuracy of the form.

The unpaired t test and Fisher's exact test were used to compare means at baseline and differences in means. The paired t test was used to compare the change in means from baseline to 1 month within each group. The homogeneity of regression slopes of the line relating change to baseline value was tested using one-way analysis of covariance. Statistical analysis was done using the PROC MIXED procedure of SAS [24].

Results

There were 5/10 males in the 'no-treatment' group, 2/8 males in the tongue depressor group and 1/10 males in the IOPI group (p = 0.11). One-way analyses of variance comparing means across three study groups indicated that there were no significant differences between the group treated with the tongue depressor and the group treated with the IOPI in mean maximum tongue strength and endurance at baseline and follow-up, as well as in change from baseline to follow-up (table 1). Therefore, these two active treatment groups were combined for further statistical analysis.

When examining change in mean maximum tongue strength from baseline to 1 month post-baseline for the no-exercise group, no significant differences were found (69.8 vs. 71.2, p = 0.62). However, when change in mean maximum tongue strength from baseline to 1 month post-baseline was examined for the two exercise groups combined, there was a significant increase in tongue strength from baseline to 1 month post-baseline (64.4 vs. 73.1, p < 0.001, table 2). There was no significant difference in baseline values between the two groups. There was a significantly greater change in the treated group than in the group receiving no treatment (8.7 vs. 1.4, p = 0.04).

The relationship between initial tongue strength and treatment effect is stronger in the active treatment group than in the no-treatment group. In the active treatment group, 40% of the variance of the dependent variable is explained by the independent variable (r^2 = 0.396), while for the no-treatment group, r^2 = 0.087.

Analysis of covariance of the change in maximum tongue strength with baseline maximum tongue strength as the covariate indicated a marginally significant difference in

Table 1. Mean (SEM) maximum tongue strength (kPa) and maximum tongue endurance (s) by treatment with tongue blade or IOPI and time of observation

	Tongue blade			IOPI			p value
	n	mean	SEM	n	mean	SEM	
Maximum strength							
Pretreatment	10	63.9	2.2	11	64.8	3.0	0.81
1 month	10	72.1	2.1	11	74.0	2.4	0.56
Difference	10	8.20	2.4	11	9.18	2.9	0.80
p value		0.009			0.009		
Maximum endurance							
Pretreatment	10	29.7	5.2	11	20.8	3.4	0.17
1 month	10	43.7	13.9	11	26.0	3.0	0.22
Difference	10	14.0	11.0	11	5.2	3.4	0.45
p value		0.23			0.16		

Table 2. Mean (SEM) maximum tongue strength (kPa) and maximum tongue endurance (s) by group (treatment with combined IOPI and tongue blade and no treatment) and time of observation

	No treatment			With treatment			p value
	n	mean	SEM	n	mean	SEM	
Maximum strength							
Baseline	10	69.8	5.6	21	64.4	1.9	0.36
1 month	10	71.2	5.4	21	73.1	1.6	
Difference	10	1.4	2.8	21	8.7	1.9	0.04
p value[1]		0.62			<0.001		
Maximum endurance							
Baseline	10	17.9	2.6	21	25.0	3.1	0.09
1 month	10	18.4	2.7	21	34.4	6.9	
Difference	10	0.5	1.1	21	9.4	5.5	0.12
p value[1]		0.66			0.10		

[1] p value compares baseline to 1 month.

Fig. 1. Change in maximum tongue strength (kPa, vertical axis) versus baseline maximum tongue strength (kPa, horizontal axis) for 21 persons receiving some treatment (closed circles) and 10 persons receiving no treatment (open circles). Bolded line is the least squares regression line for the group receiving some treatment. Unbolded line is the least squares regression line for the group receiving no treatment.
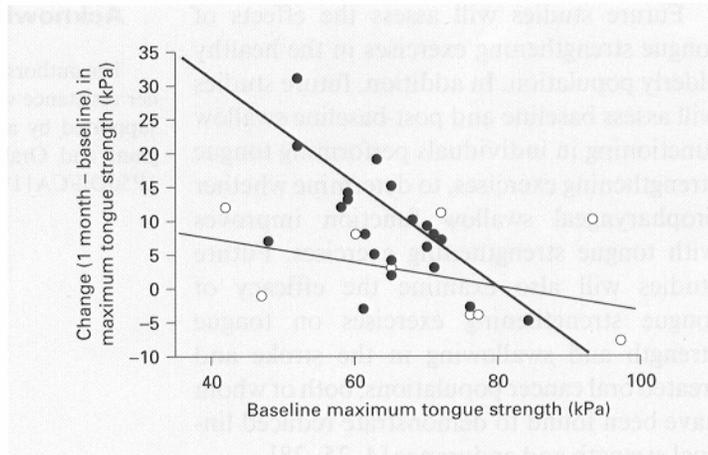
slopes of the least squares regression lines between the two groups (–0.63 in the group receiving some treatment versus –0.15 in the group receiving no treatment, p = 0.06, fig. 1). These results indicate that in persons receiving some treatment, lower maximum tongue strength at baseline was associated with greater improvement in tongue strength. No significant differences were found between and within the treatment groups in tongue endurance measures (table 2).

Discussion

It is interesting that although improvement in maximum tongue strength was observed post-baseline for the two exercise groups, there was no difference between the two groups in tongue strength post-baseline. One might have expected higher tongue strength measures post-baseline in the exercise group that was provided biofeedback (i.e., the group randomized to exercise using the IOPI). The lack of difference in tongue strength improvement for the two young normal exercise groups argues for the use of tongue blades for tongue strength treatment, rather than the more expensive IOPI device. However it may be that other patient groups, e.g., oral cancer patients or older normals could benefit from the IOPI.

Significant improvements in tongue strength for the exercise vs. no-exercise groups provide support for the theory that tongue strengthening exercises improve tongue strength in healthy young adults. Interestingly, those subjects in the exercise group with higher baseline tongue strength measures did not change as much as those with lower baseline measures. This result supports a possible benefit of tongue strength exercises for patients who are medically debilitated or who have sustained some type of damage (e.g., neural, structural) to the tongue that results in reduced tongue strength.

The lack of significant difference in tongue endurance from pre- to post-baseline for the exercise groups may be due to the fact that the subjects did not practice a tongue endurance task.

Future studies will assess the effects of tongue strengthening exercises in the healthy elderly population. In addition, future studies will assess baseline and post-baseline swallow functioning in individuals performing tongue strengthening exercises, to determine whether oropharyngeal swallow function improves with tongue strengthening exercises. Future studies will also examine the efficacy of tongue strengthening exercises on tongue strength and swallowing in the stroke and treated oral cancer populations, both of whom have been found to demonstrate reduced lingual strength and endurance [4, 25–28].

References

1 Cerenko D, McConnel FMS, Jackson RT: Quantitative assessment of pharyngeal bolus driving forces. Otolaryngol Head Neck Surg 1989; 100:57–63.
2 Meyers T: Analysis of Tongue Strength and Swallowing Efficiency in Amyotrophic Lateral Sclerosis; unpublished doct diss, Northwestern University, Evanston, 1986.
3 Reddy NP, Thomas R, Canilang EP, Casterline J: Toward classification of dysphagic patients using biomechanical measurements. J Rehabil Res Dev 1994;31:335–344.
4 Lazarus CL, Logemann JA, Pauloski BR, Rademaker AW, Larson CR, Mittal BB, Pierce M: Swallowing and tongue function following treatment for oral and oropharyngeal cancer. J Speech Lang Hear Res 2000;43:1011–1023.
5 Hakkinen K, Alen M, Komi PV: Changes in isometric force- and relaxation-time, electromyographic and muscle fibre characteristics of human skeletal muscle during strength training and detraining. Acta Physiol Scand 1985;125:573–585.
6 Gillam GM: Effects of frequency of weight training on muscle strength enhancement. J Sports Med 1981; 21:432–436.

7 Milner-Brown HS, Stein RB, Lee RG: Synchronization of human motor units: Possible roles of exercise and supraspinal reflexes. Electroencephalogr Clin Neurophysiol 1975; 38:245–254.
8 Ratzin Jackson CG, Dickinson AL, Ringel SP: Skeletal muscle fiber area alterations in two opposing modes of resistance: Exercise training in the same individual. Eur J Appl Physiol 1990;61:37–41.
9 Phillips W, Hazeldene R: Strength and muscle mass changes in elderly men following maximal isokinetic training. Gerontology 1996;42:114–120.
10 Milner-Brown HS: Muscle strengthening in a post-polio subject through a high-resistance weight-training program. Arch Phys Med Rehabil 1993;74:1165–1167.
11 Milner-Brown HS, Mellenthin M, Miller RG: Quantifying human muscle strength, endurance and fatigue. Arch Phys Med Rehabil 1986; 67:530–535.
12 Siegel IM: The management of muscular dystrophy: A clinical review. Muscle Nerve 1978;1:453–460.

13 Vignos PJ: Physical models of rehabilitation in neuromuscular disease. Muscle Nerve 1983;6:323–338.
14 Rosenbek J, LaPointe LL: The dysarthrias: Description, diagnosis and treatment; in Johns DF (ed): Clinical Management of Neurogenic Communication Disorders. Boston, Little, Brown, 1978, pp 251–310.
15 Logemann JA: Evaluation and Treatment of Swallowing Disorders, ed 2. Austin, ProEd, 1998.
16 Logemann JA: Articulation management of the oral pharyngeal impaired patient; in Perkins WH (ed): Current Therapy for Communication Disorders. New York, Thieme & Stratton, 1983.
17 Sullivan P, Hind JA, Robbins JA: Lingual exercise protocol for head and neck cancer: A case study. Dysphagia 2001;16:154.
18 Nicosia MA, Hind JA, Roecker EB, Carnes M, Doyle J, Dengel GA, Robins J: Age effects on the temporal evolution of isometric and swallowing pressure. J Gerontol Med Sci 2000;55A,11:M634–M640.
19 Mortimore IL, Fiddes P, Stephens S, Douglas NJ: Tongue protrusion force and fatiguability in male and female subjects. Eur Respir J 1999; 14:191–195.

20 Robin DA, Somodi LB, Luschei ES: Measurement of tongue strength and endurance in normal and articulation disordered subjects; in Moore CA, Yorkston KM, Beukelman DR (eds): Dysarthria and Apraxia of Speech: Perspectives on Management. Baltimore, Brookes, 1991, pp 173–184.

21 Robin DA, Goel A, Somodi LB, Luschei ES: Tongue strength and endurance: Relation to highly skilled movements. J Speech Hear Res 1992;35:1239–1245.

22 Milner-Brown HS, Miller R: Muscle membrane excitation and impulse propagation velocity are reduced during muscle fatigue. Muscle Nerve 1986;9:367–374.

23 Solomon NP, Robin DA, Luschei ES: Strength, endurance and stability of the tongue and hand in Parkinson's disease. J Speech Lang Hear Res 2000;43:256–267.

24 SAS Institute Inc: SAS OnlineDoc®, Version 8. Cary, SAS Institute Inc, 1999.

25 Goodell C, Shaker R, Bowser M, Zamir Z: Effect of aging and cerebrovascular accident (CVA) on non-deglutitive lingual pressure. Gastroenterology 1992;102:A554.

26 McNeil MR, Weismer G, Adams S, Mulligan M: Oral structure non-speech motor control in normal, dysarthric, aphasic and apraxic speakers: Isometric force and static position control. J Speech Hear Res 1990;33:255–268.

27 Robinovitch SN, Hershler C, Romilly DP: A tongue force measurement system for the assessment of oral-phase swallowing disorders. Arch Phys Med Rehabil 1991;72:38–42.

28 Thompson EC, Murdoch BE, Stokes PD: Tongue function in subjects with upper motor neuron type dysarthria following cerebrovascular accident. J Med Speech Lang Pathol 1995;3:27–40.