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ORIGINAL PAPER

A Pilot Study of the Head Extension Swallowing Exercise: New Method for Strengthening Swallowing-Related Muscle Activity

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Abstract This pilot study examined the effect of a new head extension swallowing exercise (HESE) on submental muscle activity and tongue strength in healthy volunteers. Fifteen young adults (10 females and 5 males) were instructed to extend their head backwards as much as possible, and while watching the ceiling, swallowed their saliva every 10 s for a duration of 20 min. Twenty-four treatments were performed over 8 weeks. The outcome variables evaluated at baseline, 4 and 8 weeks of training, and 12-week follow-up included mean and peak submental muscle activation amplitudes during normal and effortful swallowing measured via surface electromyography, and anterior and posterior isometric tongue pressures were measured with the Iowa Oral Performance Instrument. Results indicated that the muscle activation amplitudes during effortful swallowing increased significantly at 4 and 8 weeks compared to baseline ($p < 0.025$). However, the increases in amplitudes during normal swallowing were minor (nonsignificant) after 8 weeks compared to baseline. The isometric pressures of the tongue tip and the posterior part of the oral tongue were significantly higher at 8 weeks compared to baseline ($p < 0.025$). Thus, the 8-week HESE protocol significantly improved suprahyoid muscle activity during effortful swallowing as well as the isometric tongue pressures. The HESE appears effective in exercising and strengthening the suprahyoid muscles and tongue muscles in healthy participants. Although encouraging, these results need to be replicated in clinical trials for testing the therapeutic effects of the HESE in older adults and patients with dysphagia who present with decreased hyolaryngeal elevation.

Keywords Deglutition · Deglutition disorders · Dysphagia · Electromyography · Posture · Swallowing

Introduction

Swallowing is a complex physiological function that requires exquisite coordination of swallowing-related structures and muscles. Suprahyoid muscles (mylohyoid, geniohyoid, digastric, and stylohyoid) and tongue muscles are the representative major muscles that are important for safe swallowing [1, 2]. Weakness in these muscles could induce incomplete laryngeal elevation; post-swallow residue in the oral space, vallecula, and pyriform sinus; and resultant airway penetration or aspiration.

Rehabilitative exercises such as the head lift exercise (Shaker exercise) and Mendelsohn maneuver are commonly used to target and strengthen the hyolaryngeal muscles. However, these exercises have some limitations. Due to the fact that the sternocleidomastoid muscle would fatigue before the suprahyoid muscles during the head lift exercise, the original effect of exercise could be limited [3]. In addition, due to the fact that this exercise requires the patient to lie supine, it would not be ideal for an individual with a physical condition (e.g., back pain and kyphosis) that would make this position difficult or uncomfortable [4, 5]. Wheeler-Hegland et al. [6] reported that some healthy young adults (28 % of participants) could not perform the Mendelsohn maneuver perfectly according to the original instruction, but they could perform this maneuver only partially. Bogaardt et al. [7]

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reported that one patient who developed dysphagia after a stroke complained of dizziness while performing the modified Mendelsohn maneuver (maintaining a swallow for 8–10 s at 30-s interval for a period of 20 min). Additionally, in the clinical setting, several patients were observed to be unable to complete this maneuver due to the lack of comprehension of the precise method of performing it. Therefore, another option is needed to increase the strength of the hyolaryngeal muscles in patients who show weakness in these muscles. To this end, a new exercise that could be an alternative method to strengthen the hyolaryngeal muscles was developed in the present study.

The head extension posture is rarely investigated in studies due to the risk of aspiration [8]. Castell et al. [9] observed that when a human swallows a liquid with the head in an extended position, the degree of upper esophageal sphincter (UES) relaxation is reduced. In addition, the head extension posture impairs the coordination between pharyngeal contraction and UES relaxation. Ertekin et al. [8] showed that the dysphagia limit in healthy people and in patients with dysphagia reduced significantly with the head extended as compared with normal swallowing in a neutral position. Sakuma and Kida [10] reported that head extension increases the difficulty in elevating the pharynx and larynx, thereby hindering pharyngeal clearance and narrowing the lumen of the pharyngoesophageal segment. In Sakuma and Kida's study, swallowing in the head extension posture increased the amplitude of the submental suprahyoid muscle activity measured using surface electromyography (sEMG). Taken together, these results suggested that the difficulty during swallowing in the head extension posture could be used as a method to provide resistance to the suprahyoid muscles during a long-term swallowing exercise. Moreover, due to the fact that the submental muscles partially contribute to tongue pressure formation [5], long-term administration of a head extension swallowing exercise (HESE) could influence tongue pressures.

To the best of our knowledge, no previous study has used head extension swallowing as a rehabilitative technique. The main hypothesis for this study was that the long-term HESE would enhance the activation of muscles involved in swallowing, as measured with sEMG and significantly increase lingual strength, as measured by the Iowa Oral Performance Instrument (IOPI). As a first step, this pilot study used young, healthy volunteers to identify the effect of the HESE. When introducing a new rehabilitative exercise, establishing its effects on healthy subjects is an important first step before applying it to patient populations [4]. Generally, pilot studies of newly developed rehabilitative exercises verify the physiological effects of these exercises on healthy individuals using sEMG [4, 11, 12].

Thus, the aim of this study was to investigate the effectiveness of the 8-week HESE on submental muscle activity and tongue strength in healthy young adults.

Materials and Methods

Participants

Fifteen volunteers (10 females and 5 males) without a reported history of speech or swallowing deficits participated in the experiment. They were all examined by an occupational therapist who had majored in dysphagia therapy. The mean age of the participants was 20.4 ± 0.8 years with a range of 20–23 years. None of the participants reported any drug use that could affect swallowing or neurological functions, and none had engaged in any type of swallowing-related strength training program for at least 1 year prior to this study. Before conducting the study, all participants received a complete explanation of the purpose, risks, and procedures of the investigation, and provided written informed consent. The procedures were performed 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.

Experimental Procedure

All participants performed HESE 3 days a week on non-consecutive days, with each session lasting approximately 20 min; the total duration of the exercise was 8 weeks. Between two 10-min exercises, a 2-min rest period was allowed for all participants so as to avoid muscle fatigue. All participants were tested for submental muscle activation during normal swallowing and effortful swallowing, as well as for isometric tongue pressures of the tongue tip and posterior part of the oral tongue on four occasions (at baseline, after 4 and 8 weeks of training, and at the 12-week follow-up)

Training Protocol

The 8-week training protocol was held three times per week at the same location, and each session lasted 20 min. During training, the participants sat on an upright chair. Every 10 s, the author rang a bell. At the sound of the bell, all the participants extended their head maximally back, and watching the ceiling, swallowed their saliva comfortably. If a participant was unable to swallow due to inadequate saliva production, the participant was permitted to take a sip of water to aid swallowing in the assigned position. Each time after ringing the bell, the author

checked whether all the participants had performed the exercise appropriately. All training sessions were completed as in-person sessions and not administered independently at home.

Electrophysiological Evaluation

Measurements were preceded by one familiarization session in order to exclude learning curve effects and to improve the reliability of the values obtained. After the familiarization session, the measurements were repeated three times, with a 2-min rest period between the trials.

During the examination, each participant was instructed to sit on an upright chair and hold his or her trunk in a neutral upright position. Prior to measurement, the submental skin of each participant was cleansed with an alcohol wipe and allowed to dry for approximately 30 seconds. For recording submental muscle complex (mylohyoid, geniohyoid, and anterior digastric muscles) activity, surface wireless EMG electrodes were placed on the skin on both sides of the midline under the chin, with an interelectrode distance of 1 cm [13]. A two-channel EMG device (BTS FreeEMG 1000; BTS Bioengineering, Italy) was used to record the activities. The signals were filtered (10–500 Hz), amplified, rectified, and then integrated.

The recorded sEMG data were analyzed offline. The onset and offset representing the effort by the participant for each task were identified, and the in-between signals were analyzed to obtain the mean (root mean square value) and peak values (peak amplitude) for each participant. The onset on swallowing was defined as the point at which the EMG signal activity exceeded 2 SD from the mean values at baseline that led to the swallowing event. The offset on swallowing was defined as the point at which the EMG signal activity was below 2 SD from the mean values at baseline [10]. For each task, the mean values of the three trials were used in the analysis of the mean value or peak value. The mean and peak values derived from the left and right channels during sEMG were averaged, and this average value was used in the statistical analysis.

Tongue Pressure Measurements

Tongue pressure measurements were performed using IOPI [14] by the same evaluator on four occasions. The same conditions were maintained for each test in 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, every 4 weeks. During follow-up, an assessment was conducted at 4 weeks after the termination of the strengthening exercise.

Pressure of the Tongue Tip

Anterior lingual elevation strength was assessed with the tongue bulb positioned longitudinally 10 mm posterior to the tongue tip [15]. The 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 the tongue tip strength [16].

Pressure of the Posterior Part of the Oral Tongue

Posterior lingual elevation strength was assessed with the tongue bulb positioned 10 mm anterior to the most posterior circumvallate papilla [15]. Participants were again 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 the strength of the posterior part of the oral tongue [16].

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–Wilk test) were performed for all the outcome variables. Repeated-measures multivariate analysis of variance was used to examine the differences within participants over time during the training period. When the F value was significant, post hoc mean comparisons were analyzed with the least significant difference multiple comparisons test. The significant level was set at $p < 0.025$ (Bonferroni correction for multiple comparisons: $0.05/2 = 0.025$). A paired t test was used to examine differences within participants between 8-week and 12-week follow-up. The significance level was set at $p < 0.05$.

Results

Complaints Reported by the Participants

During the first week of the HESE, four participants (three females and one male) experienced mild anterior neck muscle soreness. These symptoms persisted until the second week. No complaints were reported by any of the participants in weeks 3 through 8.

Submental Muscle Activations

Table 1 presents the changes in sEMG peak and mean amplitudes during normal swallowing over 8 weeks. There were increases in the peak and mean values by an average

Table 1 Training effects of HESE on suprahyoid muscle activation during normal swallowing

	sEMG peak value		sEMG mean value	
	Mean ± SD	*P* value	Mean ± SD	*P* value
Baseline	66.0 ± 20.2	–	21.1 ± 6.7	–
TR 4 week	67.3 ± 22.6	>0.05	21.9 ± 6.9	0.497
TR 8 week	77.0 ± 32.7	0.099	24.4 ± 11.0	0.068
Follow-up	72.4 ± 27.8	0.575	21.9 ± 5.1	0.879

HESE head extension swallowing exercise, *TR* training

of 11 and 3.3 μV, respectively, after the 8-week training as compared with the baseline, but these changes were not statistically significant ($p = 0.099$, $p = 0.068$).

Table 2 presents the changes in sEMG peak and mean amplitudes during effortful swallowing over 8 weeks. There was a significant increase in the peak and mean values at 4 weeks ($p = 0.010$ and $p < 0.001$, respectively) and 8 weeks ($p = 0.016$ and $p = 0.122$, respectively) as compared with the baseline. These increases were also maintained at 12 weeks follow-up).

Lingual Strength

Table 3 presents the changes in isometric tongue pressure at the tongue tip and posterior part of the oral tongue. There was a significant increase in the pressures of the tongue tip and the posterior part of the oral tongue at 8 weeks as compared with the baseline ($p = 0.002$ and $p < 0.001$, respectively). These increases were also maintained at 12 weeks (follow-up).

Discussion

The present investigation introduced HESE, a new exercise protocol, which is developed as a potential alternative to hyolaryngeal musculature strengthening exercises for patients who cannot perform other exercises due to various physical and cognitive limitations, or as an additional exercise option available to clinicians. This exercise can be performed in a neutral sitting position on a chair, wheelchair, or bed without requiring additional equipment. To perform the exercise, the participants only need to swallow their own saliva with the head extended backwards.

The premise of this study was based on the findings of Sakuma and Kida [10], i.e., swallowing in the head extension posture increased the amplitude of the submental suprahyoid muscle activity measured using sEMG. This increased muscle activity is thought to correspond to the extent of muscle contraction [4]. Therefore, this study used this increased muscle activity as a resistance to strengthen suprahyoid muscles. In this posture, the effect of gravity on swallowing-related structures and the increased moving distances of those structures would have acted as a resistance. In the investigation of swallowing and related disorders, surface electrodes are typically used and placed on the submental skin surface to measure muscle activity. These surface recordings serve as an estimate of the combined activity of muscles in that region. Owing to the proximity of the floor-of-mouth musculature to the submental surface electrodes, a burst in EMG activity recorded from the submental region is considered as the result of the combined activity of the individual floor-of-mouth muscles [17]. Additionally, this study measured isometric tongue pressures (anterior and posterior) to understand how tongue strength is affected by the HESE. These pressures may

Table 2 Training effects of HESE on suprahyoid muscle activation during effortful swallowing

	sEMG peak value		sEMG mean value	
	Mean ± SD	*P* value	Mean ± SD	*P* value
Baseline	135.4 ± 39.9	–	44.9 ± 13.2	–
TR 4 week	163.7 ± 45.4*	0.010	58.6 ± 15.9*	<0.001
TR 8 week	163.9 ± 39.6*	0.016	58.5 ± 15.1*	0.002
Follow-up	163.1 ± 28.2	0.917	53.5 ± 15.2	0.122

HESE head extension swallowing exercise, *TR* training

* Significant difference versus baseline ($p < 0.025$)

Table 3 Training effects of HESE on isometric tongue pressure

	Tongue tip pressure (kPa)		BOT pressure (kPa)	
	Mean ± SD	*P* value	Mean ± SD	*P* value
Baseline	62.9 ± 12.7	–	59.2 ± 14.0	–
TR 4 week	66.8 ± 11.3	0.045	62.3 ± 12.7	0.449
TR 8 week	68.1 ± 10.5*	0.002	67.1 ± 11.8*	<0.001
Follow-up	68.3 ± 10.5	0.843	65.4 ± 6.3	0.197

BOT back of the oral tongue, *HESE* head extension swallowing exercise, *TR* training

* Significant difference versus baseline ($p < 0.025$)

provide additional information about the therapeutic mechanism underlying training effects. Both the measurements used in this study have been used in previous studies to represent the changes generated during long-term swallowing-related exercises in healthy subjects [4, 11, 18].

This study hypothesized that long-term HESE would enhance swallowing-related submental muscle activation and tongue pressure. The results of this study indicate that the peak and mean submental muscle activation amplitudes during effortful swallowing were significantly increased at 4 and 8 weeks as compared with the baseline. This could be explained as follows: the positioning and execution of this novel exercise are considered to rigorously activate the swallowing-related submental muscles. This increased muscle activity during swallowing in the HESE acted as a resistance during long-term exercise. The improvements in performance after training using the HESE suggest that this method could be a powerful strengthening exercise for the suprahyoid muscles.

The peak and mean suprahyoid muscle amplitudes during normal swallowing increased after 8 weeks of training. However, the training effects were more dramatic for effortful swallowing conditions than for normal swallowing conditions. In the normal swallowing condition, only minor increases were noted. These minor increases in normal swallowing could be explained as follows. Due to the fact that the participants in this study comprised healthy young adults with a normal neuromuscular function prior to beginning training, normal swallowing might be a submaximal task for them [19]. With reference to tongue strength, it has been reported that the maximum isometric tongue strength of healthy individuals is much higher than their tongue strength utilized during swallowing. This means that healthy individuals have more tongue strength than that is required for normal swallowing [20]. In addition, although maximum lingual isometric pressure is higher in healthy young people than in healthy older people, normal swallowing tongue pressure did not differ significantly in these two groups [21]. Burkhead et al. [22] mentioned that swallowing is a submaximal muscular activity and that the muscular force generated to successfully complete the activity is much lesser than the maximal force that could be generated by the muscle involved. Thus, in the same vein, although the degree of maximum voluntary muscle contraction increased significantly after the 8-week strengthening program in this study, the degree of muscle activation needed to swallow naturally might not significantly differ in healthy subjects. Due to the fact that the participants in this study already had no problems in swallowing at baseline, the changes that emerged as a consequence of the 8-week strengthening exercise might not be reflected in the normal swallowing condition. These results are consistent with those of previous studies describing normal swallowing as a submaximal task and demonstrating the nonsignificant effects of long-term swallowing-related exercise training administered to healthy adults [4, 18]. Therefore, this study measured parameters not only during normal swallowing but also during effortful swallowing to identify the change in submental muscle activation after the 8-week strengthening program. Due to the fact that effortful swallowing uses the maximal muscle contraction of the tongue and submental muscles [23], the increases in muscle activation after the 8-week HESE might be reflected on submental muscle activation during the effortful swallowing condition in the healthy participants in this study. It has been hypothesized that geriatric individuals or patients with dysphagia may demonstrate impairments that respond more favorably to the HESE due to the fact that many of them have a decreased hyolaryngeal elevation and related muscle weakness during ordinary swallowing [24, 25]. Data from this pilot study provide a starting point for pursuing this important clinical question in the future studies. Thus, additional research is needed to identify how the variables examined in this study impact normal swallowing in geriatric populations and patients with dysphagia under varying medical conditions.

In addition to this, the pressures of the isometric tongue tip and the posterior part of the oral tongue significantly

increased at 8 weeks, as compared with the baseline. In swallowing, the tongue plays a role as important as the suprahyoid muscles. In addition, submental muscles partially contribute to tongue pressure formation [5, 23]. Thus, in the progression of the 8-week HESE, extrinsic tongue muscles required for swallowing would have been strengthened.

The study findings also reveal that the implementation of the HESE, similar to other muscle exercises [3], could induce mild muscle discomfort that resolves spontaneously after a couple of days of exercise. Thus, candidates should be notified about anticipated muscle soreness before beginning this exercise.

Limitations

Several limitations of this study need to be acknowledged. First, the head extension posture used in this study might endanger the process of swallowing and cause aspiration [8]. Thus, the participants in this study swallowed their saliva instead of other foods. Only the participants who experienced difficulty with dry swallows due to hyposalivation were allowed to take a sip of water to aid swallowing while in the head extension posture. In older adults, xerostomia is a common complaint. Thus, the initiation of swallowing may be more difficult for older adults than for healthy young adults [26]. Not every participant in this study showed signs of penetration or aspiration while occasionally taking a sip of water to aid swallowing. Nevertheless, it might have been better to moisten the mouth with a small amount of water possibly using a swab rather than delivering a bolus to minimize the possibility of penetration or aspiration. This method of aiding swallowing should be considered in future studies. Second, the dependent variable used in this study was submental muscle activation measured with sEMG and isometric tongue pressures measured with IOPI. These surface recordings and tongue pressures serve as estimates of the combined activity of the floor-of-mouth muscles and tongue-related muscles. Although these could possibly reflect changes in muscle activation according to the progression of the strengthening exercise, the actual movements of the swallowing-related structures cannot be visualized directly. Thus, further studies using videofluoroscopy should be conducted to detect these changes in older adults and patients with dysphagia. Third, as the HESE is in the initial phase of testing, this study was conducted with healthy young adults who did not have swallowing difficulties. Thus, the results of this study may not yet serve as the basis to recommend the use of the HESE for dysphagia rehabilitation. Replication of these results in older adults or patients with dysphagia who present with decreased hyolaryngeal elevation would increase our understanding of the therapeutic effects of this novel exercise. Finally, the sample size of this preliminary study was limited to 15 motivated volunteers, and therefore, the results should be interpreted with some caution.

Conclusion

The results of this pilot study indicate that the 8-week HESE protocol significantly improved the muscle activity of the suprahyoid muscle in the effortful swallowing condition as well as the isometric tongue pressures. The HESE appears effective in exercising the suprahyoid and tongue muscles in healthy participants, and they could achieve therapeutic effects in terms of strengthening the suprahyoid and tongue muscles. While these results are encouraging, they need to be replicated in clinical trials for testing the therapeutic effects of the HESE in older adults and patients with dysphagia who present with decreased hyolaryngeal elevation.

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Compliance with Ethical Standards

Conflict of Interests The author declares no conflict of interest to report.

References

1. Matsuo K, Palmer JB. Anatomy and physiology of feeding and swallowing: normal and abnormal. Phys Med Rehabil Clin N Am. 2008;19:691–707.
2. Pearson WG Jr, Langmore SE, Yu LB, Zumwalt AC. Structural analysis of muscles elevating the hyolaryngeal complex. Dysphagia. 2012;27:445–51.
3. Easterling C, Grande B, Kern M, Sears K, Shaker R. Attaining and maintaining isometric and isokinetic goals of the Shaker exercise. Dysphagia. 2005;20:133–8.
4. Mishra A, Rajappa A, Tipton E, Malandraki GA. The recline exercise: comparisons with the head lift exercise in healthy adults. Dysphagia. 2015;30:730–7.
5. Yoshida M, Groher ME, Crary MA, Mann GC, Akagawa Y. Comparison of surface electromyographic (sEMG) activity of submental muscles between the head lift and tongue press exercises as a therapeutic exercise for pharyngeal dysphagia. Gerodontology. 2007;24:111–6.
6. Wheeler-Hegland KM, Rosenbek JC, Sapienza CM. Submental sEMG and hyoid movement during Mendelsohn maneuver, effortful swallow, and expiratory muscle strength training. J Speech Lang Hear Res. 2008;51:1072–87.
7. Bogaardt HC, Grolman W, Fokkens WJ. The use of biofeedback in the treatment of chronic dysphagia in stroke patients. Folia Phoniatr Logop. 2009;61:200–5.
8. Ertekin C, Keskin A, Kiylioglu N, Kirazli Y, On AY, Tarlaci S, Aydogdu I. The effect of head and neck positions on

oropharyngeal swallowing: a clinical and electrophysiologic study. Arch Phys Med Rehabil. 2001;82:1255–60.
9. Castell JA, Castell DO, Schultz AR, Georgeson S. Effect of head position on the dynamics of the upper esophageal sphincter and pharynx. Dysphagia. 1993;8:1–6.
10. Sakuma T, Kida I. Relationship between ease of swallowing and deglutition-related muscle activity in various postures. J Oral Rehabil. 2010;37:583–9.
11. Slovarp L, King L, Off C, Liss J. A pilot study of the tongue pull-back exercise for improving tongue-base retraction and two novel methods to add resistance to the tongue pull-back. Dysphagia. 2016;31:416–23.
12. Sze WP, Yoon WL, Escoffier N, Rickard Liow SJ. Evaluating the training effects of two swallowing rehabilitation therapies using surface electromyography-chin tuck against resistance (CTAR) exercise and the Shaker exercise. Dysphagia. 2016;31:195–205.
13. Beckmann Y, Gurgor N, Cakir A, Arici S, Incesu TK, Secil Y, Ertekin C. Electrophysiological evaluation of dysphagia in the mild or moderate patients with multiple sclerosis: A concept of subclinical dysphagia. Dysphagia. 2015;30:296–303.
14. Northwest IOPI. Iowa oral performance instrument: user's manual. Carnation: IOPI Northwest; 2005.
15. Robbins J, Kays SA, Gangnon RE, Hind JA, Hewitt AL, Gentry LR, Taylor AJ. The effects of lingual exercise in stroke patients with dysphagia. Arch Phys Med Rehabil. 2007;88(2):150–8.
16. Robin DA, Goel A, Somodi LB, Luschei ES. Tongue strength and endurance: relation to highly skilled movements. J Speech Hear Res. 1992;35(6):1239–45.
17. Palmer PM, Luschei ES, Jaffe D, McCulloch TM. Contributions of individual muscles to the submental surface electromyogram during swallowing. J Speech Lang Hear Res. 1999;42:1378–91.
18. Clark HM, Shelton N. Training effects of the effortful swallow under three exercise conditions. Dysphagia. 2014;29:553–63.
19. Steele CM. Optimal approaches for measuring tongue-pressure functional reserve. J Aging Res. 2013;2013:7.
20. Youmans SR, Youmans GL, Stierwalt JAG. Differences in tongue strength across age and gender: is there a diminished strength reserve? Dysphagia. 2009;24:57–65.
21. Nicosia MA, Hind JA, Roecker EB, Carns M, Doyle J, Dengel GA, Robbins J. Age effects on the temporal evolution of isometric and swallowing pressure. J Gerontol A. 2000;55:M634–40.
22. Burkhead LM, Sapienza CM, Rosenbek JC. Strength-training exercise in dysphagia rehabilitation: principles, procedures, and directions for future research. Dysphagia. 2007;22:251–65.
23. Huckabee ML, Steele CM. An analysis of lingual contribution to submental surface electromyographic measures and pharyngeal pressure during effortful swallow. Arch Phys Med Rehabil. 2006;87:1067–72.
24. Kim Y, McCuyllough GH. Maximum hyoid displacement in normal swallowing. Dysphagia. 2008;23:274–9.
25. Matsuo K, Palmer JB. Anatomy and physiology of feeding and swallowing: normal and abnormal. Phys Med Rehabil Clin N Am. 2008;19:691–707.
26. Anil S, Vellappally S, Hashem M, Preethannath RS, Patil S, Samaranayake LP. Xerostomia in geriatric patients: a burgeoning global concern. J Investig Clin Dent. 2016;7:5–12.

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