Effect of expiratory muscle strength training on swallowing-related muscle strength in community-dwelling elderly individuals: a randomized controlled trial

Ji-Su Park¹, Dong-Hwan Oh² and Moon-Young Chang³

¹Department of Rehabilitation Science, Graduate School of Inje University, Gimhae, Korea; ²Department of Occupational Therapy, Kyungdong University, Wonju, Korea; ³Department of Occupational Therapy, College of Biomedical Science and Engineering, Inje University, Gimhae, Korea

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Objective: This study aimed to investigate the effect of expiratory muscle strength training (EMST) on swallowing-related muscle strength in community-dwelling elderly individuals.

Background: Expiratory muscle strength training is an intervention for patients with oropharyngeal dysphagia. This training is associated with respiration, coughing, speech and swallowing, and its effectiveness has been proven in previous studies. However, the effects of EMST on elderly individuals and evidence are still lacking.

Materials and methods: This study included 24 community-dwelling senior citizens aged ≥65 years (12 men and 12 women). The experimental group trained at the 70% threshold value of the maximum expiratory pressure using an EMST device 5 days per week for 4 weeks and comprised five sets of five breaths through the device for 25 breaths per day. The placebo group trained with a resistance-free sham device. Post-intervention, muscle strength of the bilateral buccinator and the orbicularis oris muscles (OOM) was measured using the Iowa Oral Performance Instrument. Surface electromyography was used to measure activation of the suprahyoid muscles (SM).

Results: After intervention, the strength of the buccinator and the OOM in the experimental group showed statistically significant improvement. There was also statistically significant activation of the SM. In the placebo group, the strength of the orbicularis oris muscle alone improved. No statistically significant differences between groups were found for the strength of the buccinator and the OOM and the activation of the SM.

Conclusion: EMST had a positive effect on swallowing-related muscle strength in elderly participants.

Keywords: elderly, electromyography, muscle strength, oral function.

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Introduction

Presbyphagia occurs in otherwise healthy elderly adults, with a prevalence of 11.4–38.0% among community-dwelling elderly individuals¹,². It is caused by ageing-related sarcopenia due to a decrease in skeletal muscle mass and motor unit numbers³, which can affect swallowing-related muscles⁴. These age-related changes can have a negative effect on the effective and efficient flow of swallowed materials through the upper aerodigestive tract. It is distinguishable from dysphagia caused by neurological diseases⁵ such as stroke and Parkinson’s disease; however, because of the weakening of swallowing-related muscles, it is characterised by similar swallowing problems, including difficulties with bolus mastication and manipulation in the oral cavity, impaired lip closure, increased pharyngeal residue and a higher risk of aspiration⁶–⁸. This problem has been associated with dehydration, malnutrition, choking and death, highlighting the importance of treating swallowing-related problems in those who are vulnerable to swallowing, such as elderly people.
Expiratory muscle strength training (EMST) has recently been reported as a remedial approach for exercising swallowing-related muscles\(^9,10\). This training is shown to be effective for improving cough capacity by exerting a strong expiratory effect\(^11,12\), which could decrease the risk of aspiration\(^13,14\). During EMST, numerous swallowing-related muscles contract, and orofacial muscles such as the orbicularis oris muscles (OOM) and the buccinator muscles (BM) participate in the oral phase of swallowing. Continuous contraction of these muscles during mastication prevents food leakage from the mouth and prevents the bolus from blocking the lateral sulcus\(^15\). Furthermore, EMST has been reported to be effective for the activation of the suprahyoid muscles (SM: anterior belly of the digastric, mylohyoid and geniohyoid muscle) that is located in the anterior portion of neck\(^7\). In a previous study, the mean activation of SM during dry swallowing was reported to be approximately \(9.6 \pm 1.9\) \(\mu\)V for young adults and \(9.56 \pm 3.19\) \(\mu\)V for elderly individuals\(^16\).

The contraction of the SM, which initiates the swallowing reflex during the pharyngeal phase, pulls the hyolaryngeal complex in an anterior and superior direction to facilitate swallowing mechanisms, such as airway protection and the opening of the upper oesophageal sphincter\(^17\). EMST is a novel method for oral phase and pharyngeal phase training.

As previous EMST studies were conducted in patients with neurological diseases such as Parkinson’s disease\(^13\), Huntington’s disease\(^18\) and multiple sclerosis\(^19\), the usefulness of EMST in treating elderly individuals has not been determined. Therefore, this study aimed to examine the effect of EMST on the strength of the BM and the OOM and the activation of the SM in community-dwelling healthy elderly individuals without swallowing problem.

**Materials and methods**

**Participants**

This study was conducted from April to May 2015 and included 24 community-dwelling senior citizens (12 men, 12 women; age range: 65–76 years) who were recruited from public places. All participants were healthy volunteers with no reported neurological or structural damage affecting speech or swallowing function. Inclusion criteria were as follows: (i) age \(\geq 65\) years, (ii) no history of neurological diseases, (iii) ability to perform activities of daily living without the help of a caregiver, (iv) ability to communicate and cooperate and (v) a Mini-Mental State Examination score \(\geq 24\) points. The exclusion criteria were as follows: (i) severe orofacial pain, including trigeminal neuropathy; (ii) significant malocclusion or facial asymmetry; (iii) unstable breathing and pulse; (iv) hypertension; (v) impaired lip closure; and (vi) missing one or more incisors (8, 9, 24, 25) and molars (1, 2, 3, 14, 15, 16, 17, 18, 19, 30, 31, 32) according to Universal numbering system.

This study was approved by the Ethics Committee of the Inje University (2-1041024-AB-N-01 – 20150401-HR-200). We described the complete details of this study to all participants and obtained their informed consent to participate.

**Procedures**

This was a single-blind, randomized, controlled study and was scheduled to be performed over 4 weeks. The participants were randomly assigned to two groups: the experimental and the placebo groups. Before intervention, the baseline muscle strength of the bilateral BM and the OOM was assessed using the Iowa Oral Performance Instrument (IOPI Medical LLC, Carnation, WA, USA), as described previously. Immediately afterwards, SM activation was measured by a surface electromyography device (Laxtha Inc., Daejeon, Korea). The measurements were repeated post-intervention to evaluate changes in muscle strength and surface electromyogram (sEMG) value. Each assessment was performed by two evaluators, an experienced occupational therapist. The measurements were repeated following the intervention to evaluate changes in muscle strength. Experimental procedures are showed in the flow diagram (Fig. 1).

**Expiratory muscle strength training**

Before training, we measured maximal expiratory pressure (MEP) using a respiratory pressure meter (Micro RPM; Micro Medical, Basingstoke, UK) to determine the EMST threshold value for each participant. Measurements were recorded based on a study by Wheeler \(\text{et al.}\)^9 Briefly, participants were instructed to maintain an upright, seated position, and measurements were recorded by blocking airflow through the nasal cavity using a nose clip. Participants were asked to hold a disposable mouthpiece in their mouths in a state of maximum inhalation and then to exhale maximally, as strong and as fast as possible. Each participant...
repeated the manoeuvre until three trials were achieved within 5%. EMST resistance was set at 70% of the individual’s MEP value.

For training, participants were asked to open their mouths after maximum inhalation and to place the EMST mouthpiece between their lips before closing their mouths (Fig. 2). Then, they were instructed to perform a strong, fast exhalation until the pressure release valve in the EMST device opened. The pressure release valve was set to open if the expiratory pressure exceeded the targeted pressure set for the device. Evaluators confirmed whether the exercise was successful by listening for the sound of rushing air. EMST was performed 5 days per week and consisted of five sets of five breaths through the device for 25 breaths per day. During training, an approximately 1-min break was provided after each session to account for muscle fatigue and to reduce dizziness. The placebo group performed a similar procedure using a sham device that did not contain a pressure valve. It is a non-functional device with little effect of physiological load on targeted muscles.

Figure 1 Flow diagram of study.
Orofacial muscles strength measurements

The IOPI was used to measure the strength of the BM and the OOM in all participants. The IOPI includes a pressure bulb, connecting tube and main body. The bulb, which is made of polyvinyl chloride and is approximately 3.5 cm in length and 4.5 cm in diameter, is filled with approximately 2.8 ml of air. The bulb is connected to the IOPI’s main body by an 11.5-cm flexible tube. This device is designed to assess the muscle strength and endurance of the tongue, and it can also be used to evaluate those of the BM and the OOM.

BM and OOM were measured using the Clark and Solomon method. BM was measured on both the sides of the face by placing the pressure bulb between the teeth and the cheeks, and participants were asked to close their mouth gently and to squeeze the bulb as hard as possible for 2 s (Fig. 3). The instructions were as follows: ‘I will place the rubber bulb between your teeth and cheek. Please press the balloon as hard as you can using your cheek muscles’. If other muscles were used excessively or compensations were made, another assessment was performed after reiteration of the instructions.

To measure the strength of the OOM, the bulb was inserted between two tongue depressors, which were positioned between the centreline of the lips. Using this configuration, pressure was distributed evenly across the bulb’s surface. Participants were instructed to close their mouths gently, protrude their lips slightly and press the tongue depressors with their lips as hard as possible (Fig. 3). The instructions were as follows: ‘I will place the rubber bulb between your lips. Please close your mouth and protrude your lips slightly. When I ask, press the bulb using only your lips as hard as you can’. Pressure values were depicted as kilo-pascal.

Several muscles (masticatory muscles such as the masseter or risorius muscles for measuring the BM and zygomaticus major, masseter for measuring the OOM) may have been mobilised to some extent. Therefore, the following efforts were made to minimise this possibility: (i) Demonstrations and practices were executed several times before evaluation for accurate measurements. (ii) The measurements for orofacial muscle strength were usually recorded 4–6 times. If a measured value was too small or too large, it was abandoned. It was thought that the target strength was not measured properly or other muscles were mobilised. (iii) If the participant’s face was excessively distorted, or when associated reactions such as tilting head were observed, measurements were repeated.

sEMG data collection

SM activation was measured by sEMG using a Laxtha WEMG-4. sEMG activity was detected in the SM using bipolar Ag/AgCl electrodes. Before electrode attachment, the skin was cleaned with

Figure 2 Expiratory muscle strength training.

Figure 3 Measurement of buccinators muscle and orbicularis oris muscle.
an alcohol swab and beard and moustache of male participants were shaved. One pair of electrodes was placed between the mental protuberance and the hyoid bone, and the ground electrode was placed over the left clavicle. sEMG was performed when saliva was swallowed and signals were converted using the TeleScan software (Laxtha Inc., Daejeon, Korea). The sEMG sampling rate signal was set at 1000 Hz, and the band pass and notch filter were set at 20–500 Hz and 60 Hz, respectively, to eliminate signal noise. All evaluations were performed in a quiet room. sEMG was depicted as microvolt root mean square (µVRMS).

Statistical analyses
Participants’ characteristics were analysed using IBM SPSS Statistics version 20 (IBM Corp., Armonk, NY, USA). Descriptive statistics are presented as means with standard deviations. The Wilcoxon signed-rank test was used to compare the differences in muscle strength and activation before and after EMST. The Mann–Whitney U-test was used to compare pre- and post-intervention data between groups. The significance level was set at $p < 0.05$.

Results

Participants
Participants’ general characteristics are shown in Table 1. Before intervention, there were no significant differences in general characteristics (age, sex and body mass index), muscle strength of the BM or OOM or activation of the SM between groups ($p > 0.05$).

Table 1 Characteristics of participants.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Experimental group (n = 12)</th>
<th>Placebo group (n = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (year), mean ± SD (range)</td>
<td>65.33 ± 6.89 (60–84)</td>
<td>68.67 ± 7.26 (61–81)</td>
</tr>
<tr>
<td>Gender, male/female</td>
<td>6/6</td>
<td>6/6</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>160.33 ± 6.5914</td>
<td>162.17 ± 7.72</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>58.66 ± 7.7</td>
<td>63.67 ± 8.64</td>
</tr>
<tr>
<td>Body mass index</td>
<td>22.71 ± 1.69</td>
<td>24.14 ± 1.98</td>
</tr>
<tr>
<td>Denture state</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete denture</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Partial denture</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

SD: standard deviation.

Effect of orofacial muscle
Post-intervention, the experimental group showed a statistically significant improvement in muscle strength of the bilateral BM and the OOM ($p < 0.05$). Meanwhile, the placebo group showed a statistically significant improvement in the OOM strength alone ($p < 0.05$). No statistically significant differences between groups were found for the strength of the BM or OOM ($p > 0.05$) (Table 2).

Effect of the suprahyoid muscles
Post-intervention, the experimental group showed a statistically significant improvement in the activation of the SM ($p < 0.05$). Meanwhile, the placebo group showed a no statistically significant improvement in the SM activation ($p > 0.05$). No statistically significant differences between groups were found for the SM activation ($p > 0.05$) (Table 3).

Discussion
The proportion of elderly individuals in the general population is increasing on a global scale, and diverse age-related diseases are becoming serious concerns. Swallowing problems occur naturally with ageing, even in the absence of neurological diseases. Such problems lead to a reduced quality of life and cause many social problems. EMST is a remedial approach and an indirect therapy without direct use of food, its application is useful in elderly individuals with aspiration/penetration and this device has advantages of portability and easy use without assistance from specialists.

This study demonstrated the effectiveness of EMST in improving swallowing-related muscle strength and activation in elderly participants. After 4 weeks of EMST, the experimental group showed a significant improvement in the strength of the bilateral BM and the OOM. This result is presumed to reflect an increase in the strength of the bilateral BM and the OOM. Our findings are congruent with those of a previous study by Yanagisawa et al. that showed that EMST was a good expiratory training method that included various oral muscles, including the levator veli palatini and the BM. In particular, EMST requires high intraoral pressure as an expiratory activity against resistance, which is achieved through the contraction of both the cheeks. An increase in BM strength after EMST, such as that seen in our study, has not been described previously.
Table 2 Comparison of results between experimental group and placebo group.

<table>
<thead>
<tr>
<th>Sites</th>
<th>Experimental group</th>
<th>Placebo group</th>
<th>Between groups p&lt;sup&gt;b&lt;/sup&gt; values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before treatment</td>
<td>After treatment</td>
<td>Mean change (%)</td>
</tr>
<tr>
<td>RBM</td>
<td>23.7 ± 2.02</td>
<td>24.3 ± 1.57</td>
<td>0.6 ± 0.64 (2.53)</td>
</tr>
<tr>
<td>LBM</td>
<td>23.4 ± 2.16</td>
<td>23.87 ± 2.28</td>
<td>0.46 ± 0.69 (1.96)</td>
</tr>
<tr>
<td>OOM</td>
<td>18.7 ± 4.05</td>
<td>19.42 ± 3.73</td>
<td>0.72 ± 0.64 (3.85)</td>
</tr>
</tbody>
</table>

The values are mean ± standard deviation.
Unit: kilo-pascal. RBM, right buccinators muscle; LBM, left buccinators muscle; OOM, orbicularis oris muscles.
<sup>a</sup>p < 0.05; Mann–Whitney U-test.
<sup>b</sup>p < 0.05; Wilcoxon signed-rank test.

Table 3 Comparison of results between experimental group and placebo group.

<table>
<thead>
<tr>
<th>sEMG values</th>
<th>Experimental group</th>
<th>Placebo group</th>
<th>Between groups p&lt;sup&gt;b&lt;/sup&gt; values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before treatment</td>
<td>After treatment</td>
<td>Mean change (%)</td>
</tr>
<tr>
<td>Mean value</td>
<td>5.37 ± 1.96</td>
<td>6.07 ± 1.89</td>
<td>0.69 ± 0.69 (12.84)</td>
</tr>
<tr>
<td>Peak value</td>
<td>10.24 ± 2.1</td>
<td>11.42 ± 2.04</td>
<td>1.17 ± 1.55 (11.42)</td>
</tr>
</tbody>
</table>

The values are mean ± standard deviation.
Unit: Root mean square. sEMG, surface electromyogram.
<sup>a</sup>p < 0.05; Mann–Whitney U-test.
<sup>b</sup>p < 0.05; Wilcoxon signed-rank test.
Activation of the SM also significantly improved in the experimental group. Muscle activation is a successive recruitment of motor units by peripheral nerves. High amplitudes on the sEMG value represent an increase in the number of the recruited motor units or increased discharge rate of motor units. Wheeler et al.\textsuperscript{9} reported that high activation was induced immediately in the SM during EMST; therefore, continuous training is presumed to strengthen the SM. In addition, the duration of activation represents prolonged stimulation of peripheral nerves, resulting in prolonged muscle contraction. EMST has the advantage that patients can control duration of EMST performance by themselves; the longer a patient blows, the more prolonged stimulation is possible to input for muscle contraction.

The effect of EMST is divided into central and peripheral adaptation. The afferent stimulation from sensory receptors of the tongue and oropharynx increases the activation of the swallowing centre in the brain stem during EMST. Thus, EMST involves in both the central (neural) and peripheral (muscle) adaptation and contributes to the improvement of swallowing function. Findings from this study confirm that EMST has an effect on peripheral change through the increase in activation of the orofacial and the SM. In particular, improvement of the SM directly affects the hyolaryngeal excursion. The geniohyoid and the mylohyoid muscles among the SM are key muscles for the anterior and superior movement of hyoid bone during swallowing, are associated with airway protection and UES opening and contribute to safer swallowing.

Generally, the results of resistance training for improving the strength of skeletal muscles vary depending on the level of resistance and the length of the training period. The resistance threshold for increasing muscle strength is known to be effective at approximately 60% of the 1-repetition maximum (1RM)\textsuperscript{23}. This value is applied for the treatment of patients with dysphagia in the same manner\textsuperscript{24}. According to other reports, if approximately 60–75% of muscle strength is used during resistance exercises to strengthen the oropharyngeal muscle in patients with swallowing disorders, then an effective improvement of muscle strength can be expected\textsuperscript{25,26}. The resistance threshold of 70% of the 1RM applied in our study was, therefore, considered an appropriate resistance value for improving the strength of swallowing-related muscles.

Expiratory muscle strength training intervention is usually conducted for 4–5 weeks. In agreement with the protocol we used, Sapienza et al.\textsuperscript{27} also proposed that an EMST protocol consisting of five sub sessions per session, at five sessions per day, five times per week, for 4 weeks was effective. The 4-week resistance exercise period is based on a study of limb strength, and continuous muscle strength training during this period can induce peripheral or structural changes\textsuperscript{28}. Therefore, to increase the strength of skeletal muscles, at least 4 weeks of resistance training is required, and such training can induce an increase in muscle strength due to muscle enlargement\textsuperscript{29}. This theoretical grounding explains the results of our study. Therefore, this study recommends EMST as a potentially remedial approach to oropharyngeal muscles training such as SM, BM and OOM for elderly individuals with oropharyngeal swallowing problem.

The limitations of this study are as follows:

First, the results of this study cannot be generalised owing to a limited sample size. Second, this study did not confirm videofluoroscopic study. Third, brain imaging was not performed; hence, swallowing-related neural adaptation could not be confirmed.

Conclusion

We confirmed that EMST had a positive effect on swallowing-related muscle strength in healthy older adults in the community.

Acknowledgements

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References


Correspondence to: Moon-Young Chang, Department of Occupational Therapy, College of Biomedical Science and Engineering, Inje University, 197 Inje-ro, Gimhae-si, Gyeongsangnam-do 621-749, Korea. Tel.: +82 55 320 3685 Fax: +82 55 326 4885 E-mail: myot@inje.ac.kr