

Effect of Expiratory Resistive Loading in Expiratory Muscle Strength Training on Orbicularis Oris Muscle Activity

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Abstract. [Purpose] The purpose of this study was to elucidate the effect of expiratory resistive loading on orbicularis oris muscle activity. [Subjects] Subjects were 23 healthy individuals (11 males, mean age 25.5±4.3 years; 12 females, mean age 25.0±3.0 years). [Methods] Surface electromyography was performed to measure the activity of the orbicularis oris muscle during maximum lip closure and resistive loading at different expiratory pressures. Measurement was performed at 10%, 30%, 50%, and 100% of maximum expiratory pressure (MEP) for all subjects. The t-test was used to compare muscle activity between maximum lip closure and 100% MEP, and analysis of variance followed by multiple comparisons was used to compare the muscle activities observed at different expiratory pressures. [Results] No significant difference in muscle activity was observed between maximum lip closure and 100% MEP. Analysis of variance with multiple comparisons revealed significant differences among the different expiratory pressures. [Conclusion] Orbicularis oris muscle activity increased with increasing expiratory resistive loading.

Key words: Expiratory resistance load, Orbicularis oris muscle, Surface electromyography

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INTRODUCTION

Recent reports have indicated that expiratory muscle strength training (EMST) has a number of positive effects including strengthening of the respiratory muscles¹⁻⁴⁾, increasing exercise tolerance⁵⁾, and improving coughing ability^{3, 4, 6, 7)} and swallowing function⁸⁻¹¹⁾. Accordingly, EMST has attracted attention as a useful method for preventing aspiration pneumonia and stimulating the muscle groups involved in swallowing.

We previously reported a case in which EMST resulted in not only the above-mentioned effects, but also improved lip closure strength reducing the leakage of food or liquid from the mouth during meals¹²⁾. These changes might have been attributable to the effect of expiratory resistive loading due to EMST on orbicularis oris muscle activity. In an investigation of age-related changes in lip closure strength from adulthood to old age, Noro et al.¹³⁾ found that in both

men and women, lip strength begins to decrease due to aging from the age of 60 years and in the eighth decade of life drops to the value of a 3-year-old. The orbicularis oris muscle is involved in diverse functions such as vocalization, swallowing, and mastication; hence, if expiratory resistive loading due to EMST affects orbicularis oris muscle activity, EMST should be a useful method for maintaining or improving the strength of the muscle in addition to its conventional effects. To date, however, it remains unknown whether expiratory resistive loading due to EMST affects orbicularis oris muscle activity. Against this background, the objective of this study was to elucidate the effect of expiratory resistive loading due to EMST on orbicularis oris muscle activity.

SUBJECTS AND METHODS

Subjects

The subjects were 23 healthy individuals (11 males, mean age 25.5±4.3 years; 12 females, mean age 25.0±3.0 years) working at the Tokushima Prefecture Naruto Hospital, Japan. All subjects provided their informed consent to participation after receiving a full explanation of the study.

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Methods

First, respiratory resistive loading was measured using a respiratory pressure meter (MicroRPM; Micro Medical, Basingstoke, UK) to measure the maximum expiratory pressure (MEP) of each subject in a sitting position. The MEP measurement was conducted in accordance with the method of Black and Hyatt¹⁴). Briefly, while subjects wore a nose clip and held a mouthpiece in the mouth, they were instructed to maintain MEP for 3 s from a total lung capacity position. The measurement was performed in triplicate, and the largest value was used. The measured MEP was taken as the baseline (100% MEP), and other expiratory pressure settings were set as 10% MEP, 30% MEP, and 50% MEP. The apparatus used for expiratory resistive loading was a Threshold IMT[®] (Respironics, Cedar Grove, NJ, USA) which was used in the reverse orientation¹⁵). Maximum lip closure was added as a condition other than expiratory resistive loading. Lip closure strength was measured using a Lip-de-Cum[®] (Cosmo Instruments, Tokyo, Japan) and Duckling[®] (Cosmo Instruments). Measurement of the different conditions was performed in a random order.

An MP150 (BIOPAC System Inc., Goleta, CA, USA) was used to measure the surface electromyogram of the orbicularis oris muscle. Electromyography was performed using surface electrodes (Blue Sensor; Ambu A/S, Ballerup, Denmark) and a bipolar lead. The surface electrodes were placed on the nasolabial folds. The distance between the electrode centers was 20 mm. The ground electrode was placed on the clavicle. The raw electromyograms were amplified using an amplifier, subjected to analog/digital conversion at a sampling frequency of 1,000 Hz, imported to a PC, and band-pass filtered between 10–500 Hz. The electromyogram during each expiratory resistive loading used in the analysis were the values of the 1s period following the start of expiration. The electromyogram of maximum lip closure was acquired at maximum isometric contraction for 3 s, from which a stable 1 s period was extracted. Before analysis, the electromyograms were converted from the raw waveform to the root mean square value.

Statistical analyses were performed using the two-sample test for the sex differences in 100% MEP and lip closure strength. The myoelectric potentials of the orbicularis oris muscle of males and females were compared between 100% MEP and at maximum lip closure by the correlation t-test. Furthermore, myoelectric potentials of the orbicularis oris muscle during expiratory resistive loading were compared between males and females by repeated measures analysis of variance and multiple comparisons (Bonferroni post hoc

comparisons). SPSS (Ver. 17.0; SPSS Japan, Tokyo, Japan) was used for all statistical analyses, and significance was accepted for values of $p < 0.05$.

This study was approved by the Ethics Review Board of Tokushima Prefecture Naruto Hospital (approval number 1202) and was performed in accordance with the ethical standards on human experimentation of the Helsinki Declaration of 1975, as revised in 1983.

RESULTS

A significant difference between men and women was found in 100% MEP and lip closure strength ($p < 0.01$, Table 1). No significant difference was found for either males or females in the comparison of myoelectric potentials of the orbicularis oris muscle between 100% MEP and maximum lip closure (Table 2). Analysis of variance of the myoelectric potentials of each expiratory resistive loading revealed a significant difference between males and females at 100% MEP, 10% MEP, 30% MEP, and 50% MEP (men: $F(3,30)=48.69$, $p < 0.01$; women: $F(3,33)=59.74$, $p < 0.01$; Table 3). Multiple comparisons revealed there were significant differences among all the conditions ($p < 0.01$, Table 3).

Table 1. Subject characteristics

	Males (n=11)	Females (n=12)
Age (years)	25.5±4.3	25.0±3.0
Height (cm)	170.4±5.5	158.2±3.3
Weight (kg)	62.4±6.7	51.8±6.3
MEP (cmH ₂ O)	126.9±19.8	85.42±10.9*
Maximum lip closure (N)	16.6±3.6	12.7±1.6 *

MEP: Maximum expiratory pressure.

Mean±SD. Two-sample t-test. *: $p < 0.01$, compared with males.

Table 2. Comparison of electromyogram root mean square value between maximum lip closure and 100% MEP

	Maximum lip closure	100% MEP
Males	0.183±0.022	0.191±0.027
Females	0.133±0.032	0.133±0.034

MEP: Maximum expiratory pressure.

Mean±SD. paired t-test.

Table 3. Comparison of electromyogram root mean square values among expiratory pressure conditions

	100%MEP	10% MEP	30% MEP	50% MEP
Males	0.191±0.027	0.088±0.036*	0.112±0.032*†	0.135±0.033 *†#
Females	0.133±0.034	0.052±0.018*	0.070±0.019 *†	0.094±0.025 *†#

MEP: Maximum expiratory pressure.

Mean±SD. Repeated measures analysis of variance: $p < 0.01$.

Bonferroni post hoc comparisons. *: $p < 0.01$, compared with values at 100% MEP. †: $p < 0.01$, compared with values at 10% MEP. #: $p < 0.01$, compared with values at 30% MEP.

DISCUSSION

Noro et al.¹³⁾ reported that maintaining and improving lip closure strength is important because the strength of the orbicularis oris muscle decreases with age. In particular, a decrease in lip closure strength is thought to cause incomplete lip closure, leading to a deterioration in the oral environment due to the evaporation of saliva. Also, in the after effects of cerebrovascular disorder, decreased lip closure strength is thought to impair tongue movement and impair the functions of mastication, ingestion, and swallowing. We previously reported on a case in which lip closure strength was improved by EMST¹²⁾, an intervention that is commonly used in respiratory rehabilitation, but which has recently been attracting wider attention due to reports that it also improves swallowing function^{8–11)}. Based on the results of our case study, we hypothesized that expiratory resistive loading due to EMST induces muscle activity in the orbicularis oris muscle, producing the observed improvement. The present study is the first to investigate the effect of expiratory resistive loading due to EMST on the orbicularis oris muscle.

This study found significant sex differences in MEP and lip closure strength. Given this sex difference, we analyzed the data of males and females separately. We found that, for males and females alike, expiratory resistive loading due to EMST induced orbicularis oris muscle activity, and that the muscle activity became stronger at higher expiratory resistive loadings. Since no significant difference was found in the myoelectric potential of the orbicularis oris muscle at 100% MEP and maximum lip closure, we consider that 100% MEP due to EMST induces muscle activity equivalent to that induced by maximum lip closure. Significant differences were found in the analysis of variance and multiple comparisons between various load pressures: muscle activity increased in a stepwise manner in accordance with load pressure. These results suggest it is possible that stimulatory input to the orbicularis oris muscle can be adjusted by varying the expiratory resistive load during EMST on a case-by-case basis. In setting the expiratory resistive load for EMST, it is common for expiratory pressure to be set below 100% MEP at 30%MEP or 50%MEP. Since orbicularis oris muscle activity was induced at both low and high load pressures in the present study, we anticipate that even

low load pressures during EMST would exert a positive effect for the maintenance or increase of the strength of the orbicularis oris muscle. Future studies should investigate the baseline for effective expiratory pressure with respect to the orbicularis oris muscle and determine the effect of intervention in a clinical study with patients with decreased lip closure strength.

REFERENCES

- 1) Suzuki S, Sato M, Okubo T: Expiratory muscle training and sensation of respiratory effort during exercise in normal subjects. *Thorax*, 1995, 50: 366–370. [Medline] [CrossRef]
- 2) Kim J, Sapienza CM: Implications of expiratory muscle strength training for rehabilitation of the elderly: tutorial. *J Rehabil Res Dev*, 2005, 42: 211–224. [Medline] [CrossRef]
- 3) Sasaki M, Kurosawa H, Kohzaki M: Effects of inspiratory and expiratory muscle training in normal subjects. *J Jpn Phys Ther Assoc*, 2005, 8: 29–37. [CrossRef]
- 4) Sasaki M: The effect of expiratory muscle training on pulmonary function in normal subjects. *J Phys Ther Sci*, 2007, 19: 197–203. [CrossRef]
- 5) Mota S, Güell R, Barreiro E, et al.: Clinical outcomes of expiratory muscle training in severe COPD patients. *Respir Med*, 2007, 101: 516–524. [Medline] [CrossRef]
- 6) Kim J, Davenport P, Sapienza C: Effect of expiratory muscle strength training on elderly cough function. *Arch Gerontol Geriatr*, 2009, 48: 361–366. [Medline] [CrossRef]
- 7) Gosselink R, Kovacs L, Ketelaer P, et al.: Respiratory muscle weakness and respiratory muscle training in severely disabled multiple sclerosis patients. *Arch Phys Med Rehabil*, 2000, 81: 747–751. [Medline]
- 8) Pitts T, Bolser D, Rosenbek J, et al.: Impact of expiratory muscle strength training on voluntary cough and swallow function in Parkinson disease. *Chest*, 2009, 135: 1301–1308. [Medline] [CrossRef]
- 9) Troche MS, Okun MS, Rosenbek JC, et al.: Aspiration and swallowing in Parkinson disease and rehabilitation with EMST: a randomized trial. *Neurology*, 2010, 75: 1912–1919. [Medline] [CrossRef]
- 10) Wheeler KM, Chiara T, Sapienza CM: Surface electromyographic activity of the submental muscles during swallow and expiratory pressure threshold training tasks. *Dysphagia*, 2007, 22: 108–116. [Medline] [CrossRef]
- 11) 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: 1072–1087. [Medline] [CrossRef]
- 12) Yanagisawa Y, Matsuo Y, Shuntoh H, et al.: Single case study: the effect of expiratory muscle training in a patient with parkinson's disease. *Jpn J Dysphagia Rehabil*, 2012, 16: 75–80.
- 13) Noro A, Takahashi J, Yoshiaki A, et al.: The chronological changes of labial-closure-strength in adults. *J Int Soc Life Inf Sci*, 2002, 20: 426–429.
- 14) Black LF, Hyatt RE: Maximal respiratory pressures: normal values and relationship to age and sex. *Am Rev Respir Dis*, 1969, 99: 696–702. [Medline]
- 15) Suzuki S, Suzuki J, Ishii T, et al.: Relationship of respiratory effort sensation to expiratory muscle fatigue during expiratory threshold loading. *Am Rev Respir Dis*, 1992, 145: 461–466. [Medline] [CrossRef]