

Preliminary study on the combined effects of simple expiratory muscle strength device training with conventional exercise on submental muscles force and maximal expiratory pressure related to swallowing in patients with head and neck cancer

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ARTICLE INFO

Article history:

Received 16 March 2020

Accepted as revised 27 April 2020

Available online 27 April 2020

Keywords:

Head and neck cancer, maximal expiratory pressure, simple expiratory muscle strength trainer, surface electromyography.

ABSTRACT

Background: After chemo-radiotherapy, most patients with head and neck cancer (HNC) commonly show defect in swallowing and coughing function related to various weaknesses of oropharyngeal muscles. It is possible that strengthening those muscles via an expiratory force device could regain muscle strength.

Objectives: The aim of this preliminary study was to discover whether a combination of expiratory muscle strength training (EMST) together with a simple expiratory muscle strength device in conventional exercise could be performed for improving submental muscle force and expiratory muscle strength in patients with HNC during chemo-radiotherapy.

Materials and methods: The effects of combined EMST with a conventional exercise program on submental muscle force and maximal expiratory pressure (MEP) were evaluated when compare to a conventional exercise. Conventional exercise composed of neck, tongue, oral muscle, and supraglottic swallow exercise. Meanwhile, EMST was performed with a resistor at 50% and 70% of MEP. MEP and surface electromyography (sEMG) were tested at before and after a 6-week period of intervention. Satisfaction of using device was evaluated. Moreover, interviews on swallowing and pain sensation were also carried out.

Results: The results showed that sEMG amplitude decreased significantly in the conventional exercise group (n=5, aged 55.80±2.51 years). It was increased significantly in the combined EMST with conventional exercise group (n=5, aged 49.20±3.78 years). However, sEMG duration from submental contraction increased significantly in the conventional exercise group, but decreased significantly in the combined EMST with conventional exercise group. In addition, the MEP value decreased non-significantly in both groups after the 6-week period when compared to the baseline period. Finally, satisfaction of the training device from all of the five patients involved focused on comfort and easy-practical use without dyspnea. Moreover, the swallowing or food swallowing function was improved and less painful when compared to before the device was used.

Conclusion: This preliminary study showed that the combination of EMST with a simple expiratory muscle strength device, which was simple and easily developed, and a conventional exercise program, could improve the submental force among patients with HNC in the clinic, without adverse effects.

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doi: 10.14456/jams.2020.8

E-ISSN: 2539-6056

Introduction

In 2020, the database of the World Health Organization (WHO) reported that the number of new patients with nasopharyngeal cancer (NPC) was expected to increase in the European Union (EU), United States (US) and Japan.¹ In addition, cancer is the most common cause of death in Thailand, with a higher mortality rate (48.4 to 95.2 per 100,000) from 1998 to 2011. The age-standardized rate (ASR) of incidence for oral, nasopharyngeal and laryngeal cancers is 15.7 and 10.7 per 100,000 males and females, respectively.² General treatments for HNC can be performed with various interventions; for example, surgery and radiotherapy combined with chemotherapy, which depend on conditional variables such as primary site, clinical stage, and tumor removable, but most of the patients with HNC undertake clinical intervention by using chemo-radiotherapy.³ The side-effects of radiotherapy have been reported as mucositis, hoarseness, erythema and desquamation³ and those of chemotherapy are nausea, vomiting and neutropenia.⁴ Thus, combination of both these interventions presents side-effects in the voice, swallowing, nutrition, and quality of life (QOL),⁵ due to swallowing motility being dysfunctional from muscle weakness or damage to specific muscles such as the hypopharyngeal, laryngeal muscles or cervical esophageal function.^{6,7} Of all clinical problems, swallowing dysfunction or dysphagia is the most common, and it diminishes QOL profoundly through aspirated pneumonia and malnutrition.⁸

At present, application of swallowing rehabilitation in patients with HNC is very necessary both before and after chemo-radiotherapy. Previous study reported that risk of dysphagia can be prevented,⁹ by either direct therapy as modify food, promotion the swallowing and breathing coordination¹⁰ or indirect therapy as increases on expiratory muscle strength by the expiratory muscle strength training (EMST).¹¹

A systematic review showed that EMST improved airway safety during swallowing in dysphagia and increased the strength of expiratory muscles in all patient groups.¹² Previous studies reported that EMST enhanced the ability to swallow in patients with Parkinson's disease,¹³ stroke¹⁴ and multiple sclerosis¹⁵ and also in healthy-elderly people.¹⁶ They also showed that tongue strengthening exercise improved QOL and eating and speech efficiency in patients with oropharyngeal cancer, who were treated with radiotherapy with or without chemotherapy.¹⁷ In addition, EMST increased maximal expiratory pressure (MEP) and swallowing safety in patients who were chronic radiation-associated aspirators.¹⁸ Similar principle function of EMST device and inspiratory muscle trainer (IMT) is resistive pressure during inspiration or expiration. There are many commercial products available worldwide for IMT such as POWERbreath® (POWERbreathe International Ltd.) or the Threshold® device (Respironics Inc.), as well as the Inspiratory Muscle Trainer (Smiths Medical ASD, Inc., USA).¹⁹ Although previous study has claimed that EMST can be performed with an inexpensive and a comfortable device for improving dyspnea and coughing, it is still expensive for individual patients and not used widely in Thailand. From all these devices, the IMT, which has six different color-coded resistors with a central hole of 2-7 mm diameter, is very

interesting. Previous study adapted and modified plastic caps with various resistors of 2, 4 and 6 mm diameter in polyvinyl chloride (PVC) tubes for training inspiratory muscle strength in chronic obstructive pulmonary disease (COPD) patients.²⁰ Therefore, the aim of this preliminary study was to evaluate the effects of a modified device, *i.e.* an expiratory muscle strength trainer, among patients with HNC on swallowing force of submental muscles and duration of pharyngeal phase of swallowing.

Materials and methods

The protocol in this preliminary study was divided into two steps; 1) developing the expiratory muscle strength device before calculating the percentage of resistance, and 2) performing a pilot study on the effect of expiratory muscle strength device on submental muscles force and duration of pharyngeal swallowing phase in patients with HNC, while being treated with chemo-radiotherapy at Maharaj Nakorn Chiang Mai Hospital, Chiang Mai University, Thailand. The protocol of this study was approved ethically by the Ethic Human Committee at the Faculty of Associated Medical Sciences, Chiang Mai University (AMSEC-61EX-025) and Faculty of Medicine, Chiang Mai University (NONE-2561-05329), Thailand. It was conducted in accordance with the Declaration of Helsinki, and all patients provided written informed consent.

Developing the device and calculating resistance percentage

The EMST device was designed by following a previous study.²⁰ It was produced by adapting a PVC water pipe (2 cm in diameter). Each EMST device comprised a main PVC tube 11 cm long and a plastic cap with various resistors having centrally placed holes of 1 mm diameter (Figure 1).



Figure 1. Pilot expiratory muscle strength training (EMST) device.

Percentage of resistors was performed in 10 sedentary and healthy subjects. All subjects had no hospital history of pulmonary conditions such as allergy, rib fracture and chest wall deformity, or scoliosis and pleural diseases for at least 3 months. They also should have been ex-smokers with normal blood pressure and body mass index of 18.50-22.90 Kg.m². Resistance of the resistors was determined with a MicroRPM device (MicroRPM, Medical Ltd, Kent, UK). Resistance percentage of each resistor was determined by calculating the MEP between with and without a resistor. MEP was evaluated under instruction of the standard European Respiratory Society (ERS) statement guideline.²¹ All of the participants repeated three trial maneuver of

MEP by holding a disposable mouthpiece in their mouth in a state of maximum inhalation, and then exhaling maximally as strong and as fast as possible.²² Percentage of resistance can be calculated by the following formula: $[(MEP_{\text{non-resistor}} - MEP_{\text{resistor}}) / MEP_{\text{non-resistor}}] \times 100$. Finally, the resistors that presented 50% and 70% of MEP were selected for training.

Patient recruitments and Programs

Ten patients who treated with radiotherapy or chemo-radiotherapy were randomized into two groups following a randomized controlled trial (RCT) protocol (TCTR20180812002). Effectiveness of combined EMST on conventional exercise (n=5) was performed compared to a conventional exercise (n=5). Patient criteria were appropriate for the protocol of this study including good consciousness and no problem in lips and mouth closures. Patients with total laryngectomy, tracheostomy, oral cavity defect, underlying pulmonary diseases, dysphagia or hypertension were excluded. For good adherence to the conventional exercise and performance in EMST training device, log-book records were made daily and kept strictly by patients or close caregiver at home, and they were rechecked by the researcher who telephoned every two days.

Conventional exercise program

All ten patients with HNC were educated and well-trained on conventional exercise program. The program consisted of neck, tongue, oral muscle, and supraglottic swallow exercise under previous prescriptions.^{22, 23} Patients were asked to perform each exercise five times per day for a six-week period.

The EMST program

All five patients in EMST program were educated and well-trained by the time it started. A total six-week period of training was divided into two steps: 1) the first 3 weeks of achieving 50% of MEP individually, and 2) the second 3 weeks of achieving 70% of MEP. The patients used EMST device at home, 5 days per week during the 6-week training period; performing 5 sets of 5 breaths through the device for a total of 25 breaths per day, with 2-3 minutes of rest between sets.^{24, 26} Finally, satisfaction on use of device regarding sensation in swallowing and pain was found by individual interviews after completing the 6-week course.

Evaluation of outcomes

The main outcomes in this study were the maximal expiratory pressure (MEP) and surface electromyography (sEMG) on submental muscles before and after 6 weeks of complete interventions in both groups. MEP evaluation was performed according to the standardized protocol of the ERS guideline.²¹ The protocol was repeated trials in the maneuver of exhaling maximally and as fast as possible from maximal inhalation.²² The evaluated protocol of surface electromyography (sEMG) on submental muscles force was followed as detailed below.

Evaluation of the surface electromyography (sEMG)

This study detected the effect of EMST on submental muscles that relate to swallowing function or dysphagia by

surface electromyography (sEMG).²⁷ sEMG of swallowing has been confirmed as a non-invasive, simple, and reliable method for screening and initially evaluating dysphagia.²⁸ The 2-channel sEMG device (PowerLab, 4/35 Dual Bio Amp, AD Instruments, Australia), with Ag/AgCl electrodes (3M™ Red dot™ 2235, United State), was used for examinations. Parallel electrodes were placed on skin in the submental muscle groups (0.5 cm parallel to the left and right of the midline) and performed following previous description²⁹ in order to record changes in sEMG potential when having swallowed. sEMG signals from swallowing 3 times were amplified (1000 x) and filtered (width band: 500-1,000 Hz), before reporting the root of mean square values (RMSμV) of maximal amplitude and duration of pharyngeal swallowing (in seconds).

Statistical analysis

Data were represented with median (minimal and maximal data). Non-parametric Wilcoxon-Signed Rank Test was used within the groups for statistical analysis during the 6-week period. Mann-Whitney U test was used to compare the groups either before or after the training period. All statistical analyses were carried out using the Statistical Package for Social Software version 11.0 (SPSS Inc., Chicago, IL, USA) for Windows. The significant level was set at $p < 0.05$.

Results and discussion

The pilot study for the percentages of resistance on expiratory resistor in 10 healthy patients showed that 2 sewing needle holes and 1 mm diameter located centrally had $57.13 \pm 4.90\%$ and $72.54 \pm 2.30\%$ of resistance.

Results of the combined EMST with conventional exercise in 5 patients aged 49.20 ± 3.78 (4 males and 1 female) and a conventional exercise in 5 patients aged 55.80 ± 2.52 years (4 males and 1 female) are presented in Table 1. The age between groups was not statistically different. From various cancer types and stages under the standard cancer stage of the American Joint Committee on Cancer Guideline,³⁰ all patients were treated clinically with concurrent radiotherapy (CCRT) (9,996 gray weekly) and Cisplatin and carboplatin chemotherapy, using the intensity-modulated radiation therapy (IMRT) technique. The outcomes of both sEMG and MEP at before and after 6-week period individually are shown in Table 2.

The results of sEMG on submental muscle force showed the amplitude and duration during the swallowing test (Table 3). The median sEMG amplitude (0.0747 RMSμV) was increased significantly compared to those before training (0.0547 RMSμV) in a EMST combined with conventional exercise group. The significant decrease of sEMG amplitude after the 6-week period (0.0505 RMSμV) compared to baseline period (0.0605 RMSμV) was shown in the conventional exercise group (Figure 2.A). In addition, the median sEMG duration decreased statistically from before (1.17 second) to after 6-week period in the EMST and conventional exercise group (1.05 second) was contrast to a conventional exercise group (0.92 to 1.01 second) (Figure 2B).

Table 1 Characteristics, types & stage of cancer and medical treatments during 6-weeks period in both groups.

Gender	Age (years)	Cancer	TMN stage	Treatment	Radiotherapy		Chemotherapy	
					Technique	Dose	Type	Frequency
Conventional exercise group (n=5)								
male	47	NPC	T1N1M0	CCRT	IMRT	6996	Carboplatin	6
male	55	Unknown primary	T0M3M0	CCRT	IMRT	6996	Carboplatin	6
male	56	NPC	T4N2M1	CMT+CCRT	IMRT	6996	Cisplatin	6
male	62	Rt. Base of tongue	T2N0Mx	CCRT	IMRT	6996	Cisplatin	6
female	59	NPC	T3N3M0	CMT+CCRT	IMRT	6996	Cisplatin+ Carboplatin	6
Expiratory muscle strength training (EMST) with conventional exercise group (n=5)								
male	52	NPC	T2N2M0	CMT+CCRT	IMRT	6996	Cisplatin	6
female	46	NPC	T1N2M0	CCRT	IMRT	6996	Carboplatin	6
male	57	Glottis	T1aN2M0	CCRT	IMRT	6996	Cisplatin	6
male	55	Lt. Soft palate	T3N3bM0	CMT+CCRT	IMRT	6996	Cisplatin	6
male	36	Hypopharynx	T2N0Mx	CCRT	IMRT	6996	Carboplatin	6

Note: NPC: Nasopharyngeal carcinoma, T: tumor, N: nodes, M: metastasis, CCRT: concurrent radiotherapy, CMT: chemotherapy, IMRT: intensity-modulated radiation therapy

Table 2 sEMG and maximal expiratory pressure (MEP) in both groups before and after 6 weeks of intervention.

Gender	Age (years)	Amplitude (RMSμV)		Duration (seconds)		MEP (cmH ₂ O)	
		Before	After	Before	After	Before	After
Conventional exercise group (n=5)							
Male	47	0.069	0.064	0.75	1.00	125	114
Male	55	0.060	0.050	0.95	1.06	106	118
Male	56	0.058	0.040	0.92	1.02	114	79
Male	62	0.052	0.034	0.73	0.91	122	107
female	59	0.081	0.064	1.01	1.01	62	46
EMST with conventional exercise group (n=5)							
male	52	0.0611	0.0747	1.06	0.76	150	74
female	46	0.0505	0.0785	1.13	1.05	163	128
male	57	0.0547	0.0671	1.18	1.1	80	82
male	55	0.0459	0.0536	1.18	0.98	96	50
male	36	0.0696	0.084	1.17	1.12	166	127

Table 3 sEMG amplitude and duration of the swallowing maneuver test and MEP between conventional exercise and EMST with conventional exercise group.

Group	Data	Amplitude (RMS μ V)		Duration (second)		MEP (cmH ₂ O)	
		Before	After	Before	After	Before	After
Conventional exercise group (n=5)		0.0605	0.0505*	0.92	1.01*	114	107
		(0.052-0.081)	(0.034-0.064)	(0.73-1.01)	(0.91-1.06)	(62-125)	(46-118)
EMST with conventional exercise group (n=5)		0.0547	0.0747*	1.170 [#]	1.050*	150	82
		(0.045-0.069)	(0.053-0.084)	(1.05-1.17)	(0.76-1.12)	(80-166)	(50-128)

Note: Data presents the median (min-max), * $p < 0.05$ compared to pre period within the group by using the non-parametric Wilcoxon Signed Ranks Test, [#] $p < 0.05$ compared between the groups pre period by using the non-parametric Mann-Whitney U test. EMST: Expiratory muscle strength training, RMS: root mean square.

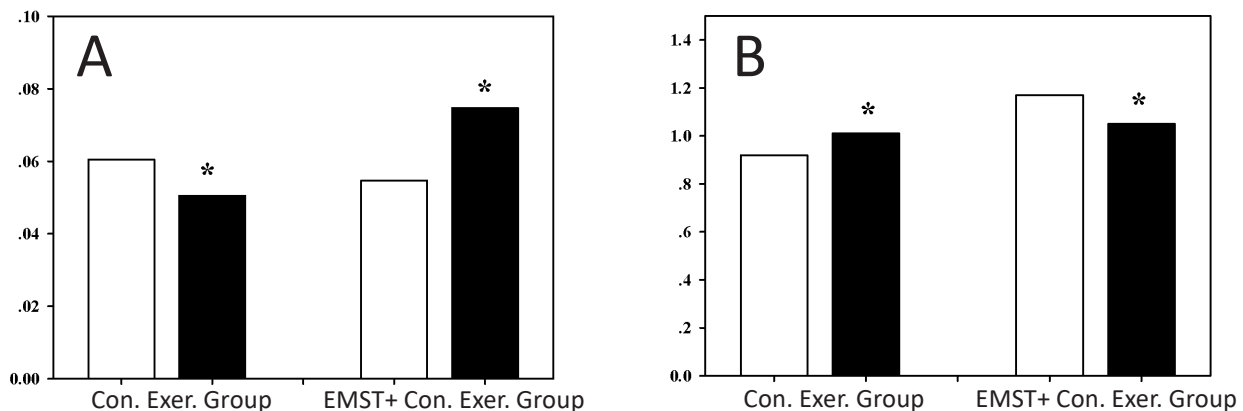


Figure 2. Median of amplitude (RMSμV, A) and duration (seconds, B) of sEMG signal from the swallowing test before (white-color bar) and after the 6-week period (black bar) in the conventional exercise (Con. Exer. Group) and EMST with conventional exercise group (EMST+Con. Exer. Group) * $p < 0.05$ when compared to pre period within the group by using the non-parametric Wilcoxon-Sign Rank Test.

The results showed that median MEP value reduced non-significantly in the conventional exercise group from 114 at baseline to 107 cmH₂O after 6 weeks of chemo-radiotherapy. In addition, when EMST and conventional exercise were applied together during chemo-radiotherapy, the MEP still decreased from 150 at baseline to 82 cmH₂O after 6 weeks of training.

Furthermore, five patients who used EMST device for 6 weeks were satisfied. It was claimed to be comfortable and easy to use with no side effects such as dyspnea. Moreover, swallowing or food swallowing after 6 weeks of EMST was easier with less painful sensation when compared to before using the device.

Discussion

This preliminary study evaluated the influence of combined EMST with conventional exercise by developing a device based on previous study, in which its participants had inspiratory muscle strength training with stable COPD.²⁰ This was interesting because HNC patients had been suffered from the side effects of chemo-radiotherapy such as swallowing and coughing defects⁵ from oropharyngeal swallowing motility dysfunction or weakness.⁶⁻⁸

To evaluate the effect of EMST with a simple device and very cheap, on submental muscles force or MEP among patients with HNC, EMST was designed with 50% and 70% of MEP for 6 weeks as in previous studies.²⁴⁻²⁶ Moreover, the target pressure between 50% and 70% of MEP in this study also was consistent with a previous research. During the first week, the expiratory load was designed to 15% of MEP and up to 60% at the end of the first month of training.³¹ Therefore, 50-70% of MEP is possibly suitable for training effect.

This preliminary study found increasing amplitude in the combination of EMST and conventional exercise group receiving chemo-radiotherapy for 6 weeks. This result was consistent with a previous study that found higher sEMG amplitude for swallowing in community-dwelling elderly people who performed EMST.¹⁶ Therefore, lower amplitude

reflects the muscle weakness that presented in the conventional exercise group, whereas sEMG signal amplitude significantly increased in the combination of EMST and conventional exercise group. Therefore, EMST possibly increased the strength of submental muscles.

However, this preliminary study found a significant decrease of MEP in both groups, especially in the conventional exercise group who received chemo-radiotherapy for 6 weeks. The finding was consistent with previous evidence.^{3, 6, 7} On the other hand, MEP decreased in the combination of EMST and conventional exercise group who could not maintain value of or increase MEP with EMST approach. This can be explained by a different protocol of training, in which the EMST was divided into two stages: starting with a lower load at 50% of MEP for 3 weeks before increasing to 70% of MEP for 3 weeks. However, a previous study was performed in 12 community-dwelling elderly people with 70% of MEP for 4 weeks.¹⁶ Its results showed a significant increase in strength of the buccinators and orbicularis oris muscles. Interesting data of a previous study on EMST at 75% of MEP for 8 weeks in 23 patients with HNC presented significantly increased MEP indicating higher intensity of resistance and longer period applied in clinical training.¹⁸ Therefore, the results of non-statistical differences of MEP in the combination of EMST and conventional exercise group were possibly from lower resistance of the resistor and shorter training period. In addition, a previous report suggested that impaired laryngopharyngeal function was presented dominantly from prolonged local post-radiotherapy and possibly reduced the expiratory force.³² Therefore, the MEP values were decreased in both groups.

The result of sEMG duration in this study was in contrast to a previous report that documented a longer duration reflected on muscles weakness or dysphagia and swallowing when compared to healthy subjects.^{27, 33} This study demonstrated the benefit of combined EMST with conventional exercise on submental muscles strength by significant higher amplitude and shorten duration of sEMG signal. Moreover, the result of swallowing sensation and pain showed an improvement after completing 6 weeks of

intervention. Thus, it can be suggested that combination of EMST and conventional exercise involves swallowing function by relating to submental muscles strength. The results of sEMG and pain possibly support the benefits of EMST by a previous theory proposing the mechanisms of EMST on peripheral nervous stimulation,¹⁶ and central nerve of the respiratory control center.³⁴

Although sEMG improved and possibly improved swallowing, but the swallowing function was not evaluated directly, as in a previous study with the Gugging Swallow Screening (GUSS).³⁵ Therefore, this study cannot confirm the benefit of EMST with conventional exercise for swallowing function or dysphagia. In future study, other specific exercise such as tongue strengthening or swallowing training program¹⁷ should be added which may be more effective than an EMST program alone.

Limitation of study

The clinical recruitment of specifically diagnosed patients with primary HNC without any diseases or medical problems was very strictly under clinical trial design in this study. In addition, the long period of 6 weeks for data collecting caused some external confounding factors such as disease complication. The low sample size of patients also was a limitation in this study. Thus, the results in this preliminary study is need to be confirmed by future researches.

Conflicts of interests

The authors declare no competing interests in this study.

Acknowledgements

The authors thank the Faculty of Associated Medical Sciences, Chiang Mai University, Thailand for supporting a grant and the sEMG equipment in this study. Moreover, the authors also thanks Associate Professor Samatchai Chamnongkich for structuring the sEMG data, and all patients for their kind cooperation and practicing during this study.

References

- [1] Carioli G, Negri E, Kawakita D, Garavello W, La Vecchia C, Malvezzi M. Global trends in nasopharyngeal cancer mortality since 1970 and predictions for 2020: focus on low-risk areas. *Int J Cancer* 2017; 140(10): 2256-64.
- [2] Tangjaturonrasme N, Vatanasapt P, Bychkov A. Epidemiology of head and neck cancer in Thailand. *Asia Pac J Clin Oncol* 2018; 14(1): 16-22.
- [3] Cook IJ. Oropharyngeal dysphagia. *Gastroenterol Clin North Am* 2009; 38(3): 411-31.
- [4] Agarwal J, Dutta D, Palwe V, Gupta T, Laskar SG, Budrukkar A, et al. Prospective subjective evaluation of swallowing function and dietary pattern in head and neck cancers treated with concomitant chemo-radiation. *J Cancer Res Ther* 2010; 6(1): 15-21.
- [5] Lazarus CL. Effects of chemoradiotherapy on voice and swallowing. *Curr Opin Otolaryngol Head Neck Surg* 2009; 17(3): 172-8.
- [6] Stenson KM, MacCracken E, List M, Haraf DJ, Brockstein B, Weichselbaum R, et al. Swallowing function in patients with head and neck cancer prior to treatment. *Arch Otolaryngol Head Neck Surg* 2000; 126(3): 371-7.
- [7] Eisbruch A, Schwartz M, Rasch C, Vineberg K, Damen E, Van As CJ, et al. Dysphagia and aspiration after chemoradiotherapy for head-and-neck cancer: which anatomic structures are affected and can they be spared by IMRT?. *Int J Radiat Oncol Biol Phys* 2004; 60(5): 1425-39.
- [8] Pikus L, Levine MS, Yang YX, Rubesin SE, Katzka DA, Laufer I, et al. Videofluoroscopic studies of swallowing dysfunction and the relative risk of pneumonia. *Am J Roentgenol* 2003; 180(6): 1613-6.
- [9] Ohba S, Yokoyama J, Kojima M, Fujimaki M, Anzai T, Komatsu H, et al. Significant preservation of swallowing function in chemoradiotherapy for advanced head and neck cancer by prophylactic swallowing exercise. *Head Neck* 2016; 38(4): 517-21.
- [10] Saitoh E. Dysphagia rehabilitation. *Rinsho Shinkeigaku* 2008; 48(11): 875-9.
- [11] Langmore SE, Pisegna JM. Efficacy of exercise to rehabilitation dysphagia: a critique of the literature. *Int J Speech Lang Pathol* 2015; 17(3): 222-9.
- [12] Brooks M, McLaughlin E, Shields N. Expiratory muscle strength training improves swallowing and respiratory outcomes in people with dysphagia: a systematic review. *Int J Speech Lang Pathol* 2019; 21(1): 89-100.
- [13] Byeon H. Effect of simultaneous application of postural techniques and expiratory muscle strength training on the enhancement of the swallowing function of patients with dysphagia caused by Parkinson's disease. *J Phys Ther Sci* 2016; 28(6): 1840-3.
- [14] Hegland KW, Davenport PW, Brandimore AE, Singletary FF, Troche MS. Rehabilitation of swallowing and cough functions following stroke: an expiratory muscle strength training trial. *Arch Phys Med Rehabil* 2016; 97(8): 1345-51.
- [15] Silverman EP, Miller S, Zhang Y, Hoffman-Ruddy B, Yeager J, Daly JJ. Effects of expiratory muscle strength training on maximal respiratory pressure and swallowing-related quality of life in individuals with multiple sclerosis. *Mult Scler J Expe Transl Clin* 2017; 3(2): 2055217317710829. doi: 10.1177/2055217317710829. eCollection Apr-Jun 2017.
- [16] Park JS, Oh DH, Chang MY. Effect of expiratory muscle strength training on swallowing-related muscle strength in community-dwelling elderly individuals: a randomized controlled trial. *Gerodontology* 2017; 34(1): 121-8. doi: 10.1111/ger.12234. Epub 2016 May 16.

- [17] Lazarus CL, Husaini H, Falciglia D, DeLacure M, Branski RC, Kraus D, et al. Effects of exercise on swallowing and tongue strength in patients with oral and oropharyngeal cancer treated with primary radiotherapy with or without chemotherapy. *Int J Oral Maxillofac Surg* 2014; 43(5): 523-30.
- [18] Hutcheson KA, Barrow MP, Plowman EK, Lai SY, Fuller CD, Barringer DA, et al. Expiratory muscle strength training for radiation-associated aspiration after head and neck cancer: a case series. *Laryngoscope* 2018; 128(5): 1044-51.
- [19] McConnell AK, Romer LM. Respiratory muscle training in healthy humans: resolving the controversy. *Int J Sports Med* 2004; 25(4): 284–93.
- [20] Leelarungrayub J, Pinkaew D, Puntumetakul R, Klaphajone J. Effects of a simple prototype respiratory muscle trainer on respiratory muscle strength, quality of life and dyspnea, and oxidative stress in COPD patients: a preliminary study. *Int J Chron Obstruct Pulmo Dis* 2017; 12: 1415-25.
- [21] Laveneziana P, Albuquerque A, Aliverti A, Babb T, Barreiro E, Dres M, et al. ERS statement on respiratory muscle testing at rest and during exercise. *Eur Respir J* 2019; 53(6): 1801214. doi: 10.1183/13993003.01214-2018.
- [22] Cnossen IC, van Uden-Kraan CF, Witte BI, Adlders, YJ, de Goede CJT, de Bree R, et al. Prophylactic exercises among head and neck cancer patients during after swallowing sparing intensity modulated radiation: adherence and exercise performance levels of a 12-week guided home-based program. *Eur Arch Otorhinolaryngol* 2017; 274(2): 1129-38.
- [23] Hutcheson KA, Bhayani MK, Beadle BM, Gold KA, Shinn EH, Lai SY, et al. Eat and exercise during radiotherapy or chemoradiotherapy for pharyngeal cancers: use it or lose it. *JAMA Otolaryngol Head Neck Surg* 2013; 139(11): 1127-34.
- [24] Baker S, Davenport P, Sapienza C. Examination of strength training and detraining effects in expiratory muscles. *J Speech Lang Hear Res* 2005; 48(6): 1325-33.
- [25] Pitts T, Bolser D, Rosenbek J, Troche M, Okun MS, Sapienza C. Impact of expiratory muscle strength training on voluntary cough and swallow function in parkinson disease. *Chest* 2009; 135(5): 1301-8.
- [26] Darling-White M, Huber JE. The impact of expiratory muscle strength training on speech breathing in individuals with parkinson's disease: a preliminary study. *Am J Speech Lang Pathol* 2017; 26(4): 1159-66.
- [27] Tseng FF, Tseng SF, Huang YH, Liu CC, Chiang TH. Surface electromyography for diagnosing dysphagia in patients with cerebral palsy. *World J Otorhinolaryngol* 2013; 3(2): 35-41. <https://dx.doi.org/10.5319/wjo.v3.i2.35>.
- [28] Vaiman M, Eviatar E. Surface electromyography as a screening method for evaluation of dysphagia and odynophagia. *Head Face Med* 2009; 5: 9. doi: 10.1186/1746-160X-5-9.
- [29] Vaiman M. Standardization of surface electromyography utilized to evaluate patients with dysphagia. *Head Face Med* 2007; 3: 26. doi: 10.1186/1746-160X-3-26.
- [30] Lydiatt WM, Patel SG, O'Sullivan B, Brandwein MS, Ridge JA, Migliacci JC, et al. Head and neck cancers-major changes in the American Joint Committee on cancer eighth edition cancer staging manual. *CA Cancer J Clin* 2017; 67(2): 122-37.
- [31] Suzuki S, Sato M, Okubo T. Expiratory muscle training and sensation of respiratory effort during exercise in normal subjects. *Thorax* 1995; 50(4): 366-70.
- [32] Hutcheson KA, Barrow MP, Warneke CL, Wang Y, Eapen G, Lai SY, et al. Cough strength and expiratory force in aspirating and nonaspirating postradiation head and neck cancer survivors. *Laryngoscope* 2018; 128(7): 1615-21.
- [33] Rademaker AW, Pauloski BR, Logemann JA, Shanahan TK. Oropharyngeal swallow efficiency as a representative measure of swallowing function. *J Speech Hear Res* 1994; 34(2): 314-25.
- [34] Wheeler KM, Chiara T, Sapienza CM. Surface electromyographic activity of the submental muscles during swallow and expiratory pressure threshold training tasks. *Dysphagia* 2007; 22(2): 108-16.
- [35] Trapl M, Enderle P, Nowotny M, Teuschl Y, Matz K, Dachenhausen A, et al. Dysphagia bedside screening for acute-stroke patients: the gugging swallowing screen. *Stroke* 2007; 38(11): 2948-52.