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ORIGINAL ARTICLE

The Effects of Different Exercise Trainings on Suprahyoid Muscle Activation, Tongue Pressure Force and Dysphagia Limit in Healthy Subjects

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Abstract
Suprahyoid muscle activation and tongue pressure force play a critical role for swallowing function. In addition, dysphagia limit is one of most important factors indicating swallowing efficiency. The purpose of this study was to compare the effects of 8-week training sessions of three different exercises including chin tuck against resistance (CTAR), Shaker exercises and chin tuck exercise with theraband on suprahyoid muscle activity, anterior tongue pressure and dysphagia limit in healthy subjects. Thirty-six healthy volunteers aged between 18 and 40 years who scored below 3 points from Turkish version of Eating Assessment Tool (T-EAT-10) were included in the study, and all participants were divided into three groups randomly. Maximal suprahyoid muscle activations and dysphagia limit of participants were assessed by superficial electromyography. CTAR and chin tuck exercise with theraband increased the maximum suprahyoid muscle activation ($p_1 = 0.004$, $p_2 = 0.018$), whereas Shaker exercise did not increase maximal suprahyoid muscle activation ($p = 0.507$) after exercise training. CTAR and chin tuck exercise with theraband increased tongue pressure ($p_1 = 0.045$, $p_2 = 0.041$), while Shaker exercise did not increase anterior tongue pressure ($p = 0.248$). There was no statistically significant difference in dysphagia limits in three groups between before and after exercise training ($p > 0.05$). As a result, although CTAR seems to be the most effective exercise in most parameters, chin tuck exercise with theraband can also be used as an alternative to CTAR to improve suprahyoid muscle activity and tongue pressure.

Keywords Deglutition · Deglutition disorders · Exercise training · Electromyography

Introduction

Swallowing function necessitates effective food transition from the oral cavity to stomach and airway protection. Airway protection is the key component for safe swallowing. Problems in airway protection cause serious problems including aspiration pneumonia, malnutrition, dehydration and even death [1]. Impaired laryngeal elevation is usually the underlying cause of inadequate airway protection. The suprahyoid muscles are primarily responsible for laryngeal elevation. Therefore, insufficient contraction of these muscles can result in laryngeal elevation problems, which is a threatening for airway protection [2].

Shaker exercises are the first exercise developed for suprahyoid muscles [3]. This exercise, which is characterized by patient's head raising in the supine position, has been accepted as one of the most basic exercises of dysphagia rehabilitation for many years. Then, the chin tuck against resistance (CTAR) exercise was developed due to

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the implementation/performing difficulty and positional discomfort of Shaker exercises [4, 5]. Theraband is a popular material which is frequently used by physical therapists for muscle strengthening. The ease of transport, low cost and the ability to adjust its resistance make this exercise material more popular [6]. Considering the advantages of theraband, we thought that we may perform resistance training of chin tuck exercise with theraband. Chin tuck exercise with theraband involves craniocervical flexion in isometric and isotonic forms which are performed with the resistance of theraband attached to the patient's forehead with a fixed point at the back. Although there are studies comparing the effects of CTAR and Shaker exercises on suprahyoid muscle activation, these are experimental studies that include one-time measurements rather than exercise training effects [4, 5]. In addition, studies including the comparison effects of these exercises on the tongue pressure and dysphagia limit which are other important parameters of swallowing were not observed. The aim of this study was to compare the training effects of CTAR exercise, Shaker exercise and chin tuck exercise with theraband on suprahyoid muscle activation, anterior tongue pressure force and dysphagia limit. We hypothesized that chin tuck exercise with theraband is more effective than CTAR and Shaker exercises to increase suprahyoid muscle activation, anterior tongue pressure force and dysphagia limit in healthy subjects.

Methods

The research study was performed at the Faculty of Physical Therapy and Rehabilitation at Hacettepe University with the cooperation of the Hacettepe University Swallowing Disorders Research and Application Center. The ethical permission was obtained from Hacettepe University Clinical Research Ethics Committee with Decision Number KA-180002. Written informed consent forms were obtained from the participants.

Participants

Thirty-six healthy volunteers who aged between 18 and 40 years and scored less than 3 points in the Turkish version of the Eating Assessment Tool (T-EAT-10) were included in the study. Participants who had disk herniation, mechanical neck pain and/or any pathology in the cervical region, any neurological or systemic disease and had a history of surgery or radiotherapy treatment on head and neck region were excluded. All participants were divided into three groups by computer assisted randomization method including CTAR group, Shaker group and theraband group.

Measurements

Descriptive information including age, gender, height and weight of all participants was recorded. The T-EAT-10 questionnaire was used for inclusion criteria. Obtaining above two points from this survey indicates a swallowing problem, and therefore, participants who scored less than 3 points in the T-EAT-10 were included in the study [7].

Measurement of Maximum Suprahyoid Muscle Activation (EMG)

Before surface EMG measurement, the skin was cleaned with alcohol wipes. 1×2.5 cm superficial electrodes with self-adhesive silver/silver chloride (Ag/AgCl) were placed on the suprahyoid muscle body after the skin dried (within 30 s). The grounding electrode was fixed to the right clavicle. Cables and electrodes were fixed with adhesive tapes to prevent artifacts during recording. All participants were asked to sit in an upright position during performing EMG assessment. Dual-channel surface EMG device which was integrated to model swallowing workstation model 7200 (Kay Pentax Corporation, Lincoln Park, NJ) was used. Output data/values were recoded as microvolt. The high-filter transition was calculated as 20 Hz, the low-filter transition was calculated as 2 kHz, and the received signal was increased 200 times. Signal transition range was set to 20 mV [8].

Semirigid cervical neck orthosis was worn to the subjects. Subjects were taught the movement before recording. It was ensured that the movement was done correctly. Recording was started after 1 s the start command was given. In order to measure maximum suprahyoid muscle activation, individuals were asked to perform opening their jaw maximum as hard as possible for 10 s against the cervical neck orthosis. Test was repeated 5 times with rest intervals of 60 s. The maximum value in five measurements was accepted for statistical analysis. Maximum suprahyoid muscle activation measurement is shown in Fig. 1.

Measurement of Dysphagia Limit

Cervical auscultation device which is integrated into swallowing workstation was placed just above cricoid cartilage in addition to EMG procedure mentioned above. Recording systems' sweep duration at 10 s and its delay line to start recording at 2 s were set. A total of 1, 3, 5, 10, 15, 20, 25 and 30 ml water were given to all participants, respectively. Water was delivered into the mouth behind the incisors by a graduated syringe. In each quantity of water, the participants began to swallow as soon as the instructions were given.

Fig. 1 Measurement of maximum suprahyoid muscle activation

After swallowing, the resulting effects were monitored for 8 s. If piecemeal deglutition or airway aspiration signs including cough and wet voice were observed, examination was completed. If there was any suspicion of piecemeal deglutition, the procedure was repeated a second time with the same amount of water. The maximum amount of water was accepted as dysphagia limit in which the symptoms of the test ending criteria were not observed [9].

Anterior Tongue Pressure Force Measurement

Iowa oral pressure instrument (IOPI, IOPI Medical LLC, WA, 98,072, USA) was used to measure anterior tongue pressure force. Participants were asked to sit in an upright position at 90°. The air-filled bulb of the IOPI was placed to anterior region of tongue. The instruction was given to all participants as 'Press the bulb with your tongue against palate as hard as possible and keep the pressure for 5 s'. This measurement was repeated for 3 times with 2-min rest intervals. Maximum measured value was recorded as kilopascal, kPa [10, 11].

All measurements was performed twice including before and after exercise program by an experienced physical therapist blinded to the group allocation.

Interventions

Another experienced physical therapist was responsible for teaching the training programs. All exercises were performed 30 min per a day and 5 days in a week (3 days with physical therapist and 2 days as home program). A standardized brochure for each training program was given to participants for the follow-up of home exercise program.

Chin Tuck Against Resistance (CTAR)

Participants were asked to place the inflatable ball with a diameter of 12 cm between the chin and the sternum. For the isometric component of the exercise, the ball was compressed between chin and sternum at maximum force for 60 s. It was repeated 3 times with rest intervals of 60 s. For the isotonic component, the participants compressed and relaxed the ball between chin and sternum for 30 times. The exercise set consisted of three isometric and an isotonic components [4].

Shaker Exercises

Participants were asked to lie in a supine position. Participants were first asked to raise their heads and look at their toes for 60 s and repeat this movement three times with 60 s rest intervals for isometric component. For isotonic component, they were asked to 30 times raise their heads and look at their toes and return initial position slowly. An exercise set consists of three isometric and an isotonic component [3].

Chin Tuck Exercise with Theraband

The OMNI Perceived Exertion Scale for Resistance Exercise with Elastic Bands (OMNI-RES EB) was used to determine the resistance/color of theraband. This exercise also includes two sub-components including isometric and isotonic. The participants were asked to sit in an 90° upright position on chair. Theraband was placed on the forehead of the participants and fixed to the back. Participants were warned not to open their mouths and avoid head flexion during exercises. In the isometric component, patients performed chin tuck and hold the position for 60 s against theraband resistance. It was repeated 3 times with rest intervals of 60 s. In the isotonic component, patients performed chin tuck against theraband resistance for 30 times. The exercise set consisted of three isometric and an isotonic components.

All exercises are illustrated in Fig. 2.

Statistical Analysis

Statistical analysis was performed with SPSS 20.0 software package (SPSS, Inc., Chicago, IL, USA) statistical program. Descriptive statistics were calculated as a number/percent (*n*/%) for qualitative data and mean ± standard deviation for quantitative data. The Wilcoxon signed-rank test was used to analyze the differences between baseline and post-intervention scores within groups. The Kruskal–Wallis test was

Fig. 2 Chin tuck with theraband exercise

used to compare intergroup differences. The Mann–Whitney *U* test was used for the Bonferroni correction.

Results

Thirty-six healthy participants who aged between 18 and 40 years were included in the study, of which 50% were male. Each group included 12 participants, and the male–female ratio was equal in all groups. The descriptive information is shown in Table 1. No difference was found in terms of descriptive characteristics of the participants between groups ($p > 0.05$). There was no statistically difference between baseline maximum suprahyoid muscle activation, dysphagia limit and anterior tongue pressure in all groups ($p_1$0.067, $p_2$0.317, p_3 0.367).

Maximum EMG Suprahyoid Muscle Activation

The maximum suprahyoid muscle activation changes in three groups before and after exercise training are shown in Table 2. Changes in maximum suprahyoid EMG muscle activity in CTAR and theraband group between pre- and post-exercise training were statistically significant ($p_1 = 0.004$, $p_3 = 0.018$). No statistically significant difference was shown in Shaker group ($p = 0.507$). Comparison of maximum suprahyoid muscle activation changes in three groups is shown in Table 3. Statistically difference was found between three groups in terms of maximum suprahyoid muscle activity before and after exercise ($p < 0.001$). Pairwise comparisons of three groups are shown in Table 4.

Table 1 Characteristics of the participants

	CTAR group mean ± SD	Shaker group mean ± SD	Theraband group mean ± SD	χ^2	*p*
Age (years)	28.75 ± 5.17	26.72 ± 3.95	28.25 ± 5.78	0.778	0.678
Height (cm)	168.69 ± 7.26	169.18 ± 10.12	171.16 ± 6.46	4.324	0.115
Weight (kg)	64.07 ± 16.07	62.81 ± 14.62	74.75 ± 16.09	1.117	0.572

Kruskal–Wallis test

SD standard deviation

Table 2 Changes in maximum suprahyoid muscle activations before and after exercise training

Maximum EMG suprahyoid muscle activation (mV)	Before training mean ± SD	After training mean ± SD	*Z*	*p*
CTAR group	197.59 ± 71.80	275.65 ± 84.53	−2.903	0.004*
Shaker group	240.11 ± 104.09	243.81 ± 121.01	−0507	0.507
Theraband group	130.09 ± 35.79	171.46 ± 35.17	−2.336	0.018*

SD standard deviation

*$p < 0.05$, Wilcoxon test

Table 3 Comparison of maximum suprahyoid muscle activation changes in three groups

	CTAR group *Δ* mean ± SD	Shaker group *Δ* mean ± SD	Theraband group *Δ* mean ± SD	χ^2	*p*
Maximum suprahyoid muscle activation difference (mV) Δ	78.05 ± 60.33	3.70 ± 5.16	32.36 ± 15.83	8.649	< 0.001*

SD standard deviation, *Δ* difference of pre–post-exercise training

*$p < 0.05$, Kruskal–Wallis test

Table 4 Pairwise comparisons of groups on maximum suprahyoid muscle activity difference

p value	CTAR group	Shaker group	Theraband group
CTAR group		< 0.001*	0.128
Shaker group	< 0.001*		0.016*
Theraband group	0.128	0.016*	

*$p < 0.017$, Mann–Whitney *U test*

Dysphagia Limit

There was no difference in all groups before and after exercise ($p_1 = 0.162$, $p_2 = 0.102$, $p_3 = 0.257$).

Anterior Tongue Pressure

Changes in the maximum anterior tongue pressure in groups before and after exercise training are shown in Table 5. There was a significant difference in terms of maximum anterior tongue pressure changes between before and after training in the CTAR and theraband group ($p_1 = 0.041$, $p_3 = 0.045$). There was no improvement in Shaker group ($p = 0.248$). There was no difference in terms of maximum anterior tongue pressure difference between three groups ($p = 0.853$).

Discussion

In the current study, the CTAR and theraband group showed an increase in maximum suprahyoid muscle activation and tongue pressure, whereas there was no change in Shaker group. No improvement was determined in dysphagia limit in three groups after exercise program.

Similar to our study results, it was reported that CTAR exercises activated suprahyoid muscles more than Shaker exercises [4, 5]. In a study by Watts et al., it was reported that Shaker exercise caused a lower level of suprahyoid muscle activation than a resistant mouth-opening exercise [12]. There are also studies showing that Shaker exercise increases muscle activation in superficial cervical flexor muscles rather than suprahyoid muscle [4, 5, 13]. It has been reported that the Shaker exercise protocol leads to/cause muscular fatigue and the patient group is able to complete only average of 50% of isometric components of this protocol [14]. Studies on the therapeutic effects of exercises to increase suprahyoid muscle function are very limited. In one of these studies, Gao et al. showed that CTAR exercise on patients with cerebral infarction was more effective in protecting the airway than Shaker exercise. The most important factor in this difference is thought to be more effective on suprahyoid muscles that play a key role in airway protection compared to Shaker exercise [13].

While CTAR and theraband exercises are performed in sitting position, Shaker exercises are performed in supine position with lifting head against gravity. This positional difference creates various biomechanical changes. For activation of the suprahyoid muscle group and deep cervical flexor muscles such as longus colli and longus capitis, cervical movement should occur in the occiput: C1–C2 segments. This movement is called craniocervical flexion. Cervical flexion is performed by sternocleidomastoid (SCM) and anterior scalar muscle, which are more superficial muscles, and it occurs in middle and lower cervical segments [15–17]. While lifting head and looking at toes movements in Shaker exercise include cervical flexion, movements in

Table 5 Changes in the maximum anterior tongue pressure in groups before and after exercise training

Tongue pressure (kPa)	Before training mean ± SD	After training mean ± SD	*Z*	*p*
CTAR group	50.88 ± 10.38	56.50 ± 6.90	− 2.041	0.041*
Shaker group	57.72 ± 10.04	62.14 ± 11.42	− 1.156	0.248
Theraband group	54.00 ± 10.24	59.71 ± 10.01	− 2.003	0.045*

SD standard deviation, *Δ* difference of pre–post-exercise training

*$p < 0.05$, Wilcoxon test

CTAR and chin tuck with theraband include craniocervical flexion. In addition, lifting the weight of the head with an average weight of 4–6 kg in Shaker exercises may cause more activity of part of superficial cervical flexor muscles which are stronger than the deep cervical and suprahyoid muscles, which may result in insufficient suprahyoid muscle activation. Less activation of suprahyoid muscles of Shaker group than theraband and CTAR group may be associated with this biomechanical difference between exercises.

Although there was no difference in improvement of suprahyoid muscle activation between CTAR and theraband group, 39.5% increase was obtained in CTAR group and 13.1% increase in theraband group. We thought that the difference of 26.4% between two groups could be clinically significant. One of the possible causes of the clinical difference between CTAR and theraband exercises which have similar biomechanics may be the proprioceptive input and biofeedback of the ball in direct contact with suprahyoid muscles in CTAR exercise. In some superficial EMG studies, the positive effect of proprioceptive input and biofeedback on increased muscle activation has been reported [18, 19]. Another possible reason that CTAR exercise was slightly more effective in suprahyoid muscle activation may be that this exercise provides the contraction of the suprahyoid muscles in the inner range position, because the head needs to be partially approached to the sternum to fix the ball in starting position of this exercise. This position may cause the optimum length–tension relationship due to the contraction of suprahyoid muscles in a relatively shortened position. Optimum length–tension relationship is known to provide much better muscle activation [20, 21].

However, CTAR exercise requires sufficient upper extremity function to fix the ball between chin and sternum. Thus, we thought that chin tuck exercise with theraband could be preferred in individuals with insufficient upper extremity function. In addition, some patients with dysphagia are tracheostomized. Therefore, CTAR exercise which performed with a 12-cm-diameter ball fixed between the chin and sternum can be a problem for this patient group. Therefore, we thought that chin tuck exercise with theraband may be an alternative to CTAR exercise in such patients.

The majority of studies on the dysphagia limit are in the patients with dysphagia. It has been reported that dysphagia limit reaches normal levels in patients with CVA and Parkinson's disease as a result of improvement in general health status with medical treatment [9, 22, 23]. The reason for this improvement has been advocated as an improvement in the neural feedback mechanism mediated by mechanical and chemical receptors with a high rate of oral cavity and pharynx, which plays a key role in the dysphagia limit [24].

Decreasing of dysphagia limit was recorded during high-temperature drinking water and after anesthesia applied to the oropharyngeal region in studies with healthy subjects. In these studies, it was emphasized that mucosal sensory input affects dysphagia limit [25, 26]. Taking into consideration these studies, there was no stimulation for oral and pharyngeal peripheral receptors in our treatment protocols, which may be the reason of no change in dysphagia limits. Ertekin et al. [27] measured the dysphagia limit in different head and neck postures and showed that these postural changes affect the dysphagia limit. As a result, they emphasized that different head and neck postures may affect pharyngeal constructive activity which plays an important role in dysphagia limit. One of the reasons why we did not see any difference in the dysphagia limit in individuals may be that none of the exercise protocols aim to strengthen the pharyngeal constructor muscles.

Oh and Kwon [28] reported that the resistive jaw-opening exercise improved strength of suprahyoid muscles and tongue pressures in healthy subjects. In another study by Oh et al., it has been suggested that effortful swallowing exercise in head extension position increases both tongue pressure and suprahyoid muscle activation [29]. In another study, during tongue pressure against palate, intrinsic and extrinsic tongue muscles and anterior belly of digastric, geniohyoid and mylohyoid muscles were investigated with invasive electrodes. It was found that there was a high correlation between the pressure generated by the tongue and the electrical activation of the muscles mentioned above [30]. Pearson Jr et al. [31] reported that stylohyoid muscle plays a critical role in elevation of the tongue. The main hypothesis of these studies is that an exercise that increases suprahyoid muscle activation also contributes positively to the tongue pressure. In our study, exercises that increase the maximum suprahyoid muscle activity are CTAR exercise and chin tuck exercise with theraband. Therefore, only these exercises improved tongue pressure. In our study, we thought that the reason for the increase in the suprahyoid muscle activation of the exercises which increase the tongue pressure is the direct or indirect contribution of the suprahyoid muscles to the tongue biomechanics which are not tongue muscles but have common origin and insertion points with tongue muscles.

Wakabayashi et al. [32] applied a 12-week strengthening training by giving manual resistance to head flexion in geriatric patients in supine position. The results of the study did not show any change in dysphagia symptoms or tongue pressure. It was seen that the strengthening exercise used in this study was not in accordance with the principle of suprahyoid muscle training. Because the patient's head flexion, which is made to see the umbilicus in supine position, creates movement in the middle cervical region, in biomechanical aspect, this exercise is for more superficial flexor muscles, such as SCM and anterior scalene, rather than deeper muscles such as suprahyoid. In our study, we think that the reason of not seeing any improvement in both suprahyoid muscle activation and tongue pressure in the Shaker group may be related to this situation.

The information regarding the development of suprahyoid muscle activation that increases laryngeal elevation is already known [33]. It may be a limitation of this study that we did not evaluate the increase in laryngeal elevation. Although we argue that the pressure generated by pharyngeal muscles may affect the dysphagia limit, it may be another limitation that we did not perform a manometric assessment to these muscles [34].

Future Directions

The study population included healthy individuals. Replication studies with patients with dysphagia would increase the understanding of the effect of exercises before clinical usage. In addition, we measured the maximal voluntary contraction of the muscles to investigate the effects of 8 weeks of exercise training. Yet, these effects could also be investigated by using particular exercise using normalized data in the future studies.

Conclusion

In conclusion, CTAR exercises and chin tuck with theraband exercises could be used to increase suprahyoid muscle activation and tongue pressure. These findings provide support for further investigation of the effects of chin tuck with theraband exercises in patients with dysphagia.

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Compliance with Ethical Standards

Conflict of interest There is no conflict of interest.

Ethical Approval All procedures performed in the study involving human participants were in accordance with the Ethical Standards of the Institutional Research Committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed Consent All participants signed an informed consent form.

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