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Augmentation of Deglutitive Thyrohyoid Muscle Shortening by the Shaker Exercise

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Abstract

Earlier studies of the effect of 6 weeks of the Shaker Exercise have shown significant increase in UES opening and anterior excursion of larynx and hyoid during swallowing in patients with upper esophageal sphincter (UES) dysfunction, resulting in elimination of aspiration and resumption of oral intake. This effect is attributed to strengthening of the suprahyoid muscles, as evidenced by comparison of electromyographic changes in muscle fatigue before and after completion of the exercise regime. The effect of this exercise on thyrohyoid muscle shortening is unknown. Therefore the aim of this study was to determine the effect of the exercise on thyrohyoid muscle shortening. We studied 11 dysphagic patients with UES dysfunction. Six were randomized to traditional

swallowing therapy and five to the Shaker Exercise. Videofluoroscopy was used to measure deglutitive thyrohyoid shortening before and after completion of assigned therapy regimen. Maximum thyrohyoid muscle shortening occurred at close temporal proximity to the time of maximal thyroid cartilage excursion. The percent change in thyrohyoid distance from initiation of deglutition to maximal anterior/superior hyoid excursion showed no statistically significant difference between the two groups prior to either therapy ($p = 0.54$). In contrast, after completion of therapy, the percent change in thyrohyoid distance in the Shaker Exercise group was significantly greater compared to the traditional therapy ($p = 0.034$). The Shaker Exercise augments the thyrohyoid muscle shortening in addition to strengthening the suprahyoid muscles. The combination of increased thyrohyoid shortening and suprahyoid strengthening contributes to the Shaker Exercise outcome of deglutitive UES opening augmentation.

Keywords

Deglutition; UES dysfunction; Thyrohyoid muscle; Shaker exercise; Dysphagia; Videofluoroscopy; Deglutition disorders

Earlier studies of healthy, elderly individuals [1] and patients with diminished upper esophageal sphincter (UES) opening resulting in severe postdeglutitive dysphagia [2] have shown that a regimen of 6 weeks of the Shaker Exercise results in a significant increase in the diameter of the anteroposterior deglutitive UES opening and elimination of postdeglutitive aspiration and dysphagic symptoms. Analysis of videoradiographic swallows has demonstrated increased anterior excursion of the larynx commensurate with increased anteroposterior deglutitive UES opening diameter after completion of the exercise regimen. The anterior laryngeal excursion occurs as the result of contraction of suprahyoid muscles, including mylohyoid, geniohyoid, and anterior belly of the digastric, and the contraction of the thyrohyoid muscle. This latter contraction rigidly apposes the thyroid cartilage and hyoid bone [3], thus allowing the transmission of distracting force from suprahyoid muscles to the thyrocricoid complex, resulting in UES opening. Although earlier studies confirmed increased anterior excursion of the thyroid cartilage after completion of the Shaker Exercise, the effect of this exercise on contraction and shortening of thyrohyoid muscles has not been studied directly. The aim of the present study was to determine the effect of 6 weeks of the Shaker Exercise on deglutitive thyrohyoid shortening and compare this effect to that seen with 6 weeks of traditionally practiced swallow therapy.

Methods

Experimental Design

This was a randomized controlled trial of two therapeutic procedures, traditional therapy or the Shaker Exercise, designed to improve pharyngeal dysphagia. The primary therapeutic outcome measure was the change in thyrohyoid muscle shortening measured from videofluoroscopic swallow images before and after 6 weeks of therapy. The study was approved by the Institutional Review Boards of the participating institutions: Medical College of Wisconsin and Northwestern University. After explanation of the study, all subjects provided informed written consent.

Subject Selection

Nineteen patients with postdeglutitive dysphagia were voluntarily enrolled in the study. General eligibility criteria included pharyngeal phase dysphagia due to stroke or chemoradiation for head and neck cancer. Subjects with a history of pharyngeal surgical

procedures were excluded from study enrollment. A complete list of inclusion/exclusion criteria is presented in Table 1.

Entry and Randomization

Subjects received an initial videofluoroscopic swallow evaluation to define the physiology of their swallow and to verify their qualification for study participation (i.e., incomplete UES opening and postdeglutitive aspiration). Subjects were then randomly assigned to one of the two therapy programs (traditional or Shaker Exercise). To maintain confidentiality, all subject data were labeled with an identification code.

Videofluorographic (VFG) Recordings at Baseline and Postintervention

Each subject received pre- and postintervention VFG. VFG was performed no more than 5 days before initiation of therapy and on the day following completion of the 6 weeks of their assigned treatment program. Each subject's swallow was studied with the subject in an upright position during the VFG in the lateral and anteroposterior projections. For calibration of the videofluoroscopic measurements and to compensate for possible measurement error due to radiographic magnification, a penny (1.78 cm in diameter) was taped to each patient's chin before each study for subsequent spatial calibration of distance measurements described in the Fluoroscopic Data Analysis subsection below.

During the VFG, the subjects were instructed to hold their heads in a neutral position while the swallow images were recorded from a lateral projection. Each frame included the following images: lips anteriorly, pharyngeal wall posteriorly, soft palate superiorly, and the cervical esophagus to C7 inferiorly. Videofluoroscopic recordings were obtained at 90 keV using a 9-in. image intensifier mode and appropriate collimation so that an image of the region described above was obtained. Fluoroscopic images were recorded on VHS tape using a videocassette recorder. Before and after completion of their assigned treatment programs, each subject performed three swallow trials of 3- and 5-ml barium liquid and paste boluses recorded at 30 frames/s. Videofluoroscopic recordings for each subject were 4–5 s, equaling less than 2 min of fluoroscopy time. Intolerance to specific volume or consistency, penetration, and aspiration events were recorded at the time of occurrence.

Fluoroscopic Data Analysis

Videofluoroscopic images were digitized onto compact discs from VHS tape using ADS hardware and Capture Wizard 3.8 DVD Xpress DX2 software (ADS Technologies, Cerritos, CA). Videofluoroscopic images were analyzed in a blinded fashion wherein treatment group and exercise status were unknown to those researchers evaluating the recordings. Video loops of the 5-ml liquid swallows were reviewed, and the best single swallow, as determined by fluoroscopic quality and bolus passage, for each subject was converted and saved as individual bitmaps to a password-protected computer using VirtualDub 1.5.10 (Avery Lee, GPL, SourceForge, 1998–2003) software. For each subject's 5-ml swallow, an image every 0.1 s was analyzed using ImageJ 1.36b software (NIH, Bethesda, MD). The thyrohyoid distance was calculated by measuring from the most anterior-inferior point on the hyoid bone (insertion of the thyrohyoid) to the most anterior point of the subglottic air column that demarcates the true vocal cords (Fig. 1). This point was chosen as a consistent landmark on every subject because it represented the thyroid cartilage (origin of the thyrohyoid muscle).

Of the 19 subjects enrolled in the study, two were excluded because of repeatedly failed swallows, defined as an inability to move the bolus past the UES as observed on the videofluoroscopic recordings, both before and after completion of the therapy regime. Three subjects were excluded because of an inability by the researchers to identify the anatomic landmarks used for comparative measurement from the fluoroscopic images. Three subjects

were lost to follow-up (Fig. 2). Eleven subjects (6 traditional, 5 Shaker) completed the protocol and the data for these subjects are included in this analysis.

Treatment Programs

Both the traditional and Shaker Exercise treatment programs were conducted by a certified speech language pathologist and included biweekly 45-min therapy sessions for 6 weeks. The speech language pathologist demonstrated the specific exercises to the subject, determined if the subject was accurately performing the assigned exercise, and reviewed the subject's therapy practice log.

Traditional therapy focused on laryngeal and tongue range-of-motion exercises and swallowing maneuvers. The laryngeal range-of-motion exercise included falsetto, i.e., vocalizing at a very high pitch and holding the vocalization for 1 s. The tongue base range-of-motion exercise involved a series of movements starting with pulling the tongue back in the mouth as far as possible and holding this position for 1 s; yawning and holding the extreme yawn position for 1 s; gargling for 1 s; and then holding the tongue base position for 1 s. The coordinated swallowing maneuvers consisted of the Super-Supraglottic Swallow, the Mendelsohn Maneuver, and the Effortful Swallow. The Super-Supraglottic Swallow was performed by having the subject take a breath and bear down, holding this during a swallow, and coughing at the end of the swallow. The Mendelsohn Maneuver was performed by having the subject initiate a normal swallow, but keep the "Adam's apple" lifted at the top of the throat for several seconds while completing the swallow [4]. The Effortful Swallow was performed by having the subject swallow very hard while squeezing the tongue toward the soft palate [5]. Subjects were instructed to perform all of these exercises five times daily in the same sequence and for the same duration of time.

The Shaker Exercise is defined as an isometric and isokinetic head-lift exercise performed in the supine position three times per day for 6 weeks. To obtain the target head-lift position, patients were instructed to raise their head high and forward enough to be able to observe their toes without raising their shoulders off the ground (Fig. 3). The isometric strengthening component involved three consecutive head lifts held for 60 s each with a 60-s rest period between each head lift. The isokinetic strengthening component involved 30 consecutive head lifts at a constant velocity, performed without holding or rest periods.

Statistical Analysis

Statistical analysis was performed using StatsDirect v2.4.6 2005 software (StatsDirect Ltd, Cheshire, UK). Paired *t* tests for each exercise group were utilized to compare the average percent change in thyrohyoid distance from baseline to maximal anterior-superior hyoid excursion before and after therapy. Unpaired *t* tests were utilized to compare the average percent change in thyrohyoid distance between the two groups both before and after therapy. Two-sided *p* values were calculated assuming equal variances.

Results

Demographic information of the 11 enrolled subjects is provided in Table 2. Maximum thyrohyoid muscle shortening occurred close to the time of maximal anterior-superior hyoid excursion. Analysis of videofluoroscopic recordings showed that before exercise, the traditional group and the Shaker Exercise group had average percent changes in thyrohyoid distance from baseline to maximal anterior-superior hyoid excursion of 9.35 and 13.73%, respectively ($p = 0.54$). After traditional therapy, the percent change in thyrohyoid distance was 13.30%. However, after 6 weeks of the Shaker Exercise, the average change in thyrohyoid distance from baseline to maximum anterior-superior hyoid excursion increased to 26.10%.

The unpaired t test showed that the percent changes in thyrohyoid distance after exercise were statistically significant between the traditional therapy group and the Shaker Exercise group (13.30% vs. 26.10%, $p = 0.034$). This significance was not due to an increase in the resting length of the thyrohyoid muscle following either therapy. There was no statistically significant difference in the average percent change in thyrohyoid distance between before and after traditional therapy ($p = 0.48$) and between before and after the Shaker Exercise ($p = 0.066$) using paired t test (Table 3, Fig. 4).

Discussion

Dysphagia secondary to stroke or chemoradiation for head and neck cancer can be a challenging clinical problem. There are limited options when dysphagia is caused by abnormalities of UES opening mechanisms. The mechanisms of deglutitive opening of the UES are complex. The UES opening during swallowing is influenced by (1) distensibility of the UES [6], (2) myoelectric relaxation of the UES tone [7,8], (3) distraction of the sphincter by contraction of the suprahyoid UES opening muscles [9], and (4) distending force of the bolus traversing the UES [10]. Among these components, the contraction of the UES opening muscles is amenable to direct rehabilitation. Earlier studies have demonstrated the effect of rehabilitation techniques such as the Mendelsohn Maneuver and the Shaker Exercise [1,11]. The Shaker Exercise has been shown to increase the magnitude of the anterior excursion of the larynx, the maximum anteroposterior diameter, and the cross-sectional area of the UES opening. It has been shown to decrease hypopharyngeal intrabolus pressure and decrease hypopharyngeal residue and restore oral feeding in patients with deglutitive failure due to abnormal upper esophageal sphincter opening [2].

Earlier studies that determined increased swallow-induced anterior excursion of the larynx did not address the contribution of the thyrohyoid muscle contraction to this outcome. In this study we determined the effect of the Shaker Exercise on thyrohyoid muscle shortening during deglutition and compared this effect to that seen with traditional dysphagia rehabilitation therapy. We found that the Shaker Exercise resulted in a significant improvement in thyrohyoid shortening compared to that seen with traditional therapy. These findings support the concept that the Shaker Exercise improves function in both suprahyoid and infrahyoid muscle groups.

There are several limitations to this study, the most important of which is the small sample size resulting from the dropout of initially enrolled subjects. The small sample size leads to inadequate statistical power for certain analyses such as the within-group change in percent thyrohyoid muscle shortening for the Shaker Exercise group, where a doubling of the percent shortening just missed statistical significance ($p = 0.06$). The small sample size prevents comparisons between cancer and stroke subjects and prevents generalization of the findings to subjects with different locations of cerebrovascular lesions from stroke. Our results demonstrate a trend toward increasing deglutitive thyrohyoid shortening with the Shaker Exercise, but additional studies with larger sample sizes need to be undertaken to confirm these findings and evaluate the precise effects on cancer and stroke subjects. Finally, it is not possible from this analysis to assess the relative importance of changes in thyrohyoid shortening relative to changes in deglutitive UES opening and clinical improvement following the Shaker Exercise intervention. However, the increased thyrohyoid muscle shortening may contribute to and enhance the effect of suprahyoid muscle contraction upon UES opening.

In summary, we have demonstrated an effect of the Shaker Exercise on increasing deglutitive thyrohyoid shortening compared to that seen with traditional dysphagia therapy and maneuvers. This effect would be expected to contribute to enhanced deglutitive UES opening and improved dysphagic symptom relief in patients with postdeglutitive dysphagia.

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Fig. 1.
Videofluoroscopic analysis at initiation of deglutition and at maximal anterior-superior hyoid excursion

Fig. 2.
Subject dropout

Fig. 3.
Shaker exercise

Fig. 4.
Results

Table 1**Inclusion/exclusion criteria**

Inclusion criteria	Exclusion criteria
Pharyngeal phase dysphagia due to stroke or chemoradiation for head and neck cancer (without surgical intervention to the strap muscles, including the mylohyoid, geniohyoid, anterior digastric, and thyrohyoid muscles). Subjects with head and neck cancer must be at least 3 months post chemoradiation therapy and 1 month post surgery before study entry	Pharyngeal surgical procedures of the strap muscles (mylohyoid, geniohyoid, anterior digastric, and thyrohyoid muscles)
Incomplete UES opening and postdeglutitive aspiration, or incomplete UES opening with pre- and postdeglutitive aspiration	Other neuromuscular disorders: metabolic myopathies, steroid myopathy, Kearns-Sayre syndrome, oculopharyngeal and other dystrophies, myasthenia gravis
Hypopharyngeal (pyriform sinus) residue or vallecular residue alone or in combination	Cervical spine injury, lesions, or large osteophytes
Able to comply with protocol mandates, willing to perform exercise programs, and ability to attend study sessions	Inability to lift the head and flex the neck
Dysphagia with aspiration of at least 3-months duration	Inability to exercise independently or with a caregiver
	Lack of cognition
	Current use of anticholinergics, benzodiazepines, antihistamines
	Absent pharyngeal swallow on VFG
	Aspiration during the swallow (intradeglutitive aspiration)
	History of alcoholic neuropathy

Table 2

Demographic data

	Traditional therapy group	Shaker exercise group
Number of subjects	6	5
Age: mean $\pm$ SD (years)	70.5 $\pm$ 9.5	64 $\pm$ 22.8
Age range	56–81	26–84
Number of males	5 (83%)	3 (60%)
Number of females	1 (17%)	2 (40%)
Etiology of dysphagia		
CVA	4 (67%)	2 (40%)
Cancer	2 (33%)	3 (60%)

Table 3Results for average percent change in thyrohyoid muscle shortening (mean % $\pm$ SD)

	Traditional therapy group	Shaker exercise group	<i>p</i> value
Number of subjects	6	5	
Before	9.35 $\pm$ 9.5	13.73 $\pm$ 13.2	0.54
After	13.30 $\pm$ 9.8	26.10 $\pm$ 6.4 ^a	0.034 ^a

^a
p < 0.05