2013

The efficacy of the Masako (tongue-hold) maneuver

BOSTON UNIVERSITY

SARGENT COLLEGE OF HEALTH AND REHABILITATION SCIENCES

Thesis

THE EFFICACY OF THE MASAKO (TONGUE-HOLD) MANEUVER

by

JESSICA MAXHAM PISEGNA

B.A., Hamilton College, 2006
M.Ed., Long Island University, 2008

Submitted in partial fulfillment of the

requirements for the degree of

Master of Science

2013

Approved by

First Reader [redacted]
Susan E. Langmore, PhD, CCC-SLP, BRS-S
Clinical Professor of Speech, Language, and Hearing Sciences
Director of Speech-Language Pathology, Boston Medical Center

Second Reader [redacted]
Cara E. Stepp, PhD
Assistant Professor of Speech, Language, and Hearing Sciences

Third Reader [redacted]
Elizabeth Hoover, MS, CCC-SLP, BC-ANCDS(A)
Clinical Assistant Professor of Speech, Language, and Hearing Sciences

Dedication

This work is dedicated to
my mom, who always had dinner ready for me,
my dad, who always had a joke ready for me, and
my husband, who always supports me.

Acknowledgements

I would like to thank my advisor and mentor Dr. Susan E. Langmore for her guidance and support throughout this project. I would also like to thank the other members of my thesis panel Professor Elizabeth Hoover and Dr. Cara E. Stepp for their guidance and support.

I would also like to thank Dr. Melanie Matthies for her guidance regarding the statistical analyses of this project and Dr. Daryush Mehta for statistical guidance as well as editing and visual layout support.

I also must acknowledge the support from my classmates and professors at Sargent College who provided continual encouragement and fostered an environment that always made me believe what we are doing is important. Specifically, Katie Field and Asako Kaneoka have been tremendous support.

Finally, I wish to thank the participants who committed to 6 weeks of an exercise of uncertain effectiveness in the name of research.

THE EFFICACY OF THE MASAKO (TONGUE-HOLD) MANEUVER

JESSICA M. PISEGNA

ABSTRACT

Purpose

Clinicians commonly recommend the tongue-hold maneuver, also called the Masako, as an exercise to strengthen swallowing muscles. Although this exercise is widely used, limited empirical data support this maneuver as an effective exercise. The goal of the present study is to observe, over multiple sessions, the effects of the tongue-hold maneuver as a 6-week exercise in subjects with dysphagia. The results of this study will help to address whether the tongue-hold maneuver is beneficial and, if so, which muscle groups are strengthened by this exercise.

Methods

Five subjects with dysphagia and one healthy adult performed a set of tongue-hold maneuvers 3 times a day, 5 days per week, for 6 weeks. The number of repetitions per set was individually calculated based on 80% of the maximal repetitions until fatigue. At baseline and 6 weeks, 4 measures were observed: a subject-reported quality-of-life swallowing scale, lingual strength, the amount of residue in the valleculae, and the pressures generated by pharyngeal muscles during a normal swallow. Four healthy adults who did not perform the tongue-hold maneuver were used as controls for the lingual measures, completing the measures of lingual strength at baseline, 3 weeks, and 6 weeks.

Results

No overt trends in the subject-reported swallowing scale were noted; after 6 weeks of exercise, about half ranked their swallowing as worse and half ranked their

swallowing as better. The treatment group demonstrated a non-significant overall 2.3% increase in anteromedian lingual strength and 8.4% increase in posteromedian lingual strength. These changes did not set the treatment group apart from the control group, who demonstrated an increase of 3.8% and 6.3% in the anteromedian and posteromedian positions, respectively. Regarding pharyngeal residue, 2 subjects did not show any changes in residue scores. However, the other 3 subjects demonstrated reduced residue in the valleculae with a cracker bolus. Out of the 3 subjects who were measured with manometry, 2 demonstrated higher oropharyngeal pressures on normal swallows after 6 weeks of exercise, although great variability was present. These results are limited by the small sample size and heterogeneity of the treatment group, as well as high variability in instrumental measurements.

Conclusion

This study investigated the tongue-hold maneuver as an exercise and provides preliminary support for its use, with caution. Specifically, clinicians should be sure to prescribe regimens that fatigue swallowing muscles and push them past normal use. When using the Iowa Oral Performance Instrument (IOPI) as a tool, clinicians should also keep in mind that a learning effect is likely to occur over the first few trials. This pilot study suggests that clinicians should continue to prescribe the tongue-hold maneuver as an exercise with caution, as some patients may benefit from it while others may not. Further investigation is required.

Preface

Eating and drinking are pleasurable and necessary parts of our everyday lives. Almost all social events, traditions, and holidays revolve around food and drinks. Safe swallowing is largely taken for granted and the majority of people do not think twice when they eat or drink. Yet for someone with problems swallowing, every bite or sip comes with concern. It is clear why people with dysphagia would report lower quality of life.

When a patient presents with a condition that may cause, or is causing, dysphagia due to a weak swallow, clinicians often recommend exercise as a preventative or correctional approach to rehabilitation. Various studies have found several exercises, such as the Mendelsohn and Shaker, to be effective in strengthening swallowing and, as a result, reduce symptoms of dysphagia. However, other widely-used exercises, such as the Masako, should strengthen the swallowing mechanism in theory but lack empirical evidence to support their use. More research is needed to confirm these exercises' validity as well as the best frequency at which to perform them.

Table of Contents

List of Tables

List of Figures

Introduction

Clinicians commonly recommend the tongue-hold maneuver, also called the Masako maneuver, as an exercise to strengthen swallowing muscles. However, limited evidence supports this technique as an exercise. A tongue-hold maneuver involves protruding the tongue as far forward as comfortably possible and holding it between the teeth while swallowing one's saliva.

During normal swallowing, the oropharyngeal muscles synchronize complicated contractions to facilitate the passage of a bolus. The tongue propels the bolus from the oral cavity, using the tongue tip as an anchor on the alveolar ridge and the dorsum of the tongue as the power that pushes the bolus posteriorly to the pharynx where the base of tongue continues to advance the bolus (Kahrilas et al., 1993). The glossopharyngeus muscle extends from the sides of the base of tongue to the posterior pharyngeal wall, specifically the superior pharyngeal constrictor (Fujiu & Logemann, 1996). When swallowing, the base of tongue and superior pharyngeal constrictor are thereby pulled together first before other muscles of the pharynx contract. Continuing with the normal swallow's physiology, the three stacked constrictor muscles of the posterior pharyngeal wall contract superiorly to inferiorly in a peristaltic fashion. When the pharyngeal wall contracts, the lateral walls and posterior wall medialize until they firmly oppose the base of tongue (BOT), making a complete seal. The lateral and posterior pharyngeal wall will hereby be referred to as one unit, the pharyngeal walls (PW). When viewed on lateral videofluoroscopy, the medialization of the lateral and posterior PW create a 'bulge' that is commonly referred to in the literature. The PW and BOT then squeeze together to propel the bolus down the pharynx. This act has been named "one of the most critical elements in the pharyngeal phase of swallowing" and is the cornerstone of the tongue-hold maneuver (Fujiu et al., 1995, p. 24).

For subjects with an impaired swallow, this process may not function properly due to many reasons including muscle weakness. For instance, the elderly may experience dysphagia due to sarcopenia, the reduction of Type II muscle fibers resulting in less muscle mass and strength. Subjects with head and neck cancer may have a dysphagia due to surgery or deconditioning. Of interest to this research is the weak swallow and how to rehabilitate it.

Too often dysphagia treatments are limited to compensatory strategies such as thickening liquids and tucking the chin. These strategies, while sometimes effective, may negatively affect quality of life. A more assertive and empowering approach, on the other hand, attempts to address the underlying pathophysiology of the swallow through exercise and rehabilitation. Many exercises exist that aim to improve swallowing function for people with dysphagia. Although the oropharyngeal musculature differs from the well-understood limb musculature, it is known that through exercise, oropharyngeal muscles have the ability to strengthen (Burkhead et al., 2007; Vincent et al., 2002; Thompson et al., 2001; Robbins et al., 2007; Robbins et al., 2009; Lazarus et al., 2003). Some exercises proven in clinical trials to show an increase in strength are the effortful swallow and the Shaker Head Lift. The effortful swallow has been endorsed by the American Speech-Language Hearing Association (ASHA) as evidence-based practice in rehabilitating weak swallows with patients who exhibit submental muscle weakness and reduced hyolaryngeal excursion (Wheeler-Hegland et al., 2009). The Shaker Head Lift, a combination of isometric (resistance without movement) and isokinetic exercise (shortening the muscle against resistance), has been shown to improve the strength of the suprahyoid muscles and increase the opening of the upper esophageal sphincter (Shaker et al., 1997; Shaker et al., 2002). Frequently, clinicians recommend other exercises to strengthen the swallowing muscles, but there is little data to support the efficacy of some of these exercises and their exercise regimens.

The original intent of the tongue-hold maneuver was to target the PW. The idea originated from observations of increased PW movement in post-operative subjects who had anterior lingual resections due to oral cancer (Fujiu & Logemann, 1996). With limited tongue movement, greater movement of the PW resulted. Fujiu and Logemann (1996) suggested that a tongue-hold maneuver could be used as both a means to evaluate PW functioning and to engage the PW therapeutically. The anteriorly anchored BOT pulls the glossopharyngeus forward thereby causing the posterior attachment of the glossopharyngeus (the PW) to contract more anteriorly in order to contact the BOT. The researchers anticipated that "over time, this may result in greater activity of the [PW] musculature" (Fujiu et al., 1995, p. 29). The exercise is therefore often cited for its potential as an exercise that, "based on the theoretical prerequisites," could strengthen a swallow (Doeltgen et al., 2009). Yet this maneuver as an exercise is still only theoretically supported. As of this writing, there has been no available research supporting the long-term use of the tongue-hold maneuver as an exercise to strengthen swallowing in subjects with dysphagia. Oddly enough, in this author's opinion, it is one of the most frequently-prescribed exercises.

Several studies have observed the *immediate* effects of the tongue-hold maneuver and found that it does, indeed, pull the BOT anteriorly and, consequently, pharyngeal muscles contract beyond normal limits. Fujiu et al. (1995) observed the compensatory movement of the PW in subjects who had the anterior section of their tongue removed (the impetus for the maneuver named after Dr. Masako Fujiu). More than half of the study's subjects exhibited a 30% increase in PW movement postoperatively (Fujiu et al., 1995). In a follow-up study, Fujiu and Logemann (1996) found that in all of the healthy, young, male subjects, the PW's bulge increased significantly during the tongue-hold maneuver.

Other studies have observed pressure changes in the pharynx during the tongue-hold maneuver. One study reported an increase in pharyngeal pressure during the tongue-hold maneuver in head and neck cancer subjects, perhaps due to an increased effort when swallowing with the tongue-hold maneuver (Lazarus et al., 2002). This was recently confirmed by a similar study using electromyography (Hammer et al., 2013). Other studies discount this report; lower pharyngeal manometric pressures were found during the tongue-hold maneuver when compared to control swallows in both young and old, healthy subjects (Doeltgen et al., 2009; Doeltgen et al., 2011). This is presumably because the BOT is being held forward and cannot exert as much force on the PW. Umeki et al. (2009) found the only increase in manometric pressure to be in the contraction of the upper esophageal sphincter while swallowing with the tongue-hold maneuver. More research is needed to clarify the effects of the tongue-hold maneuver. Therefore, this study included manometric pharyngeal measures as pre- and post-exercise data.

The tongue-hold maneuver also has the potential to strengthen the dorsum of the tongue. Although not discussed in or supported by the literature, it is possible that the tongue-hold maneuver strengthens the tongue as it retracts against resistance. No studies currently exist that investigate the relationship between the tongue-hold maneuver and lingual strength, possibly because it was originally intended to target only the PW. However, many other studies have shown that lingual-strengthening exercises can improve swallowing. Robbins et al. (2005) demonstrated that healthy elderly subjects significantly strengthened their tongues with isometric tongue exercises and, in turn, strengthened their swallow, as indicated by higher lingual swallowing pressures and increased lingual volume. In a small sample of stroke subjects who performed tongue exercises, Robbins et al. (2007) observed increased tongue strength in addition to associated improvements in swallowing pressures, airway protection, and lingual volume. Another study demonstrated that training lingual strength in one direction generalized to all directions (Clark et al., 2009). This study speaks to the tongue's muscular hydrostat properties, insofar as any given muscle fiber of the tongue may be recruited for a number of movements. That is, the tongue may not train to only one task (Clark, 2012; Clark, 2011). Such generalization may be an important factor in applying improved lingual strength to swallowing functions.

In 2011, Oh and colleagues researched the implications of the tongue-hold maneuver. The researchers studied the 4-week effect of the maneuver as an exercise in 10 healthy, young subjects. The authors found no improvement in the following biomechanical parameters of swallowing: hyolaryngeal movement, posterior PW movement, and pharyngeal constriction ratio. However, the study contained various limitations including the feasibility of swallowing with the tongue-hold maneuver every 5 seconds for 20 minutes (240 swallows in one sitting). This was repeated once a day, 5 days per week, for 4 weeks. Additionally, marked improvements may not be observed in young subjects with an already healthy, strong swallow (quite different from a patient with dysphagia). Moreover, literature about muscle adaptation reports that at least 5 weeks of training is required before sufficient strengthening occurs (Burkhead et al., 2007). It remains unknown if, in subjects with dysphagia, repetitive contraction of the PW and resistance against the BOT result in an increase in strength of the PW, the tongue, or both. The question remains: is the potential increase in strength from the tongue-hold maneuver as an exercise enough to functionally improve a weak swallow on its own?

Understanding the basic principles of exercise is critical when attempting to strengthen muscles. Striated muscles can be generally categorized as slow twitch (Type I) and fast twitch (Type II). The oropharyngeal musculature is a made up of a unique hybrid of muscle fibers, different from any other skeletal muscle (Kent, 2004). Put simply, the anterior portion of the tongue consists of mostly Type II muscle fibers and the dorsum consists of Type I. The unique properties of the tongue as a muscular hydrostat also define its abilities: it is a structure comprised almost entirely of muscle that does not move around a joint; the intrinsic and extrinsic muscles connect on intersecting planes allowing for constant volume and complimentary movements (Clark, 2012). When performing swallowing exercises, therefore, one must consider the type of muscles targeted and how to optimize training. Four general principles of exercise physiology that are important considerations for the tongue-hold maneuver are contraction type, task specificity, overload, and dose.

Contraction Type
Muscle adaptation will differ depending on the type of contraction: isometric (increasing tension without changing muscle length) or isokinetic (changing the length of the muscle while maintaining the same tension). Isometric exercises strengthen the force of contraction while isotonic exercises improve the speed of contraction (Stathopoulos & Duchan, 2006).

Task specificity
A specific task recruits specific motor units. Training a specific task will address the motor units involved in the task and will not as effectively generalize to other related tasks. This is why the literature supports task-specific training in rehabilitation, such as swallowing exercises over non-swallowing exercises. Clark and Shelton (2011) demonstrated task specificity in their study. Those who practiced effortful swallows improved strength in effortful swallowing (not normal swallows). Those who trained in sucking straws only got better at sucking straws. The study demonstrates the importance of task specificity. It must be noted, however, that the tongue itself is a unique muscle and will demonstrate general training effects. Increases in lingual strength may generalize to untrained lingual movements (Luschei, 1991).

Overload
Burkhead et al. (2007) provide an excellent synopsis of the overload principle. The authors state, "engaging in exercise that is not intense enough to push the system beyond the level of activity to which it is accustomed will not result in adaptation. The exercise task must exceed usual levels of activity and be performed for an adequate duration [see *Dose* below]" (p. 255). Moreover, as the muscles increase in strength, the demand must also continuously increase in order for strengthening to continue to improve. For this reason, the subjects of the present study were asked to increase their repetitions of tongue-hold maneuvers throughout the duration of the study, maintaining adequate challenge to the

muscular system. It must be stated, however, that this principle is based on skeletal muscle. The direct effects of strengthening oropharyngeal muscles remain unknown.

Dose

Unanswered questions in dysphagia rehabilitation are how much, how often, and how intense? At the 2011 ASHA annual conference, an expert panel concluded that the answers are still unknown and until more research is provided, most programs are based on literature of the limb musculature. Increasing the number of repetitions per set will improve both endurance and power, if completed to the point of fatigue (Clark, 2003). Studies have prescribed exercises anywhere from 3 times a week to 7 times a week, depending on the exercise. Finally, at least 5 weeks of strength training must occur for a sufficient degree of hypertrophy to occur in muscle (Burkhead et al., 2007).

Exercise principles are difficult to apply to the tongue-hold maneuver. Swallowing requires submaximal force, meaning the amount of strength required to execute a swallow is well below the maximal force that can be generated by the muscles. Because it is difficult to provide overload to these muscles, they are fatigued past their normal use via multiple repetitions in an over-extended position (a passive load). Therefore the tongue-hold maneuver has the characteristics of both strengthening and actively stretching (targeting increased range of movement of the posterior PW) (Clark, 2003; Burkhead et al., 2007; H. Clark, personal communication, June 12, 2012). In sum, the critical aspects of the tongue-hold maneuver that must be executed in order to strengthen the muscles enough to function normally are maximal tongue protrusion to optimize range of motion beyond normal limits and sufficient intensity to fatigue oropharyngeal musculature on an increasing scale.

Purpose

The purpose of this study is to investigate the effectiveness of the tongue-hold maneuver as an exercise in strengthening a weak swallow. Specifically, the goal is to learn if an exercise regimen of the tongue-hold maneuver will strengthen and improve the swallow, as measured by the amount of residue in the valleculae after a normal swallow and by a change in the pharyngeal pressures of a normal swallow. After 6 weeks of exercise, it is predicted that

1) The amount of residue will be significantly lower than at baseline,
2) Tongue strength and pharyngeal strength will be significantly greater than baseline measures, and
3) Quality of life will improve, as measured by the Dysphagia Handicap Index.

This is a Phase I pilot study that attempts to determine whether this intervention has any effect on swallowing function.

Methods

Subjects were recruited from the Boston Medical Center Otolaryngology Clinic. Subjects qualified for the study if their dysphagia met the main criterion of mild or greater amount of residue in the valleculae, as observed on instrumental exam, along with the following inclusion criteria:

1.) English-speaking subjects over the age of 18 years with dysphagia as documented on an instrumental swallowing exam,
2.) No recent or current exercise-based therapy for their dysphagia, and
3.) The ability to understand and comply with the instructions for the exercise, as judged by the Principal Investigator and a score ≥27 on the Mini-Mental State Exam (O'Bryant et al., 2008).

Table 1 outlines the demographics of the 5 subjects. The study began with 7 enrolled subjects but 2 dropped out early in the study due to health issues. Of note, the Principal Investigator (PI), who did not have dysphagia, performed the exercise as an investigatory opportunity to observe the effects of the exercise in a healthy adult after confirmed *absolute* compliance over 6 weeks. The PI's data is not included in the statistical analyses but is reported in the results. Four healthy adults were used as controls for the lingual measures, completing the measures of lingual strength at baseline, 3 weeks, and 6 weeks. The 4 controls did not perform any oral exercises and only participated in measures of lingual strength. All controls had negative histories for speech and swallowing impairment.

Table 1. Subject demographics
*The Principal Investigator did not have dysphagia but performed the exercise as an investigatory opportunity.

	Age	Gender	Diagnosis	Dysphagia Severity
Subject 1	63	Male	Head and neck cancer	Severe
Subject 2	75	Male	Parkinson's disease	Moderate
Subject 3	47	Male	Head and neck cancer	Mild
Subject 4	69	Female	Cerebral vascular accident	Severe
Subject 5	57	Male	Head and neck cancer	Moderate
PI*	28	Female	None	N/A

	Age	Gender
Control 1	59	Female
Control 2	59	Male
Control 3	24	Female
Control 4	32	Male

Ethical Consideration

The portion of this study utilizing individuals with dysphagia was approved by the Institutional Review Board of Boston Medical Center. The portion utilizing control participants was approved by the Boston University Institutional Review Board. There was no charge or reimbursement to subjects to participate in this study. Before beginning any data collection, the Principal Investigator reviewed the Informed Consent Form with each subject and obtained his or her signature.

Instrumentation

Baseline and post-baseline data collection was performed using 4 measures:

- *The Dysphagia Handicap Index (DHI)* (Used with all 5 subjects)

  The DHI is a subject-reported scale that has been psychometrically validated (Silbergleit et al., 2011). It is a 25-item questionnaire used as a quality-of-life assessment. The scores on the DHI range from 0 (best) to 100 (worst).

- *The Iowa Oral Performance Instrument (IOPI)* (Used with all 5 subjects)

  Tongue strength was measured with the IOPI (Blaise Medical, Hendersonville, TN). This instrument is a hand-held machine connected via a plastic tube to a small, air-filled bulb that is placed on top of the tongue to measure tongue strength. There is no regular calibration necessary for the IOPI and all pressures are reported in kilopascals (kPa). The IOPI is one of the most commonly-used tools to assess lingual function and strength (Steel et al., 2009; Youman & Stierwalt, 2006; Youman et al., 2009).

- *Fiberoptic Endoscopic Evaluation of Swallowing (FEES)* (Used with all 5 subjects)

  FEES is well-known and safe instrumental procedure used to evaluate oropharyngeal dysphagia (Langmore et al., 1988; Aviv et al., 2000; Aviv et al., 2005; Warnecke et al., 2009). This procedure has been shown to result in judgments of more severe residue than videofluoroscopic swallow studies, as well as better detection of penetration and aspiration than a videofluoroscopic swallow study (Rao et al., 2003; Kelly et al., 2006; Kelly et al., 2007).

  To grade the severity of residue, the *Boston Residue and Clearance Scale* (BRACS) was used. This assessment tool is an 11-step ordinal ranking scale that has been shown to be more reliable than clinical judgment and demonstrated excellent inter-rater and test-retest reliability (Kaneoka et al., 2013).

- *Manometry* (Used with only S4, S5, and the PI due to equipment malfunction)

> The pressures generated by the pharynx during a normal swallow are indicative of pharyngeal strength (in mmHg). Pharyngeal strength was measured by a manometer. Before every session, the manometer was calibrated to 125 mmHg using the Digital Manometer model 8205 (KayPentax). The manometer used for this study contained 3 pressure transducers on its distal end.

Procedure

At baseline and post-baseline, all 5 subjects reported to the outpatient otolaryngology clinic at Boston Medical Center. Due to logistics, only 2 subjects came to the 3-week halfway session to assess progress. At baseline and post-baseline sessions, the 4 measures were performed in the manner described below.

Subject Perception of Swallowing

Subjects were asked to complete the DHI. Because 2 subjects were partially tube fed, not all items were applicable to each subject. If a subject omitted an item, the paired response on the other DHI administration was also omitted in attempt to create equal scoring. The DHI produces two scores, an **overall self-perceived severity rating** from normal (1) to severe (7) and a **subscale total score** of the 25 items (Silbergleit et al., 2011).

Lingual Pressures

Subjects were asked to push the air-filled bulb of the IOPI against the roof of the mouth with the tongue as hard as they could in one swift push because strength was being assessed, not endurance. Because the intrinsic musculature of the tongue varies greatly, two areas were measured to note the effect of the exercise on the different muscle fibers: the anteromedian position and the posteromedian position. Every effort was made to ensure consistent and exact posteromedian placement of the IOPI on the dorsum of the tongue, as anteromedian lingual pressures have been shown to be significantly higher than posteromedian pressures (Gingrich et al., 2012; Kays et al., 2010). Anteromedian placement was defined as placing the bulb on the center of the most anterior portion of the tip of the tongue. Posteromedian placement was defined as placing the bottom edge of the bulb parallel to the anterior edge of the back molars (Gingrich et al., 2012). In each position, three trials were obtained with an average 30-second rest between trials. All trials were encouraged, meaning the investigator provided verbal coaching in order to ensure maximal effort. Subjects were allowed to see the numbers displayed on the IOPI as added encouragement to beat their previous trial.

In a study observing lingual strength with the IOPI, Clark et al. (2003, p. 49) found that

> "with respect to whether $P_{maximum}$ [the single highest value of all the trials] or $P_{average}$ [the average of all the trials] provides the better operational definition of tongue strength, our study indicates that both measures relate similarly to subjective measures of tongue strength and oral-phase swallowing function."

In accordance with Clark's study and other extant literature, the present study recorded the single highest pressure generated across three motivated trials, rather than the average, as the maximal lingual strength for each position (anteromedian and posteromedian). Unfortunately, due to limitations within a working clinic, the anteromedian lingual measures were collected for only 2 of the 5 subjects and the PI.

Pharyngeal Residue

For the FEES procedure, a single clinician (a speech pathologist at Boston Medical Center) sprayed no more than 0.1 cc of Lidocaine and 0.2 cc of Neo-synephrine into both nasal passages. This is the approved amount for this procedure by the Boston

University Pharmacy and Safety Committee. All FEES procedures were performed using a KayPentax Digital Laryngoscope that was attached to a Kay Swallow Workstation, which displayed the video recording and manometric waveforms. Subjects sat in a comfortable chair in an upright position. After the Lidocaine and Neo-synephrine had time to take effect (approximately 5 minutes), the endoscope was lubricated and then inserted transnasally to the pharynx to observe the pharynx and larynx during deglutition. Subjects were allowed to adapt to the endoscope before the trials began. The subjects were given food and liquid that were dyed green to assist in visualization. One trial of each of the following boluses was attempted:

- 5 cc puree (apple sauce)
- 5 cc fruit cocktail (approximately 3 pieces of canned fruit)
- ¼ of a Saltine cracker (original cracker size: 2 inches by 2 inches)

Between each bolus, subjects were asked to clear any residue with an effortful swallow, expectoration, or a liquid wash, depending on their ability. All exams were reviewed and scored for residue and swallowing ability by the Principal Investigator using the Boston Residue and Clearance Scale (BRACS; Kaneoka et al., 2013).

Pharyngeal Pressures

The manometric data of pharyngeal pressures were collected on the Kay Swallowing Workstation and began after the swallow exam was completed; the endoscope was held in place while the manometer was inserted transnasally through the subjects' other nostril, through the pharynx, and through the upper esophageal sphincter (UES). The placement of the manometer was visualized on video by the endoscope and confirmed by visualizing the pressure waveforms on the KayPentax computer display.

The optimal placement of the three sensors was (1) in the oropharynx directly posterior to the BOT, (2) in the hypopharynx, and (3) in the UES. The proper placement was confirmed by noting the high resting pressures of the tonically-contracted UES. Before the swallow trials began, the catheter was raised one additional centimeter so the UES relaxation could be measured at the height of the swallow when the larynx was elevated (Butler, n.d.). The subject was then asked to perform a comfortable, normal swallow at least three times (using only saliva), with a rest period between each swallow. In some cases, if the subject complained of a dry mouth, a small sip of water was given to facilitate a natural swallow. Due to equipment malfunctioning, manometric data was only collected for 2 subjects and the PI.

For data analyses, the swallowing pressures of every swallow were examined and averaged over the number of trials in the following ways:

- Oropharyngeal pressure (mmHg)
- Hypopharyngeal pressure (mmHg)
- UES at rest (tonic-contraction pressure) (mmHg)
- UES (1^{st} and 2^{nd} peak of M-wave) (mmHg)
- UES relaxation pressure (mmHg)
- UES relaxation duration (seconds)
- Oropharyngeal peak to hypopharyngeal peak duration (seconds)
- Onset of UES relaxation to oropharyngeal peak contraction (seconds)

Exercise Regimen

After teaching the subjects the tongue-hold maneuver using the same instructions outlined in Fujiu and Logemann (1996), the maximum number of swallows until extreme fatigue while using the tongue-hold maneuver were counted. Extreme fatigue was defined as the subjects reporting that they could not perform just one more swallow with the tongue-hold maneuver. Finding the maximum number of swallows allowed for the calculation of 80% of this number, which was the prescribed number of repetitions. This follows the theory that over-training at maximal loads (100% of maximum repetitions) may result in over-use injuries (Burkhead et al., 2007). Therefore, there is a fine line between not enough effort and too much effort. Setting the number of repetitions to 80% of the maximal number until extreme fatigue was this study's attempt to optimize the exercise regimen. If the subject's maximal number was 10 or below, 80% was not calculated in effort to ensure adequate exercise. Table 2 demonstrates each subjects' repetitions during the 6 weeks.

Table 2. Prescribed number of repetitions based on maximal number until fatigue.
∞If the subject's maximal number was 10 or below, 80% was not calculated in effort to ensure adequate exercise.
★At 3 weeks, S3, S4, and S5 were not able to meet so the number of repetitions was adjusted over the phone based on subject-reported levels of fatigue. At weeks 4 and 5, repetitions were increased based on subject-reported levels of fatigue.
*The Principal Investigator did not have dysphagia but performed the exercise as an investigatory opportunity.

Subject	**Baseline Maximal repetitions until fatigue**	**Baseline 80% of maximal repetitions**	**At 3 weeks★**	**At 6 weeks★**
S1	13	11	11 (max 14)	11
S2	13	11	12 (max 15)	12
S3	30	24	24	non-compliant
S4	7	NA∞	8	10
S5	10	NA∞	15	20
PI*	20	16	30	42

Each subject received an exercise regimen to follow 3 times a day, 5 days per week for 6 weeks. The number of repetitions was defined as 80% of the maximum number (for example if 10 swallows with the tongue-hold maneuver was the maximum, then 8 would be the number of swallows executed for each set. Each set was performed 3 times a day). Each week, the Principal Investigator called the subjects to encourage compliance. Subjects marked their completion of the exercise on a daily log sheet indicating the number of repetitions and sessions per day. At the 3-week halfway mark, subjects were asked to return for a re-assessment of their swallowing strength to maintain a regimen at 80% of their potentially-increasing strength. However, 3 subjects did not attend the half-way appointment. In this case, although not optimal, phone conferences were held to encourage the subject to increase the number of repetitions by a few to ensure consistent fatigue of the muscles.

At 6 weeks, all baseline measures were repeated. Due to logistics, some subjects were unable to return at exactly 6 weeks and therefore continued the exercise until they were able to visit the clinic (at most 8 weeks from baseline).

Results

Statistical Analysis

With such a small, heterogeneous sample size, typical tests used for detecting significant change are not warranted. The test that best fits the repeated-measures data from the present study is a sign test because the data set is small and nonparametric (thus excluding the t-test) and asymmetric (thus excluding the Wilcoxon signed-rank test). However, because published, scientific papers and extant literature in the field of speech pathology have used such typical tests when no others have fit, the data from the present study will also be analyzed in a similar fashion. Moreover, a comprehensive evaluation of the data is warranted seeing as non-parametric statistical tests may over-compensate and produce false-negatives (a Type II error). A nominal *p* value of 0.05 was regarded as statistically significant.

Subject perception of swallowing

Baseline and post-baseline scores from the DHI are reported in Table 3 (see Appendix). The group mean of the **subscale totals** increased (from a group sum of 42.0 ±25.8 to 44.4 ±27.5). Three of the 5 subjects indicated a perceived worsening in swallowing. Yet for 2 of the subjects, their subscale scores decreased, indicating a perceived improvement in swallowing.

The overall **self-reported severity** level of dysphagia (on a scale of 1–7) increased by 2 points to a more severe rank for 2 of the subjects, improved by 2 points for one subject, and remained the same for 2 others. The group mean stayed the same (5.2 ±2.2 to 5.2 ±1.5).

Lingual Pressures

Subjects' posteromedian lingual pressures are reported below in Table 4. (Anteromedian pressures are listed in Table 5 the Appendix because no reasonable conclusions could be made on such a limited set of data.) Due to the lack of consistent data from the 3-week check-in, no analyses were performed comparing the limited 3-week data to other time points.

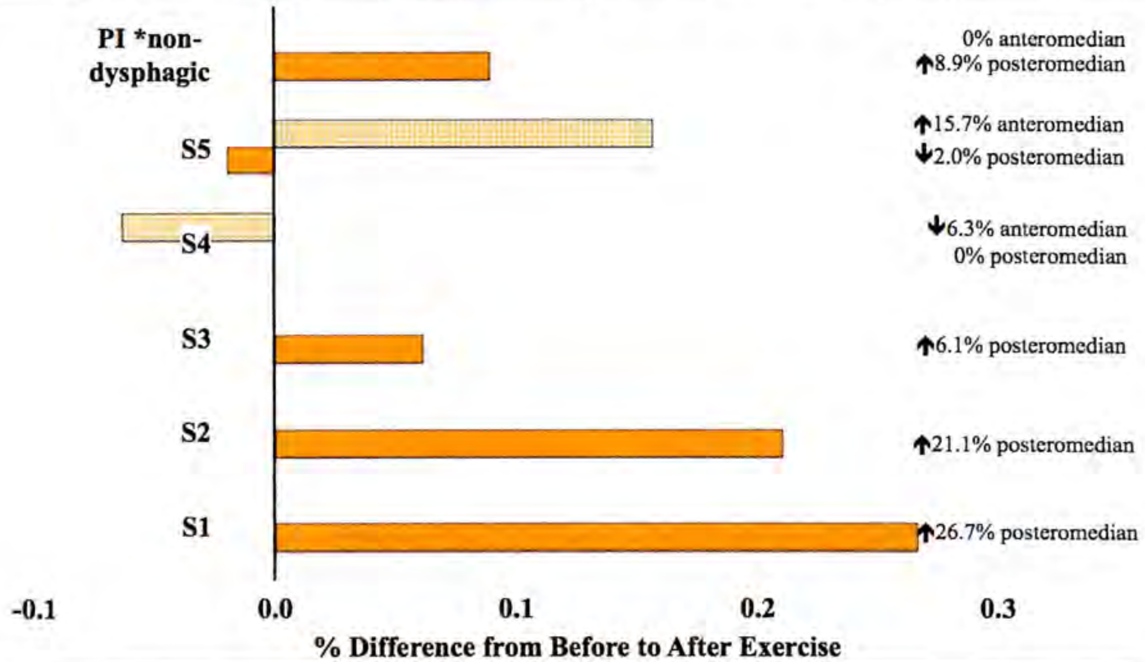
Table 4. Subjects' maximal posteromedian lingual pressures, as measured by the IOPI and reported in kilopascals (kPa). Dashes represent data that was not obtained (due to subjects missing the session, broken equipment, and time constraints in a working clinic).

Maximal POSTEROMEDIAN pressures (kPa)	Baseline	3 weeks	6 weeks	% difference Baseline to 6 weeks
S1	45	58	57	↑ 26.7%
S2	38	46	46	↑ 21.1%
S3	49	-	52	↑ 6.1%
S4	78	-	78	no change
S5	51	-	50	↓ 2.0%
Group Average ±SD	***52.2 ±15.3***	***52.0 ±8.5***	***56.6 ±12.6***	↑ ***8.4%***
*PI *non-dysphagic*	*56*	*59*	*61*	↑ *8.9%*

The changes in the posteromedian position from baseline to 6 weeks were not found to be significant by a sign test (M=1, p=0.63), Wilcoxon signed-rank test (Z=1.46, p=0.14), or t-test (t=1.79, p=0.15). The null hypothesis is not rejected due to an insignificant median difference at the 0.05 level.

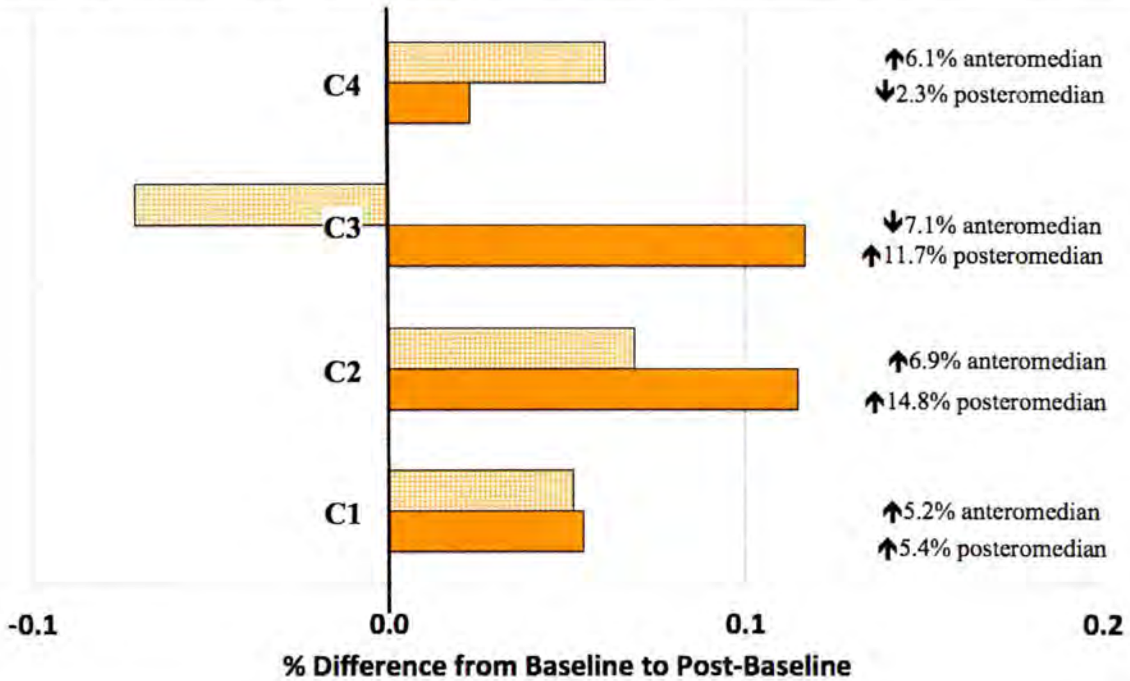
Figure 1 demonstrates the increase in posteromedian pressures for 4 out of the 6 subjects.

Figure 1. Percent difference between the before- and after-exercise pressures of the subjects' maximal anteromedian (plaid) and posteromedian (orange) lingual pressures, as measured by the IOPI. Anteromedian pressures were obtained for only 2 subjects (S5 and S4) and the PI. Posteromedian pressures were obtained for all 5 subjects and the PI. The PI performed the tongue-hold exercise as described in the protocol and underwent the same observations as other subjects even though she does not have dysphagia.



The control group's maximal lingual pressures are listed in the Appendix (Table 6). The pre- and post-baseline measures for the controls in the posteromedian position were not found to be significant by a sign test (M=1, p=0.63), Wilcoxon signed-rank test (Z=4, p=0.25), or t-test (t=2.27, p=0.11). Even though the controls did not perform any exercise, 3 of the 4 controls showed an increase in both anteromedian and posteromedian pressures, as shown in Figure 2 below, suggestive of a learning effect.

Figure 2. Percent difference between baseline and 6 weeks of the controls' maximal anteromedian (plaid) and posteromedian (orange) lingual pressures, as measured by the IOPI. The controls did not perform any oral exercise.



Pharyngeal Residue

There was no statistically significant difference in the FEES scores. The data are listed in Table 7, below.

Table 7. Subjects' total scores on the *Boston Residue and Clearance Scale* (BRACS). The bolus sizes were 5 cc puree, 5 cc fruit cocktail, and ¼ cracker. Dashes represent data that were not obtained (due to diet restrictions and concern for aspiration).

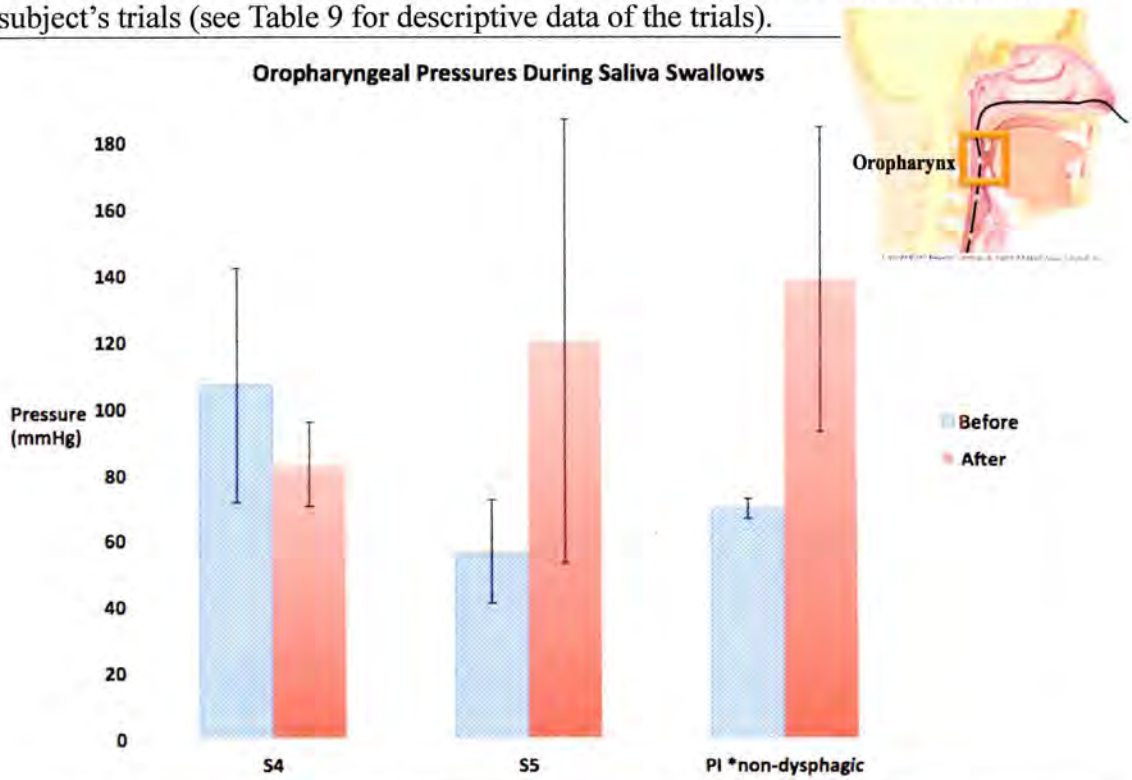
	S1		S2		S3		S4		S5	
	Before	After	Before	After	Before	After	Before	After	Before	After
Puree	9	9	5	6	6	6	2	3	11	8
Fruit Cocktail	-	-	5	5	-	6	4	0	-	7
Cracker	-	-	7	4	3	6	8	4	-	-

When analyzed descriptively, there was very little change in the puree bolus' residue. However, one subject (S4) improved with the fruit cocktail (from 4 to 0) and 2 out of 3 subjects improved with the cracker bolus (S2 and S4). The amount and location of residue changed, as well as one subject's ability to clear the residue. An example of one subject's BRACS ratings before and after 6 weeks of exercise is listed in the Appendix (Table 8).

Pharyngeal Pressures

Two subjects and the PI were assessed with the manometer (see Table 9 in the Appendix). Due to equipment problems at the time of their visit, the other 3 subjects were unable to undergo manometry. In this case, no statistical analyses were performed due to the presence of only 2 subjects' data. Certain trends are noted, however, seen in Figure 3 below.

Figure 3. The average oropharyngeal pressures of saliva swallows from 2 subjects and the PI before exercise and after exercise. Error bars represent ±1 standard deviation of each subject's trials (see Table 9 for descriptive data of the trials).



Discussion

The purpose of this study was to investigate the effectiveness of the tongue-hold maneuver as a long-term exercise in strengthening a weak swallow. The study attempted to answer the clinically-pertinent questions "Is the tongue-hold maneuver beneficial?" and "What muscle groups are strengthened by this exercise?" This is the first study, as of this writing, to determine the efficacy of the tongue-hold maneuver across multiple sessions in subjects with dysphagia. Five subjects with dysphagia and 1 healthy subject reported performing at least 6 weeks of the tongue-hold maneuver as an exercise 3 times a day, 5 days per week. This study observed 4 outcome measures.

Subject perception of swallowing

No overt trends in the subject-reported outcomes on the swallowing scale were noted: approximately half reported improvement, half reported worsening. It is possible that the subjects became more cognizant of their swallowing, due to enrolling in this study and performing the exercises, and thus more aware of their swallowing abilities, be it negative or positive.

Lingual Pressures

In general, the exercise group showed increases in lingual pressures (albeit non-significant), but not much greater than the expected variability (Adams et al., 2013). Notable are two recent studies by Adams et al. (2013), who looked at the test-retest reliability of the IOPI. These researchers found a large learning effect between the first two sessions for frail elderly and a small learning effect in healthy adults. Nonetheless, although the within-subject variation from the 51 healthy subjects and 30 frail elderly subjects was higher than desirable, intra-class correlations, also known as within group comparisons, were reliable, especially if familiarization was provided. The implications of Adams et al.'s study are of great importance to the present study's results. Seeing as they found individualized variance suggestive of a learning effect while using the IOPI, the present data must take into account the expected variance.

Measurements were taken from two different positions on the tongue: the anteromedian area near the tip and the posteromedian area on the dorsum. In theory, the anterior portion of the tongue is not involved in the tongue-hold maneuver. It is not contracted or fatigued. Thus, measurements of tongue tip strength should be similar in both pre- and post-baseline testing. The results do not confirm this expectation; in the anteromedian position, the exercise group increased an average of 2.3% and the control group increased an average of 3.8% (percent change in group mean). The change demonstrates the expected variability when measuring tongue strength with the IOPI. In comparison, Adams et al. (2013) used the IOPI for repeated measures. They found an increase of 11.5% in the group mean in the anteromedian position for frail elderly and 1.7% increase in healthy adults not performing any exercise. Therefore, the anteromedian values demonstrate the variability of the IOPI results. Another important factor, seeing as all but one of the controls scored higher values on their second trial, is a learning effect. Adams et al. (2013) confirmed this effect in weeks 1 to 2 as opposed to weeks 3 and 4.

The posteromedian position of the tongue, on the other hand, may be active during a tongue-hold maneuver as it works to retract against restriction. The exercise group increased an average of 8.4% in the posteromedian values after 6 weeks. However, the control group also increased an average of 6.3% after 6 weeks of no exercise. In healthy adults, an average of 2.5% change is expected as a learning effect (Adams et al., 2013). It is unclear why the control group would increase so much. Clearly, the IOPI has a learning effect and this should be considered when using it as a tool to measure lingual strength. In the same vein, placement is crucial. The IOPI placement could have been variable within subjects, depending on the precision of bulb placement for each trial. The data here suggest that although the subjects only increased slightly more than the control group, the tongue-hold maneuver did, on average, strengthen the dorsum of the tongue in the exercise group.

Pharyngeal Residue

Regarding pharyngeal residue, a broad glance at the lack of statistical significance and lack of improvement on total scores does not adequately represent very real changes that may have occurred. Therefore, a closer look at the specific changes in residue is warranted. Interestingly, residue on the BOT and in the valleculae was generally reduced after 6 weeks of the exercise. This is precisely the goal of the exercise: to increase the strength of the BOT contacting the posterior PW. Due to restricted diets, only 3 subjects attempted the cracker bolus in baseline and post-baseline measures (Table 10). Even so, after 6 weeks of exercise, all 3 subjects showed improvements in the BOT residue for the cracker bolus. One subject (S4) improved, specifically in the BOT location, on **all** bolus consistencies (*not shown in Table 10*, puree [2→1], fruit cocktail [4→0], and cracker [3→2]). It is possible that the exercise strengthened this subject's swallow and therefore decreased residue on the BOT. This result is promising and suggests that a larger sample size may have yielded significant improvement.

Table 10. BRACS scores for ¼ cracker before and after exercise for 3 of the 5 dysphagic subjects. The two other subjects did not receive this bolus due to concerns for swallow safety. The base of tongue (BOT) and valleculae scores are highlighted as well as the effectiveness of the spontaneous clearing swallows. The residue scale is as follows: 0=no coat, 1=mild residue (<⅓), 2=moderate residue (⅓ – ⅔), 3=severe residue (>⅔) CNV=could not visualize

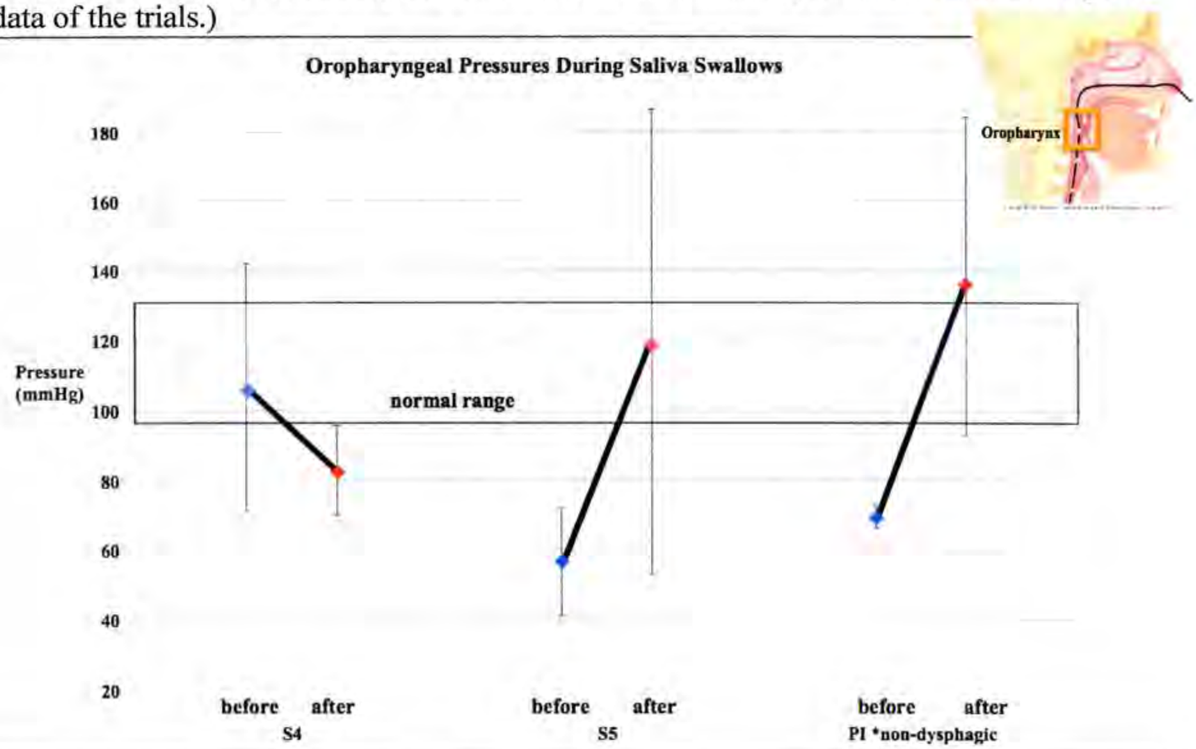
	S2		S3		S4	
1/4 CRACKER	Before	After	Before	After	Before	After
Lateral pharyngeal walls, PPW	1	0	0	0	0	0
BOT, valleculae, tip of epiglottis	3	2	3	2	3	2
Lateral channels	1	0	0	0	0	0
Piriform recess	1	2	0	0	0	0
Post-cricoid region	0	1	0	1	0	0
Rim of AE fold, rim of epiglottis	0	0	0	0	0	0
Arytenoids (outside)	0	0	0	0	0	0
Arytenoids (inside)	0	0	0	0	0	CNV
Laryngeal suface of epiglottis	0	0	0	0	0	CNV
Laryngeal surface of AE folds, FVF	0	0	0	0	0	CNV
Anterior commisure, TVF body, posterior commisure	0	0	0	0	0	CNV
WORST SCORE:	3	2	3	2	3	2
Residue in vestibule at any time? 0- No 1- Yes - a little 2- Yes - a lot	0	0	0	0	0	0
Spontaneous clearing swallows? 0- Yes or NA 1- No	0	0	0	0	1	0
Did spontaneous swallows eliminate residue? 0- Very effective 2 - Partially effective 4- not effective	4	2	0	4	4	2
TOTAL SCORE:	7	4	3	6	8	4

Two subjects demonstrated better clearance. One subject, S3, did not show better clearance. In fact, his clearing swallows worsened to a score of 4, 'not effective.' A note must be made here about compliance. Although all efforts were made to ensure compliance (phone calls, exercise logs, check-in appointments), compliance could not be confidently verified. The one subject, S3, who showed a worsening in clearing swallows, was one who consistently reported not complying with the exercises. Remembering to find time to perform exercises is a frequent complaint and compliance issue reported by subjects performing exercises for dysphagia (Easterling et al., 2005). Therefore, while certain changes can be expected to result from normal variability in measurement, a worsening or lack of change in the swallow may occur when a subject does not comply with the program. Unfortunately this variable is difficult to account for and measure.

Pharyngeal Pressures

The pharyngeal pressures suggest that 1 out of 2 measured subjects and the PI strengthened their oropharyngeal pressures on saliva swallows. Unfortunately, the data are variable and manometry was performed on only 2 of the 5 subjects and the PI due to equipment problems. Most concerning is the variability of the manometer pressures, which have the potential to be drastically different with just a few millimeters' difference in placement. With this in mind, 2 of the 3 subjects demonstrated higher oropharyngeal pressures on normal swallows after 6 weeks of exercise. As demonstrated in Figure 4 below, after 6 weeks of the tongue-hold maneuver, two of the subjects pressures moved into the expected range (97–133 mmHg) for oropharyngeal pressures during a saliva swallow (Doeltgen et al., 2009; Doeltgen et al., 2011).

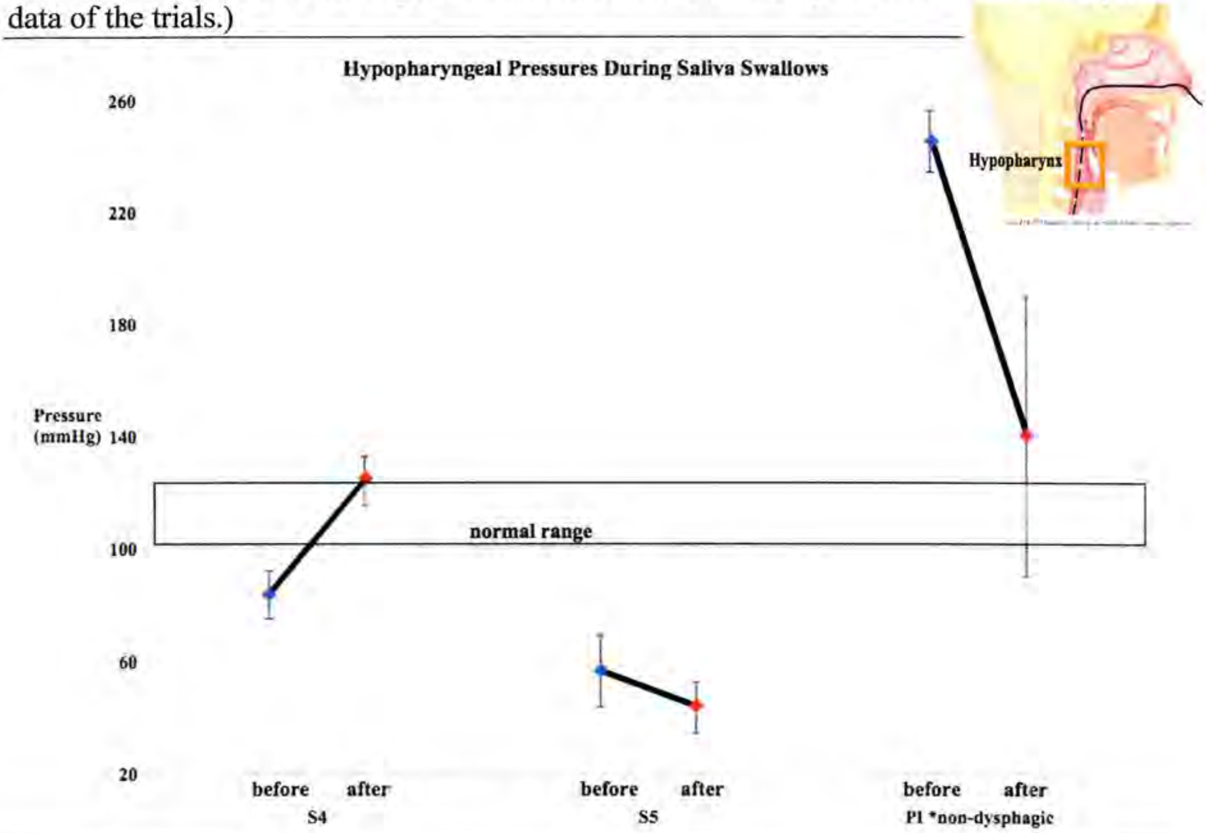
Figure 4. Oropharyngeal pressures during saliva swallows before exercise and after exercise. The shaded box represents the expected oropharyngeal pressures based on normative data (Doeltgen et al., 2009; Doeltgen et al., 2011). Error bars represent ±1 standard deviation of each subject's data across several trials. (See Table 9 for descriptive data of the trials.)



Increased pharyngeal pressure is indicative of a more functional swallow, one that can advance and clear difficult boluses more easily. It is unclear why subject S4 demonstrated a decrease in pressures in this area. The first consideration must be the placement of the manometer, as even a few millimeters can negatively influence pressure readings. Another variable to consider is S4's diagnosis of supraglottic cancer. The radiation he has received to this area could influence the muscle fibers' overall functioning and receptiveness to strengthening. Also unclear is why the PI, a healthy young adult, demonstrated such low pressures at baseline. These considerations raise concerning issues about the reliability of the instrumentation. Although every attempt was made to control confounding variables, some data do not make sense. Certain variables remain, such as precise placement of the manometer and consistent calibration of the instrument. It is possible that the validity of the certain measures is not reliable. Therefore, a more valid take-away message from the present study might be that the instrumentation used is still too unreliable for clinical use unless more precautions are put in place.

S5 and the PI demonstrated lower hypopharyngeal pressures (Figure 5). It is unclear why the hypopharyngeal pressures would decrease; logical hypotheses point to unreliable instrumental variability.

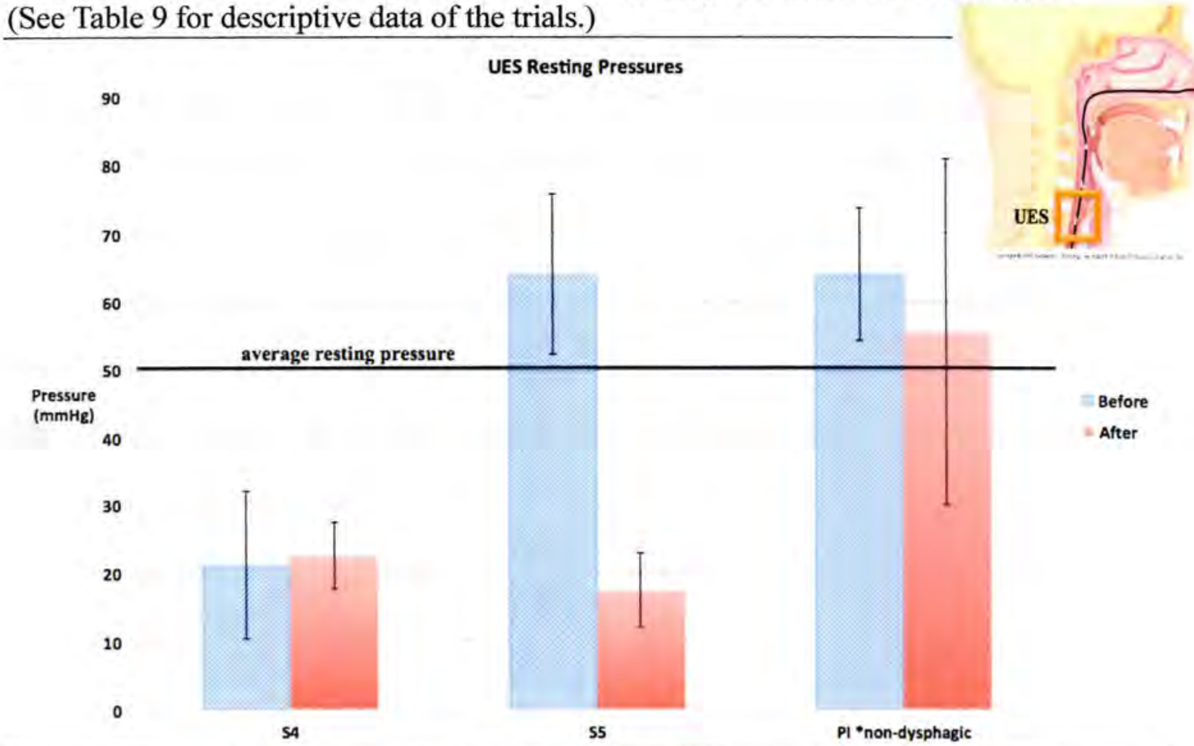
Figure 5. Hypopharyngeal pressures during saliva swallows before exercise and after exercise. The shaded box represents the expected hypopharyngeal pressures based on normative data (Doeltgen et al., 2009; Doeltgen et al., 2011). Error bars represent ±1 standard deviation of each subject's data across several trials. (See Table 9 for descriptive data of the trials.)



The direction and degree of change of pharyngeal pressures could be affected by age, gender, the amount of protrusion of the tongue, number of repetitions, and anatomical differences. Instrumental variability is also a considerable factor. Further investigation is required.

Also worth investigating is the tongue-hold maneuver's effect on UES functioning. Previous studies have investigated the effects of exercise on the UES and found that the Shaker and Mendelsohn increase the magnitude and duration of the UES opening (Shaker et al., 2002). What are the effects of 6 weeks of the tongue-hold maneuver on the UES? The present study found an interesting decrease in the UES resting pressure for S5 (see Figure 6).

Figure 6. UES resting pressures of 3 subjects before (blue) and after (red) exercise. The black line indicates the average resting pressure of adults (50 mmHg) (Cook et al., 1987). Error bars represent ±1 standard deviation of each subject's data over several trials. (See Table 9 for descriptive data of the trials.)



Notably, S5 had an extremely tight UES that underwent dilation many months before enrolling in the study. Six weeks of the tongue-hold maneuver reduced her UES resting pressure from 63 to 17 mmHg. If the exercise did, indeed, play a role in her UES function, this suggests that repetitive and altered hyolaryngeal movement patterns from the tongue-hold maneuver may indirectly reduce resting pressures of the UES. This finding is worthy of future investigation.

Limitations and Future Studies

A large limitation of this study was the heterogeneous sample size. Future studies should strive to include a large group of homogeneous subjects and thus limit the external variables that come from such a small population of different subjects. Similarly, patients with different dysphagia etiologies may have different strengthening potential and should be studied as separate treatment groups. Stroke subjects may strengthen differently than head and neck subjects. Based on the literature (Robbins et al., 2007) and after more research is done to investigate the potential shown by the present study, the tongue-hold maneuver may be a valuable alternative for lingual strengthening as dysphagia rehabilitation in the stroke population.

The placement and recordings of the instrumentation are important variables to consider. The IOPI placement could have been variable within subjects, depending on the precise placement of the bulb for each trial. More concerning is the manometer, which has the potential to read drastically different pressures with just a few millimeters' difference in placement. Although all efforts were made to ensure consistency in these measures, human error is likely. Future studies should ensure all efforts are made to eliminate these variables. Simple changes, such as taping the manometer to the face to prevent movement, would have provided better consistency. Additionally, future studies would benefit from adding several raters of residue rather than just one.

Interesting, unexpected results from this study were the changes in tongue pressures. The tongue-hold maneuver has long been claimed to strengthen the posterior PW. The results suggest that further investigation is warranted regarding the relationship between the tongue-hold maneuver and lingual strength. On the other hand, the results also warrant further investigation of the reliability of the IOPI. Further, unpredicted changes occurred for some subjects in oropharyngeal pressures versus hypopharyngeal pressures. Functional MRIs or electromyography may allow for more precise and consistent measurements of the muscles affected by this exercise.

Compliance is usually an issue for any rehabilitation program, and the tongue-hold maneuver was not an exception. Aside from the compliance of the PI, absolute completion of the exercises as prescribed cannot be guaranteed and, thus, the outcomes may or may not be effects of the maneuver. An interesting extension of this study would be one that adds the 7-step program outlined in Easterling et al.'s study (2009), which helped older adults initiate and adhere to a regular exercise program.

Finally, the dosage of the exercise is based on previous limb literature. The field would benefit from future studies comparing the doses of exercises (number of repetitions, number of times per week, and number of weeks). Such information would be extremely valuable for clinicians working with dysphagia rehabilitation.

Conclusion

The purpose of this study was to investigate the effectiveness of the tongue-hold maneuver as an exercise in strengthening a weak swallow. An extremely small sample size hinders generalization of the results. However, interesting outcomes are noted. One, the IOPI has a learning effect that may be responsible for the observed increase in pressures over the first 2 sessions (Adams et al., 2013). Despite this variability, the subjects who performed the tongue-hold maneuver as an exercise increased their tongue strength slightly more than the control group in the posteriomedian position. Thus, the tongue-hold maneuver may improve lingual strength. Two, the results of the change in residue indicate that after 6 weeks of the tongue-hold maneuver, subjects showed less residue in the valleculae with a cracker bolus. Three, the pharyngeal pressures suggest that some subjects strengthened their oropharyngeal pressures on saliva swallows, although the instrumental variability is called into question. Finally, the results from the current study suggest that there may be a relationship between the tongue-hold maneuver and UES resting pressures. The abovementioned changes were slight and not enough to improve the quality of life reports from most subjects.

This study's findings contribute to the clinical practice of rehabilitating a weak swallow. This investigation elaborates on the tongue-hold maneuver as an exercise and provides preliminary support for its use, with caution. Specifically, clinicians should be sure to prescribe regimens that fatigue the muscles and push them past normal use. When using the IOPI as a tool, clinicians should also keep in mind a learning effect occurs over the first few trials. This pilot study suggests that clinicians should continue to prescribe the tongue-hold maneuver as an exercise with caution, as some patients may benefit from it while others may not.

Appendix

Table 3. Subjects' Dysphagia Handicap Index scores

	Subscale Totals: Before	Subscale Totals: After	Subscale Totals: Point Difference	Subscale Totals: Outcome	Self-Reported Severity: Before	Self-Reported Severity: After	Self-Reported Severity: Point Difference	Self-Reported Severity: Outcome
S1	16*	8*	−8	*better*	7	5	−2	*better*
S2	46	50	+4	*worse*	4	5	+1	*worse*
S3	20	34	+14	*worse*	2	3	+1	*worse*
S4	80	84	+4	*worse*	7	7	0	*same*
S5	48❖	46	−2	*better*	6	6	0	*same*
Average ±SD	**42.0 ±25.8**	**44.4 ±27.5**			**5.2 ±2.2**	**5.2 ±1.5**		

*Only 4 items were answered (the same 4 items pre- and post-baseline)
❖3 items were skipped, so the same 3 items were omitted from the After total

Table 5. Subjects' maximal anteromedian lingual pressures, as measured by the IOPI and reported in kilopascals (kPa). Dashes represent data that was not obtained (due to subjects missing the session, broken equipment, and time constraints in a working clinic).

Maximal ANTEROMEDIAN pressures (kPa)

	Baseline	3 weeks	6 weeks	**% difference Baseline to 6 weeks**
S1	-	-	-	-
S2	-	-	-	-
S3	-	-	-	-
S4	63	-	59	↓ 6.3%
S5	51	-	59	↑ 15.7%
Group Average ±SD	***57.0 ±8.5***	-	***59.0 ±25.8***	**↑ *3.5%***
*PI *non-dysphagic*	*58*	*58*	*58*	*no change*

Table 6. The control group's anteromedian and posteromedian maximal lingual pressures recorded as the highest generated pressure from three motivated trials on the IOPI.

Maximal ANTEROMEDIAN pressures (kPa)

	Baseline	3 weeks	6 weeks	**% difference Baseline to 6 weeks**
C1	58	62	61	↑ 5.2%
C2	58	62	62	↑ 6.9%
C3	42	47	39	↓ 7.1%
C4	82	90	87	↑ 6.1%
Group Average ±SD	***60.0 ±16.5***	***65.3 ±17.9***	***62.3 ±19.6***	↑ ***3.4%***

Maximal POSTEROMEDIAN pressures (kPa)

	Baseline	3 weeks	6 weeks	**% difference Baseline to 6 weeks**
C1	55	60	58	↑ 5.5%
C2	54	60	62	↑ 14.8%
C3	60	63	67	↑ 11.7%
C4	87	90	85	↓ 2.3%
Group Average ±SD	***64.0 ±15.5***	***68.3 ±14.6***	***68.0 ±11.9***	↑ ***6.3%***

Table 8. An example of Subject 4's BRACS rating for ¼ cracker ***before*** 6 weeks of exercise. (Continued…)

BEFORE:

1/4 cracker	**None**	**Coat**	**Mild**	**Moderate**	**Severe**
Lateral pharyngeal walls, PPW	0				
BOT, valleculae, tip of epiglottis					3
Lateral channels	0				
Piriform recess	0				
Post-cricoid region	0				
Rim of AE fold, rim of epiglottis	0				
Arytenoids (outside)	0				
Arytenoids (inside)	0				
Laryngeal suface of epiglottis	0				
Laryngeal surface of AE folds, FVF	0				
Anterior commisure, TVF body, posterior commisure	0				
WORST:					**3**
Residue in vestibule at any time?					**0**
0- No					
1- Yes - a little					
2- Yes - a lot					
Spontaneous clearing swallows?					**1**
0- Yes or NA					
1- No					
Did spontaneous swallows eliminate residue?					**4**
0- Very effective				(liquid wash effective)	
2 - Partially effective					
4- not effective					
TOTAL SCORE:					**8**

Table 8. (…Continued) An example of Subject 4's BRACS rating for ¼ cracker ***after*** 6 weeks of exercise. CNV=could not visualize

AFTER:

1/4 cracker	None Coat	Mild	Moderate	Severe
Lateral pharyngeal walls, PPW	0			
BOT, valleculae, tip of epiglottis			2	
Lateral channels	0			
Piriform recess	0			
Post-cricoid region	0			
Rim of AE fold, rim of epiglottis	0			
Arytenoids (outside)	0			
Arytenoids (inside)	CNV			
Laryngeal suface of epiglottis	CNV			
Laryngeal surface of AE folds, FVF	CNV			
Anterior commisure, TVF body, posterior commisure	CNV			
WORST:			**2**	
Residue in vestibule at any time?			**0**	
0- No				
1- Yes - a little				
2- Yes - a lot				
Spontaneous clearing swallows?			**0**	
0- Yes or NA				
1- No				
Did spontaneous swallows eliminate residue?			**2**	
0- Very effective	(dry swallow partially effective)			
2 - Partially effective				
4- not effective				
TOTAL SCORE:			**4**	
***CNV=Could not visualize**				

Table 9. Descriptive statistics for the 2 subjects and PI who had their swallowing pressures measured with a manometer before and after exercise. AVG=average SD=standard deviation

BEFORE

		Normal Saliva Swallows					
		S4		S5		PI	
		AVG of 5	SD	AVG of 4	SD	AVG of 6	SD
Oropharynx	**(mmHg)**	**106.65**	35.38	**56.39**	15.60	**69.36**	3.02
Hypopharynx	**(mmHg)**	**83.16**	8.57	**56.15**	12.75	**244.91**	10.98
UES at rest avg	**(mmHg)**	**21.08**	10.78	**63.92**	11.75	**63.92**	9.80
UES (1st peak of M-wave)	**(mmHg)**	**32.19**	18.38	**38.90**	8.16	**25.36**	4.80
(2nd peak of M-wave)	**(mmHg)**	**214.40**	29.61	**35.85**	8.02	**141.80**	27.41
UES relaxation pressure	**(mmHg)**	**-12.23**	2.06	**33.31**	9.18	**5.29**	4.99
UES relaxation duration	**(s)**	**0.68**	0.09	**0.21**	0.13	**0.59**	0.11
Oro peak to Hypo peak duration	**(s)**	**0.07**	0.01	**0.08**	0.10	**0.06**	0.04
Onset of UES relaxation to Oro peak	**(s)**	**0.23**	0.05	**0.09**	0.12	**0.21**	0.08

AFTER

		Normal Saliva Swallows					
		S4		S5		PI	
		AVG of 3	SD	AVG of 5	SD	AVG of 4	SD
Oropharynx	**(mmHg)**	**82.72**	12.77	**119.72**	66.85	**138.47**	45.72
Hypopharynx	**(mmHg)**	**123.70**	8.95	**43.20**	9.14	**139.63**	50.02
UES at rest avg	**(mmHg)**	**22.47**	4.87	**17.39**	5.46	**55.44**	25.55
UES (1st peak of M-wave)	**(mmHg)**	**12.12**	9.67	**38.01**	11.92	**39.46**	5.89
(2nd peak of M-wave)	**(mmHg)**	**135.81**	9.74	**35.19**	13.47	**157.09**	23.06
UES relaxation pressure	**(mmHg)**	**-15.83**	4.23	**32.48**	11.48	**-0.02**	2.26
UES relaxation duration	**(s)**	**1.04**	0.04	**0.21**	0.22	**0.72**	0.02
Oro peak to Hypo peak duration	**(s)**	**0.16**	0.06	**0.16**	0.25	**0.19**	0.06
Onset of UES relaxation to Oro peak	**(s)**	**0.29**	0.06	**-0.08**	0.12	**0.29**	0.05

References

Adams, V., Mathisen, B., Baines, S., Lazarus, C., & Callister, R. (2013, March). *Reliability of measurements of strength and endurance using the Iowa Oral Performance Instrument with frail elderly adults in an aged care facility*. Paper presented at the annual convention of the Dysphagia Research Society, Seattle, Washington.

Adams, V., Mathisen, B., Baines, S., Lazarus, C., & Callister, R. (2013, March). *Reliability of measurements of strength and endurance using the Iowa Oral Performance Instrument with healthy adults*. Paper presented at the annual convention of the Dysphagia Research Society, Seattle, Washington.

Aviv, J.E., Kaplan, S.T., Thomson, J.E., Spitzer, J., Diamond, B., Close, L.G. (2000). The safety of flexible endoscopic evaluation of swallowing with sensory testing (FEESST): an analysis of 500 consecutive evaluations. *Dysphagia, 15*(1), 39–44.

Aviv, J.E., Murry, T., Zschommler, A., Cohen, M., & Gartner, C. (2005). Flexible endoscopic evaluation of swallowing with sensory testing: Subject characteristics and analysis of safety in 1,340 consecutive examinations. *Annals of Otology, Rhinology, and Laryngology, 114*, 173–176.

Burkhead, L.M., Sapienza, C.M., & Rosenbek, J.C. (2007). Strength-training exercise in dysphagia rehabilitation: Principals, procedures, and directions for future research. *Dysphagia*, 22, 251–265.

Butler, S.G. (n.d.). *The SLP's clinical use of pharyngeal and upper esophageal manometry*. Wake Forest University Baptist Medical Center, Center for Voice and Swallowing Disorders, Winston-Salem, North Carolina.

Clark, H. (2003). Neuromuscular treatments for speech and swallowing: A tutorial. *American Journal of Speech-Language Pathology*, 12, 400–415.

Clark, H.M. (2012). Specificity of training in the lingual musculature. *Journal of Speech, Language, and Hearing, 55*, 657–667.

Clark, H.M., Henson, P.A., Barber, W.D., Stierwalt, J.A.G., & Sherrill, M. (2003). Relationships among subjective and objective measures of tongue strength and oral phase swallowing impairments. *American Journal of Speech-Language Pathology, 12*, 40–50.

Clark, H. M., O'Brien, K., Calleja, A., & Newcomb, S. (2009). Effects of directional exercise on lingual strength. Journal of Speech, Language, and Hearing Research, 52, 1034–1047.

Clark, H. M., & Shelton, N. (2011, March). *Specificity effects of tongue and straw exercise*. Poster presented at the annual meeting of the Dysphagia Research Society, San Antonio, Texas.

Cook, I.J., Dent, J., Shannon, S., & Collins, S.M. (1987). Measurement of upper esophageal sphincter pressure. Effect of acute emotional stress. *Gastroenterology, 93*(3), 526–532.

Doeltgen, S.H., Witte, U., Gumbley, F., & Huckabee, M. (2009). Evaluation of manometric measures during tongue-hold swallows. *American Journal of Speech-Language Pathology*, 18, 65–73.

Doeltgen, S.H., Macrae, P., & Huckabee, M. (2011). Pharyngeal pressure generation during tongue-hold swallows across age groups. *American Journal of Speech-Language Pathology*, 20, 124–130.

Folstein, M.F., Folstein, S.E., & McHugh, P.R. (1975). "Mini-mental state:" A practical method for grading the cognitive state of subjects for the clinician. *Journal of Psychiatric Research, 12*(3), 189–198.

Fujiu, M., Logemann, J. A., & Pauloski, B.R. (1995). Increased postoperative pharyngeal wall movement in subjects with anterior oral cancer: Preliminary findings and possible implications for treatment. *American Journal of Speech-Language Pathology, 4*(2), 24–30.

Fujiu, M., & Logemann, J.A. (1996). Effect of a tongue-holding maneuver on posterior pharyngeal wall movement during deglutition. *American Journal of Speech-Language Pathology, 45*(1), 23–30.

Gingrich, L.L., Stierwalt, J.A., Hageman, C.F., & LaPointe, L.L. (2012). Lingual propulsive pressures across consistencies generated by the anteromedian and posteromedian tongue by healthy young adults. *Journal of Speech, Language, and Hearing Research*, 55, 960–972.

Hammer, M., Jones, C., Mielens, J., Kim, C., & McCulloch, T. (2013, March). *Evaluating the tongue-hold maneuver using high-resolution manometry and electromyography*. Paper presented at the annual convention of the Dysphagia Research Society, Seattle, Washington.

Kahrilas, P.J., Logemann, J.A., Krugler, C., & Flanagan, E. (1991). Volitional augmentation of upper esophageal sphincter opening during swallowing. *American Journal of Physiology, 260*(3 pt. 1), G450–G456.

Kahrilas, P.J., Lin, S., Logemann, J.A., Ergun, G.A., & Facchini, F. (1993). Deglutitive tongue action: Volume accommodation and bolus production. *Gastroenterology, 103,* 128–136.

Kaneoka, A., Krisciunas, G., Field, K., Scheel, R., McNally, E., Walsh, M., O'Dea, M., Cabral, H., & Langmore, S. (2013, March). *The Boston Residue and Clearance Scale: Reliability Testing*. Paper presented at the annual convention of the Dysphagia Research Society, Seattle, Washington.

Kays, S.A., Hind, J.A., Gangnon, R.E., & Robbins, J. (2010). Effects of dining on tongue endurance and swallowing-related outcomes. *Journal of Speech, Language, and Hearing Research, 53*, 898–907.

Kelly, A.M., Leslie, P., Beale, T., Payten, C., & Drinnan, M.J. (2006). Fiberoptic endoscopic evaluation of swallowing and videofluoroscopy: Does examination type influence perception of pharyngeal residue severity? *Clinical Otolaryngology, 31*(5), 425–432.

Kelly, A.M., Drinnan, M.J., & Leslie, P. (2007). Assessing penetration and aspiration: How do videofluoroscopy and fiberoptic endoscopic evaluation of swallowing compare? *The Laryngoscope, 117*(10), 1723–1727.

Langmore, S.E., Schatz, K., & Olsen, N (1988). Fiberoptic endoscopic examination of swallowing safely: A new procedure. *Dysphagia, 2*, 216–219.

Lazarus, C.L., Logemann, J.A., Pauloski, B.R., Rademaker, A.W., Larson, C.R., Mittal, BB, et al., (2000). Swallowing and tongue function following treatment for oral and oropharyngeal cancer. *Journal of Speech, Language and Hearing Research, 43*(4), 1011–1023.

Lazarus, C., Logemann, J.A., Song, C.W., Rademaker, A.W., & Kahrilas, P.J. (2002). Effects of voluntary maneuvers on tongue base function for swallowing. *Folia Phoniatrica et Logopaedica, 54*(4), 171–176.

Lazarus, C., Logemann, J., Huang, C., & Rademaker, A. (2003). Effects of two types of tongue strengthening exercises in young normals. *Folia Phoniatrica et Logopaedica,* 55, 199–205.

Luschei, E.S. (1991). Development of objective standards of nonspeech oral strength and performance. In C. A. Moore, K. M. Yorkston, & D. R. Beukelman (Eds.), *Dysarthria and apraxia of speech* (pp. 3–13). Baltimore: Paul H. Brookes.

Miller, A.J. (1982). Deglutition. *Physiological Reviews, 62*, 129–184.

O'Bryant, S.E., Humphreys, J.D., Smith, G.E., Graff-Radford, N.R., Petersen, R.C., & Lucas, J.A. (2008). Detecting dementia with the Mini-Mental State Examination in highly educated individuals. *Achieves of Neurology,* 65, 963–967.

Oh, J.C., Park, J.W. Cha, T.H., Woo, H.S., & Kim, D.K. (2011). Exercise using tongue-holding swallow does not improve swallowing function in normal subjects. *Journal of Oral Rehabilitation, 39*(5), 364–369.

Robbins, J., Gangnon, R.E., Theis, S.M., Kays, S.A., Hewitt, A.L., & Hind, J.A. (2005). The effects of lingual exercise on swallowing in older adults. *American Geriatrics Society, 53*(9), 1483–1489.

Robbins, J., Kays, S.A., Gangnon, R.E., Hind, J.A., Hewitt, A.L., Gentry, L.R., et al. (2007). The effects of lingual exercise in stroke subjects with dysphagia. *Achieves of Physical Medicine and Rehabilitation,* 88, 150–158.

Robbins, J., Butler, S.G., Daniels, S.K., Gross, R.D., Langmore, S., Lazarus, C.L., et al. (2008). Swallowing and dysphagia rehabilitation: Translating principles of neural plasticity into clinically oriented evidence. *Journal of Speech, Language, and Hearing Research, 51,* S276–S300.

Silbergleit, A.K., Schultz, L., Jacobson, B.H., Beardsley, T., & Johnson, A.F. (2011). The dysphagia handicap index: Development and validation. *Dysphagia*, 27(1), 407–414.

Shaker, R., Kern, M., Bardan, E., Taylor, A., Stewart, E.T., Hoffman, R.G., et al. (1997). Augmentation of deglutitive upper esophageal sphincter opening in the elderly by exercise. *American Journal of Physiology, 272*(35), 1518–1522.

Shaker, R., Easterling, C., Kern, M., Nitschke, T., Massey, B., Daniels, S., et al. (2002). Rehabilitation of swallowing by exercise in tube-fed subjects with pharyngeal dysphagia secondary to abnormal UES opening. *Gastroenterology, 122*(5), 1314–1321.

Steele, C. M., Bailey, G. L., Molfenter, S. M., & Yeates, E. M. (2009). Rational for strength and skill goals in tongue resistance training: A review. *Perspectives on Swallowing and Swallowing Disorders, 18,* 49–54.

Strathopoulos, E., & Duchan, J.F. (2006). History and principles of exercise-based therapy: How they inform our current treatment. *Seminars in Speech and Language, 27,* 227–235.

Thompson, D., Throckton, G., & Buschang, P. (2001). The effects of isometric exercise of maximum voluntary bite forces and jaw muscle strength and endurance. *Journal of Oral Rehabilitation, 28*(10), 909–917.

Umeki, H., Takasaki, K., Enatsu, K., Tanaka, F., Kumagami, H., & Takahashi, H. (2009). Effects of a tongue-holding maneuver during swallowing evaluated by high-resolution manometry. *Otolaryngology – Head and Neck Surgery*, 141, 119–122.

Vincent, H., Shanely, R., Stewart, D., Demirel, H., Hamilton, K., & Ray, A. (2002). Adaptation of upper airway muscles to chronic endurance exercise. *American Journal of Respiratory and Critical Care Medicine*, 166, 287–293.

Warnecke, T., Teismann, I., Oelenberg, S., Hamacher, C., Ringlestein, B., Schabitz, W., & Dziewas, R. (2009). The safety of fiberoptic endoscopic evaluation of swallowing in acute stroke. *Stroke, 40*, 482–486.

Wheeler-Hegland, K., Frymark, T., Schooling, T., McCabe, D., Ashford, J., Mullen, R., et al. (2009). Evidence-based systematic review: Oropharyngeal dysphagia behavioral treatments. Part V – Applications for clinicians and researchers. *Journal of Rehabilitation Research and Development, 46*(2), 215–222.

Youmans, S.R., & Stierwalt, J.A.G. (2006). Measures of tongue function related to normal swallowing. *Dysphagia, 21*, 102–111.

Youmans, S.R., Youmans, G.L., & Stierwalt, J.A.G. (2009). Differences in tongue strength across age and gender: Is there a diminished strength reserve? *Dysphagia, 24*, 57–65.

[redacted]

[redacted]

[redacted] [redacted] [redacted]
[redacted] [redacted]

[redacted] [redacted] [redacted]
[redacted]

[redacted] [redacted] [redacted]
[redacted]

[redacted]

[redacted] [redacted]
[redacted]

[redacted] [redacted]
[redacted]

[redacted] [redacted]
[redacted]

[redacted]

[redacted] [redacted]
[redacted]

[redacted] [redacted]

[redacted] [redacted]

[redacted] [redacted]

[redacted] [redacted]

[redacted] [redacted]

[redacted] [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted] [redacted]
[redacted]

[redacted] [redacted]
[redacted]

[redacted] [redacted]
[redacted]

[redacted]

[redacted] [redacted]
[redacted]

[redacted] [redacted]
[redacted]

[redacted] [redacted]
[redacted]

[redacted] [redacted]
[redacted]

[redacted] [redacted]
[redacted]

[redacted] [redacted]
[redacted]