EFFECT OF EFFORTFUL SWALLOW TRAINING ON LINGUAL - LABIAL STRENGTH AND ENDURANCE AND SWALLOWING CAPACITY IN TYPICAL YOUNG ADULTS

ROJA RANI. M

Register No: 18SLP029

A Dissertation Submitted in Part Fulfillment for the Degree of
Master of Science (Speech-Language Pathology)
University of Mysore,
Mysuru

ALL INDIA INSTITUTE OF SPEECH AND HEARING,
MANASAGANGOTHRI,
MYSURU - 570006
JULY 2020

CERTIFICATE

This is to certify that this dissertation entitles '**Effect of Effortful Swallow Training on Lingual - Labial Strength and Endurance and Swallowing Capacity in Typical Young Adults**' is a bona fide work submitted in part fulfilment for the degree of Master of Science (Speech-Language Pathology) of the student Registration No: 18SLP029. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any diploma or degree

Mysuru
July 2020

Dr. M. Pushpavathi
Director
ll India Institute of Speech and Hearing
Manasagangothri
Mysuru– 570 006

CERTIFICATE

This is to certify that this dissertation entitles ‘**Effect of Effortful Swallow Training on Lingual - Labial Strength and Endurance and Swallowing Capacity in Typical Young Adults**’ has been prepared under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other university for the award of any diploma or degree.

Mysuru
July 2020

Dr. N. Swapna
Guide
ociate Professor of Speech Pathology,
tment of Speech-Language Pathology,
India Institute of Speech and Hearing
Manasagangothri
Mysuru– 570 006

DECLARATION

This is to certify this Master's dissertation entitled **'Effect of Effortful Swallow Training on Lingual - Labial Strength and Endurance and Swallowing Capacity in Typical Young Adults''** is the result of my study under the guidance of Dr. N. Swapna, Associate Professor of Speech Pathology, Department of Speech-Language Pathology, All India Institute of Speech and Hearing, Mysuru and has not been submitted to any other university for the award of any Diploma or Degree.

Mysuru, Registration No. 18SLP029

July, 2020

ACKNOWLEDGEMENT

COVID-19 Quarantine times........
Not knowing what the future holds, I'm here, trying to take hold of every passing minute of the present, in vain!

Let's step in with a prayer,
My dear heavenly father, you answered me when I called; you came for my rescue, when I was drowning in fear; you told me, "you have sought the right one, I and I will deliver you from all fears and know what, I'll make your face radiant too!" Thank you father and May everyone get the same privilege. I enjoy it, yeah. Here I am, witnessing the Lord's grace, the one who teaches to TREAD on WATER!

Acknowledging the Lord in my work is of course the ABC, but how about the Lord acknowledging you? Yeah, isn't it stunning! Isaiah 43:1 says, "Fear not, for I have redeemed you; I have called you by name, you are mine."

"Jennyyyyyyyy" – that's how it would sound! I'm acknowledged.

Writing this with so many thanks that I really cannot afford,
Thank you, Amma. You taught me to write the first letters, just by sight reading, though you knew not how each sounds. Oh, the sacrifices you offered me as though I'm God! Your love exceeds my vocabulary; I run out of words to describe!

Thank you, Appa. How much pleasure it brings to picturize your beaming smile! I've always been proud to say that I'm your daughter, the daughter of an auto driver; now sooo proud and I'm out of stock of thanks!

Thank you, Vincyma, my supposedly little one. Your selfless care for me has always knocked for six. I think of how you make me comfortable when I used to have my night study at home. Whoa your reinforcement, I haven't even learnt in Speech pathology! I missed you so much for that here! Never mind, I'm done at last!

Thank you, Chitti, your endearing addresses never failed to win me! Your fun talks, moral support and encouragement are treasures, though they don't go well together. Ha Ha.

Thank you, Chittapa, you certainly are my second father, never secondary. You've backed me up every time when I blinked in need; you still keep doing that. You are a blessing to the family, the Good Samaritan. My dissertation would've been beyond possibility without this laptop. Love in action!

Thank you, Dada. Yes, I mean dada. You've been the helping hand, the running start, and always the first crack; the one person whom I can any time, lookup for a spiritual intervention! Your love is a bonus star in my sky; shining at the darkest! I owe a lot for your encouragement in writing my dessert-a-tion.

Thank you, Dr. Pushpavathi Ma'am, for providing us with the best of facilities. We were blessed with unlimited library access, both online and offline. You backed us up with extensive technical support, and your words have always made us urge for being the best.

Thank you, Dr. Swapna Ma'am, for being the best guide. You have been so patient and considerate with me, when 'time' was not. Your motherly advice and teacherly guidance is the best combination. I'm so grateful for having got you as the guide; it means so much to me as a student. You have been a great listener, even approving my naive ideas and suggestions, yet supporting with your rich insights. Your extra time and devoted work have inspired me so much. Kudos ma'am, you are a great teacher! Your investment in me will never be forgotten.

Thank you, Dr. Yeshoda Ma'am, I stand in awe of your knowledge and practicality.

Thank you, Dr. Sreedevi Ma'am, I cherish the moments of being your JC student.

Thank you, Dr. Rajasudhakar Sir, your knowledge and tranquillity are exemplary.

Thank you, Dr. Jayashree Ma'am, for your constant approval and consistent instructions.

Thank you, Gayathri Ma'am, for sharing your lines of thought since the kickoff.

Thank you, Geetha Ma'am, for being a friendly teacher and a source of practical knowledge.

Thank you, Deepa Ma'am, for your expert directions.

Thank you, Dr. Vignesh Sir, for your teachings and lectures in my formative years.

Thank you, Dr. Jaya Ma'am, for helping me remain informed in the clinical practice.

Thank you, "Fellowship-an army rising gurlz". You people always come with a bang. You girls were my never-failing prayer support, my refuge in need (of coffee) and the exclusive source of joy in the Kapila!

Thank you, CPC for being the place I transformed; for igniting my deep-hidden faith and counting me among the wise; for discovering the temple within me. **Thank you, Achacha,** for finding the writer in me. I'm forever grateful for your leadership!

Thank you, Latha Aunty, Raji Aunty for being with me and my mom. Every help of yours at our urgent times is counted.

Thank you, Ganesh Medicals, Your timely generosity meant so much.

Thank you, my participants, Joel, Shinsi, Bandhan, Athul, Freddy, Shyam, Praveen, Jerusha, Reheema, Aparna, Namitha, Sween, Ameena, Abhranil, Jeeva, Devraj, Mandhan, Dhruva, for offering participation for thus study. Without you people, the next 100 pages would have been just a dream! Certainly it's not an easy task to stay behind for the entire 42 days (6 weeks), some even beyond that. Heartfelt thanks.

Thank you, my dissertation partners, Neeru and Sundu. Oh our hidden chuckles during the discussion times!

Thank you, Devi for being there! And that's all is needed. I'm sure you feel the same.

Thank you, Binu for becoming so close to my heart, staying behind during the best and the worst. Your 'mmm' proved you very much a great listener.

Thank you, Jassy for accompanying me every time. You never failed to include me. I've never felt alone when you were beside.

Thank you, Gracia. Your support and words gave a lot of hope. Thanks for offering help every time. Our gym times made a good routine to strengthen our link.

Thank you, Sarah, Your run to help me is the quickest. Your motivation has always been the pat on my back.

Thank you, Sam, for loving me; for those good conversations, the chocolates at every visit, and also for the unkept coffee promise.

Thank you, Sashi. Your guidance and instructions were worthwhile. Our prayer times and late night coffees are unforgettable.

Thank you, Ranji, for your kind words and concerns. Your prayers have inspired me a lot. Your devotion for work and the sincerity that you display are incredible. Hats off!

Thank you, Rishisha. You are my first friend at AIISH; you still stay special. Our prayer times and midnight talks were great.

Thank you, Aji, for your part in my life. Wishing all the wellness for you. I enjoyed being your friend. Hope that remains.

I wanted to write more, and lo, I'm realizing I'm at the eleventh hour! All the love I experienced renders me so grateful. After all, life revolves around LOVE; the rest is only secondary. Thank you all for mimicking the love of God. One day we'll all see the real one in its utter fullness.

"For now we see in a mirror dimly, but then face to face; now I know in part, but then I will know fully just as I also have been fully known". 1 Corinthians 13:12

How great it is to write informally so long after that formal dissertation writing! Yes God gave me words to hold on, thoughts to write out and yes, a pen to think with (scratching)! The strife has no end.

-Jeni (aka. Roja Rani)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Dysphagia is one of the common multidimensional conditions, impairing the swallowing function, of which oro-pharyngeal dysphagia is the commonest, resulting in greater rate of morbidity, mortality and warranting greater cost of management. Dysphagia is associated with a wide variety of disease states, usually reported as a consequence of anatomic aberrations in the oral regions or neuromuscular dysfunction pertinent to the gastrointestinal system.

Swallowing manoeuvres are used to rehabilitate oro-pharyngeal dysphagia. One of the manoeuvres, effortful swallowing can be used both as a compensatory maneuver and as a strength training exercise to improve swallowing and eliminate pharyngeal residue (Molfenter, Hsu, Lu & Lazarus, 2018). Authors refer to effortful swallowing as *"volitional manipulation of oropharyngeal phase of swallowing"* (Nekl, Lintzenich, Leng, Lever, & Butler 2012, p. 2). The maneuver involves the tongue to be pushed firmly against the palate in an upward-backward motion and to squeeze the throat muscles while swallowing as hard as possible (Park, Oh, Yoon, & Park, 2019).

Unlike normal swallowing, the effortful swallow renders heightened oral and pharyngeal pressure including clearing pressure and propulsive force of tongue (Coulas, Smith, Qadri, & Martin, 2009) and decreased upper esophageal sphincter (UES) exertions over long duration of swallow. Also, effortful swallow produces immediate alterations in the biomechanics of swallow in the following front: increased tongue-base retraction, early and maximum extent of superior hyoid excursion, longer duration of maximum hyoid excursion, maximized contact duration between base of the tongue and posterior pharyngeal wall (Lazarus, Logemann, Song, Rademaker, & Kahrilas, 2002), maximum laryngeal vestibule closure time, greater extent and duration of epiglottic tilt (Jang, Leigh, Seo, Han, & Oh, 2015), increased opening duration of upper esophageal sphincter (Hind, Nicosia, Roecker, Carnes, & Robbins, 2001) improvising the airway protection, improved clearance of vallecular residue (Jang et al., 2015). It mainly aids in reducing the depth of laryngeal penetration and facilitates swallowing efficiency (Hind et al., 2001); lengthened airway closure, and reduced bolus residue functionally enables the effortful swallow to augment safe bolus propulsion thereby decreasing the risk of aspiration (Nekl et al., 2012).

Tongue weakness is proven to be one of the predicting signs for dysphagia (Stierwalt & Youmans, 2007). Researchers have observed that reduced tongue strength showed significant relation to aspiration (swallowing safety) in typical older adults (Molfenter et al., 2018). Many studies have been conducted on tongue strengthening procedures, providing evidences for tongue strength and fatigability measures. Most of them inform regarding the training effects of tongue strengthening regimes. Also, tongue has been proven to display task-specific training effects, i.e., strength, endurance, and power in accordance to the approaches of training (Oh, 2015). Pertinent training effects include lingua-palatal pressures on the production of non-effortful and effortful swallows, and maximal isometric pressure (MIP) observed in the lips and tongue, also known as strength and fatigability of the lips and tongue measured in terms of endurance (Clark & Shelton, 2014). Specifically, tongue strength can be gauged by the pressing of the tongue with maximal effort against a resistor like palate, and is called as isometric tongue strength, else, it can be measured during swallowing (Todd, Lintzenich, & Butler, 2013), a sub-maximal pressure task.

During the process of swallowing, at the oral phase, the anterior portion of tongue squashes the bolus against the hard palate for transporting it to the tongue base. The posterior tongue reaches to press the posterior pharyngeal wall to achieve velopharyngeal closure. Lip works for the closure of the oral cavity, preventing anterior spillage of the bolus. In all these functions, tongue and lips suffers pressurization from the adjacent structures. Since tongue presses against the bony hard palate, which acts as a resistor (Park, Oh, Yoon, & Park, 2019), it is as good as a resistance exercise. This indicates that even a normal swallowing process would impart some change in the tongue strength over a considerable duration (Kays et al., 2010). Since lips constantly play role in maintaining the oral-cavity seal, each lip is also offered with resistance by the other, which result in strengthening of the lip musculature.

However, in modified swallowing procedures like the effortful swallowing, an overload is exerted on the stomatognathic structures. Overload refers to the taxing of a muscle beyond its normal use. It is usually offered by resistance exercises. In previous studies, effortful swallow was found to exert highest amount of pressure on the tongue relative to normal swallowing of thin as well as semisolid boluses (Witte et al., 2008), which is probably due to repetitive resistance offered by the hard palate against the tongue (Park et al., 2019). Since effortful swallow exerts greater pressure on tongue and lips, it is hypothesized that it will lead to greater training effects on tongue and lips than would normal swallowing process. This leads to a curiosity to study the measures of lip and tongue function in effortful swallow conditions.

Evaluating lip and tongue function is essential in the assessment and management of chewing, swallowing and other speech disorders. Researchers in the earlier studies investigated training effects of tongue under various strength training exercises.

A study in healthy adults within the age 20-29 years made comparison of the effects of two types of tongue strengthening exercise regime – strengthening using tongue depressor and strengthening with the IOPI. They reported significant increment in mean maximal tongue strength compared to the baseline after a 1-month training period (Lazarus, Logemann, Huang, & Rademaker, 2003).

One study provided encouraging results that after the period of a 8-week progressive lingual resistance exercise, increased isometric tongue strength along with a carried over enhancement in swallowing function was seen in healthy older adults. The researchers found significant raise in peak isometric lingual pressure way early, in the 4th week of the commencement of the training regime (Robbins et al., 2005).

Research literature has also documented differential training effects on anterior and posterior tongue. Kim et al. (2017) reported that anterior tongue strength increased to about 9.2 kPa and posterior tongue strength to 11 kPa as a result of a period of tongue resistance training in patients with post-stroke dysphagia. A recent study in healthy adult participants found significant increases in both anterior and posterior maximum tongue pressures by strength training exercises targeted only on anterior lingual muscles (Yano et al., 2019).

Also, a large number of studies were found to have probed the effortful swallow maneuver to unravel its influence on the biomechanical aspects of swallow and its potency in promoting the pharyngeal propulsion of bolus in healthy as well as in disordered population. One study displayed that changes occur in the biomechanical aspects of swallow and also the bolus-flow characteristics in healthy middle-aged and elderly individuals, under effortful and normal swallow conditions of 3-mL boluses using videofluoroscopy (Hind et al., 2001). A pharyngeal manometric study in healthy adults revealed that effortful swallow generated greater as well as longer duration of peak pressure in the mid-pharyngeal region than normal swallow (Witte et al., 2008).

However, very few studies have reported changes in individual oral function measures such as strength and endurance of lips and tongue.

Clark and Shelton in 2014 conducted the very first study reporting the training effects of effortful swallow training. They investigated the pre-test and post-test tongue strength changes after a period of high effort lingual-elevation exercises paired with effortful swallow training in healthy adult population. A well-established paired effect of lingual elevation exercise and effortful swallow training on tongue strength was found (Clark & Shelton, 2014). Park and Kim in 2016 reported an increment in lingual strength of 8.1 kPa in healthy older adults after a 4-week period of tongue pressing effortful swallow training (Park & Kim, 2016). Another recent study reported significant increase in anterior as well posterior tongue strength after 4-week period of effortful swallow training in individuals with post-stroke dysphagia (Park et al., 2019).

Lip strength is also related to neurologic conditions and overall swallowing function but is not as extensively studied as is tongue strength. Evidences show that labial activity is more while drinking with straw when compared with other drinking conditions. Clark and Shelton in 2013 studied the changes in lip strength after a training period of discrete sips from high-resistant straws and showed improved lip strength. They speculated that straw drinking may contribute to the overload on the labial muscles and that strength increment would be seen following exercise programs with high-effort sips from straws (Clark & Shelton, 2014).

Similarly, consensual report of authors testify increment in lingual pressures during effortful swallowing accompanied by changes in oropharyngeal biomechanics, thereby rendering enhanced swallowing function (Hind et al., 2001). A video-fluoroscopy study found that head and neck cancer patients after performing an effortful swallow exercise regimen before chemo-radiation therapy showed significant betterment in post treatment swallow functions (Clark, Brien, Calleja, & Corrie, 2009).

Literature provides evidences for improved swallow capacity associated with improved oral function measures. A study done by Kim and colleagues in 2016 reported that tongue to palate resistance training (TPRT) in patients with post-stroke dysphagia resulted in significant increase in lingual strength and swallowing function simultaneously (Kim et al., 2017). Till date, no study has reported the isolated training effects on tongue and lips and changes in swallowing capacity after an effortful swallowing training regime which emphasizes the need to study on that regard.

Need for the study

In the past, many studies have been carried out to appraise the effects of various strength training exercises, swallow maneuvers, etc. in different target population (typical and disordered) on lingual measures such as maximum isometric pressure, maximal strength and endurance. However, research on the effects of effortful swallow maneuver on lingual and labial strength (defined as maximum isometric pressure) and lingual endurance (defined as the length of time 50% of maximum pressure can be maintained) has not been carried out. Research shows that the only swallowing exercise with positive evidence from a randomized control trial was the Mendelsohn manoeuvre. The other swallowing exercises have indeed been investigated, but not within the context of a well-designed study to determine their long-term effects which warrants for a longitudinal study.

Extant literature evinces wide range of studies on swallowing behavior and dysphagia, explaining the processes, biomechanics, standard metrics and parameters of normal as well as disordered swallowing. Also, various assessment and management methods have been discussed. Effortful swallowing, one of the intervention option has been extensively studied in literature. Nevertheless, its long-term effect on lingual-labial structures and swallowing capacity has not called on for a greater degree of attention. Also, individualized effects of effortful swallowing are limitedly reported, because most studies have examined effortful swallow in the context of an array of multiple exercises (Clark, 2012; Clark et al., 2009) applied together. Though studies reporting training effects of effortful swallow have targeted elderly population who are subjected to general decline in skeletal muscle mass and strength, research on young participants is scarce. Specifically, studies have been conducted in evaluating the tongue strength and endurance under effortful swallowing conditions in older adults, but tongue function measures in healthy young adult population is understudied. Moreover, not all parameters of tongue and lip functions have been investigated during modified swallow behaviours such as effortful swallowing in the typical population.

Thus far, results of studies on older adults are considered to be masked by the age factor. There is still an unmet need in establishing the efficiency of effortful swallow training to induce changes in normal swallowing physiology which is only possible if a study would be conducted on young adults, who actually possess normal swallowing mechanism.

As previously stated, anterior and posterior regions of tongue respond differentially towards strengthening treatments, probably due to the difference in the type of muscles present and due to the differences in their function. During effortful swallowing, anterior and posterior tongue work differently with posterior tongue suffering greater pressure exertion, resulting in maximum training effects. This notion was proved by a study by Kim and colleagues in 2017 which showed that tongue resistance training in post-stroke dysphagia patients showed increase in lingual strength to about 9.2 kPa in the anterior tongue, 11 kPa in the posterior region of the tongue (Kim et al., 2017).

Although swallowing capacity has been investigated under normal swallow conditions, there is a lacuna in the literature studying the change in swallowing capacity after a period of effortful swallow regime. Further, though there are a few studies investigating immediate influences of effortful swallow maneuver on lingual functions, not many studies have reported about the long-term effects of continuous exercise using effortful swallowing over the course of a training period by conducting periodic assessments. Also, there are strong evidences for strength measurements which were especially well-established for measurements of tongue strength. However, only a handful of studies have measured lip strength. Studies pertaining to the assessment of endurance of lips and tongue following effortful swallow exercise regime has also not been reported in the literature. This warrants the need to examine the effects of effortful swallow training on measures of tongue and lip functions, particularly targeting the young adult population. Studying the changes in strength and endurance with effortful swallow maneuver may have some implications for speech production as well. Moreover, standardizing the instructions for eliciting an effortful swallow based on its physiological and functional impacts is deemed to be vital, minding the fact that no randomized controlled trial has been performed on effortful swallowing (Bahia & Lowell, 2020).

Aim of the Study

Keeping all these aspects in view, this study was planned with the aim of investigating the effects of a period of effortful swallow regime on isometric lingual strength and endurance, labial strength and endurance and swallowing capacity in young adults with normal swallowing. The specific objectives of the study included:

- To investigate the effects of lingual strength and endurance measures after a 6-week period of controlled effortful swallowing regime.
- To investigate the effects of labial strength and endurance measures after a 6-week period of controlled effortful swallowing regime.
- To explore any interaction between the anterior tongue and posterior tongue in strength and endurance measures on completing a 6-week period of controlled effortful swallowing regime.
- To assess the change in swallowing capacity, if any, after a 6-week period of controlled effortful swallowing regime**.**

Null Hypotheses

- There is no significant effect of lingual strength and endurance measures after a 6-week period of controlled effortful swallowing regime.
- There is no significant effect of labial strength and endurance measures after a 6-week period of controlled effortful swallowing regime.
- There is no interaction between the anterior tongue and posterior tongue in strength and endurance measures on completing a 6-week period of controlled effortful swallowing regime.
- There is no significant change in swallowing capacity after a 6-week period of controlled effortful swallowing regime.

CHAPTER II

REVIEW OF LITERATURE

Swallowing is a basic vital human process operated for digestion and nourishment (Rosen, 2018). In this process the food is thrust from the mouth into the pharyngeal cavity and finally into the oesophagus to be delivered into the stomach. It is a complex sensorimotor function executed by movement integration of a number of muscle groups. The visceral, somatic, afferent and efferent nerves have to be well coordinated with the associated striated and smooth muscles.

The process of swallowing

Understanding the physiology and pathophysiology of feeding and swallowing is indispensable for assessing and managing swallowing disorders, and establishing suitable rehabilitation schemes. Swallowing includes both volitional and reflexive events, **employing** more than 30 muscles pairs (Matsuo & Palmer, 2008), six cranial nerves (V, VII, IX, X, IX and XII). Sensorimotor integration of swallowing in the central nervous system is orchestrated by the combination of various cortical, subcortical and bulbar structures (Vose et al., 2018).

The term “swallowing” is a wide term, encompassing all feeding aspects and reflexive motor activity, salivation and the regulation of the viscera (Zald & Paldo, 1999). It is withal the process through which food is transported from the mouth to the stomach. The preparatory/oral phase is volitional, while the pharyngeal and esophageal phases are involuntary mediated mainly by the swallowing reflex which implies that the neuromuscular control of the oral, pharyngeal, and esophageal phases are different but inclusive.

As the bolus descends through the esophagus, its lumen, and the lower esophageal sphincter (LES), relaxes to allow bolus passage. Thus, a large part of a liquid bolus may plunge into the stomach by gravity only in case of an erect posture. The residual bolus is emptied by the peristalsis. However, solids do not descend by gravity but needs peristaltic contraction for the transfer. A food bolus crosses the pharynx within 1 second, at the speed of about 40 cm/sec by the pharyngeal peristalsis. Bolus moves through esophagus in about 5 to 6 seconds with a peristaltic velocity of about 3 to 4 cm/sec (Humbert & German, 2013).

Logemann, in 1980s reported first about the distinct stages of typical swallowing process. “The four stages are,

I. The Oral Preparatory Stage
II. The Oral Stage
III. The Pharyngeal Stage
IV. The Esophageal Stage”

In humans, the normal swallow was initially illustrated with a three staged sequential model, classified into Oral, Pharyngeal, and Esophageal stages according to the bolus position. Later, the Oral stage was divided into Oral Preparatory and the subsequent Oral Propulsive stage, that gave birth to the four stage model (Logemann, 1984;1998). Afterward, researchers reformed the earlier descriptions with new models and constructions, of which some are explained henceforth.

Process Model of Swallowing

Palmer and his colleagues proposed the Process Model of feeding to explain the mechanism of food and liquid swallowing (Matsuo & Palmer, 2008). It was designed to overcome the limitations in the existing models in describing oropharyngeal bolus formation and food transport (Palmer & Hiiemae, 1992). According to the Process Model, “Ingestion” refers to entry of food into mouth. “Stage I Transport” refers to the transport of food from anterior oral cavity to the molar region, “Processing” is chewing and mixing of the food with saliva, and “Stage II Transport” is transport of food from the molar region to oropharynx (Palmer & Hiiemae, 1992).

Feeding is characterized by constant rhythmic movement of the jaws, tongue, and the hyoid with tongue and jaw movements coordinated in specific ways. Most importantly, after Ingestion, bolus formation in preparation for swallowing did not occur in the oral cavity, as predicted by the four-stage model of swallowing. Rather, triturated food was propelled between the faucial pillars into the oropharynx, where it accumulated prior to swallowing. The pharyngeal swallow then transferred the bolus from the oropharynx into the esophagus.

Stage II Transport begins during Processing and coincides with it. Stage II Transport may continue for many cycles the while a bolus accumulates in the oropharynx. Bolus stasis in the oropharynx may persist for five or even ten seconds. When a bolus has accumulated in the oropharynx, pharyngeal swallowing begins by the backward thrust of tongue into the oropharynx. This is referred to as Hypopharyngeal Transit. During the Hypopharyngeal Transit Time (HTT) the larynx and nasopharynx are sealed, and the UES opens, permitting the bolus to pass. When the entire bolus has passed into the esophagus, a peristaltic wave is generated and thus commences the esophageal stage of swallowing.

The Process Model is proposed to revise the theoretical model of swallowing based on these new findings on the normal processes of eating and drinking. Note that HTT and the esophageal stage are common to both models.

Revised swallowing model

The revised model retains the traditional use of anatomically-based divisions: oral, pharyngeal and esophageal, while incorporating aspects of the Process Model. They refer to “phases” instead of “stages”, in order to connote that phases overlap in time, or even begin simultaneously (Palmer & Hiiemae, 1997).

The Oral Phase, as traditionally defined, includes Ingestion, Stage I and Stage II Transport, and Processing. It is redivided into both an Oral Preparatory Phase and an Oral Propulsive Phase. Triturated solid food may remain in the oropharynx for a long period before the Pharyngeal Phase begins. This makes the processes of swallowing liquids and chewed solids quite different.

In the revised model, the Pharyngeal Phase is equivalent to Hypopharyngeal Transit Time. It begins at the end of Stage ll Transport, after bolus formation in the mesopharynx. Numerous Stage II Transport cycles may occur prior to HTT. When subjects drink liquids, the Pharyngeal Phase begins immediately after the first Stage II Transport cycle, because there is no bolus stasis in the oropharynx. The figure 2.1 depicts the phases of the process model and the swallowing model.

The Esophageal Phase is defined the same way as the Esophageal Stage of the traditional model. It is essential to note that the Oral Phase activity may continue during the Esophageal Phase. At the time of swallowing, a brief cessation of breathing occurs when soft palate elevates and epiglottis tilts inducing an airway closure along with suppression of breathing in the brainstem. The “exhale – swallow – exhale” temporal sequence prevails during eating. Nevertheless, when performing sequential swallows during cup drinking, respiration resumes with inspiration (Palmer, Rudin, Lara & Crompton, 1992).

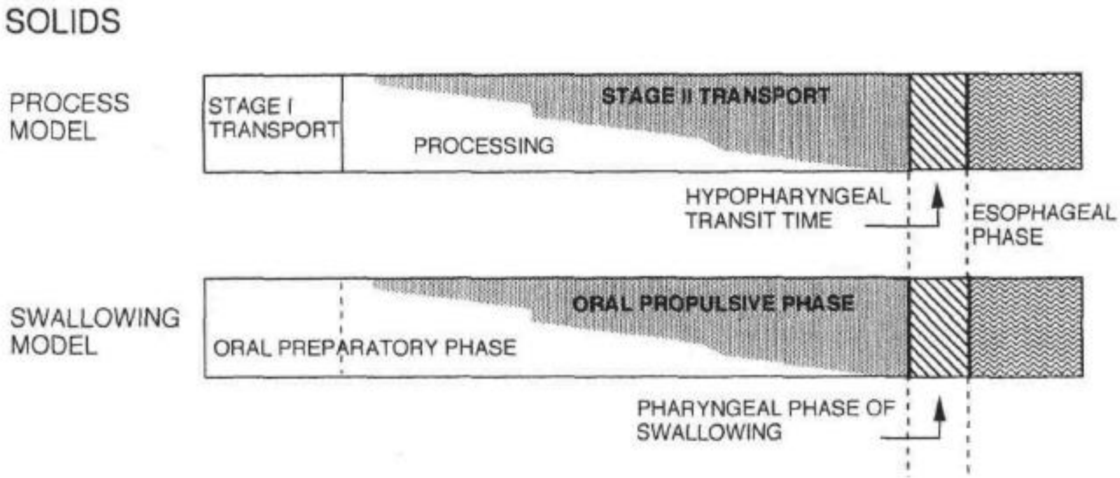

Figure 2.1 Reprinted from "Integration of oral and pharyngeal bolus propulsion: a new model for the physiology of swallowing" by Palmer, J. B., & Hiiemae, K. M., 1997, *The Japanese Journal of Dysphagia Rehabilitation, 1*(1), p. 2332. Adapted with permission.

Dysphagia

With the knowledge of what the process of swallowing holds, it is vital to be informed of the disruptions that could occur in swallowing to recognize dysphagia, to understand the possible contributing factors based on age, comordities and other risk factors that will facilitate clinicians and researchers to compute proper assessment and treatment plans (Roden & Altman, 2013).

Dysphagia is one of the common multidimensional conditions, impairing the swallowing function, of which oro-pharyngeal dysphagia is the commonest, resulting in greater rate of morbidity, mortality and warranting greater cost of management. In the oral stage, reduction in lateral tongue motion, failure to initiate swallow, failure to push food from front of mouth, drooling, failure to clear residue after the swallow are seen. "Operationally defined, oral phase dysphagia includes a single impairment or any combination of the following: poor bolus formation and manipulation, reduced containment in the oral cavity (anteriorly, laterally, or posteriorly), impaired mastication, and weakened or absent lingual propulsion of the bolus" (Stierwalt & Youmans, 2007, p. 150). At the pharyngeal stage, residues in the valleculae or pyriform sinuses or aryepiglotic folds or posterior pharyngeal wall, decreased hypo-pharyngeal movement, abnormality in UES opening, reduced upward and forward movement of hyoid and diminished velopharyngeal competency are observed. Dysphagia can cause issues such as penetration, aspiration, pneumonia, dehydration, and even death in serious cases.

Incidence and prevalence

Any illness that results in weakness, either from specific neurologic or muscular pathology or from a generalized debilitation is likely to indicate dysphagia associated with it. This connotes that dysphagia is a sign for an underlying ailment and not a primary medical diagnosis by itself. Now, dysphagia may point to mechanical or obstructive origin in young individuals, and neurologic/muscular origin in older population (Carrau & Murry, 1999). In infants dysphagia is linked with neurodevelopmental delay; in children and adolescent, the cause is upper respiratory infection and tonsillitis (Roden & Altman, 2013).

Hoy and colleagues examined 100 successive patients reporting to a tertiary care centre for swallowing for a period of 15 months with mean age of 62 years. They found that in 27% of the patients, dysphagia resulted from reflux disease; 11% reported swallowing difficulty due to cricopharyngeus muscle dysfunction; 14% witnessed post-radiation dysphagia (Hoy et al., 2013).

According to American Speech-Language-Hearing Association (ASHA, 2020), dysphagia is reported in 33%–83% children with craniofacial disorders. Oropharyngeal dysphagia is prevalent in 19.2%–99.0% of children with cerebral palsy. In adults, dysphagia occurs in 29%–64% of stroke patients; about 35% to 82% of individuals with Parkinson's disease report dysphagia. Other neurogenic populations reporting dysphagia are individuals with multiple sclerosis (24%–34%) and traumatic brain injury (38%–65).

About 3% to 64% report dysphagia following endotracheal intubation (ASHA, 2020). Research accounts high incidence and prevalence of dysphagia among patients with neurological impairments, individuals with head and neck malignancies, and tracheostomees, ventilator dependent individuals of non-neurological disorder. According to ASHA, regardless of etiology, dysphagia precipitates potential health risks ensuing increased susceptibility to serious aspiration, malnutrition, pneumonitis, and indeed death (ASHA, 2020).

While disease control is of paramount importance, functional impact of dysphagia on swallowing function and postliminary quality of life should be considered in tandem. An optimal understanding of the structural and physiological origin of the swallowing problem is imperative for appropriate management and rehabilitation of individuals with dysphagia (Manikantan et al., 2009).

Causes of Dysphagia

Structural Abnormalities: Structural causes of dysphagia can be congenital or acquired. In congenital cleft lip and palate, lip control for sucking is hampered, strength of oral suction is decreased, velopharyngeal inadequacy and nasal regurgitation is seen; mastication is impaired due to underdeveloped maxilla and dental misalignment. Zenker's diverticulum in pharynx or esophagus is a pulsion diverticulum that originates from a weak spot in the muscle wall. The bolus can misgo into the pocketing diverticulum, to get accumulated and be regurgitated to the pharynx that leads to coughing and aspiration (Ferreira, Simmons, & Baron, 2008).

Cancers of the oral cavity are the greatest contributor of oropharyngeal dysphagia. Pharyngeal, esophageal or other sphincteric webs and strictures obstruct bolus movement and are more symptomatic with solids. UES, which is the most commonly obstructed site, may structurally or functionally fail in case of strictures (Ferguson, 2005). In elderly, cervical osteophytes are seen more common. The bony outgrowths emanate from cervical vertebrae and narrow the esophagus diverting the bolus towards airway. Trauma to the airway or generally, the neck can cause serious dysphagia, apart from death. Burns and OPS poisoning gravely scrape the luminous tissues renders the worst cases of dysphagia. Also, prolonged intubation and tracheostomy can result in temporary or long-term dysphagia (Malandraki et al., 2012).

Functional abnormalities: Functional abnormalities are largely of neurological origin. Insufficient lip closing pressure results in drooling and thus inefficient feeding. Buccal weakness causes food to be trapped in the buccal cavity or labial vestibule and impairs bolus clearance. Tongue dysfunction, in case of palsy promotes incoordination and sensory impairment and results in inefficient chewing, bolus formation, and transport. Weak pharyngeal contraction can cause premature bolus spillage. Chemoradiation therapy causes xerostomia, delayed swallow onset, limited pharyngeal transport, and checks laryngeal safety.

Velopharyngeal incompetency may cause nasal regurgitation and reduction in pharyngeal pressure in swallowing process (Parkinson, 2002). Dysfunction in tongue base retraction or the pharyngeal constrictor muscle results in insufficient force for pharyngeal propulsion and bolus retention and spillage in valleculae and pyriform sinuses during or post swallowing. Inadequate UES relaxation can be caused by hypertonic UES, as seen in inflammation or fibrosis.

Esophageal dysfunction is not uncommon and is mostly asymptomatic. Hyperactivity (esophageal spasm), hypoactivity (weakness), or muscular in-coordination can lead to inefficient peristalsis and inadequate clearance. Retained bolus can result in regurgitation increasing the risk of aspiration and gastroesophageal reflux disease (GERD). Poor oral hygiene results in increased the bacterial content in the aspirate, heightening the susceptibility for bacterial pneumonia (Matsuo & Palmer, 2008).

Management – Towards Understanding Concepts

Dysphagia can delay medical recovery, and leads to extended hospitalizations and a heightened demand for long-term care. Aspiration pneumonia, a common sequela of dysphagia, is associated with high risk for morbidity and even mortality. Upgrading diagnosis and intervention methods is the utmost need of clinician groups presently and pertinent research to explore the ways for wellness and quality of life in individuals with dysphagia has become inevitable (Burkhead, Sapienza & Rosenbek, 2007).

Dysphagia intervention aims at increasing swallowing safety and sufficient oral intake necessary for nutritional stability and a healthy equilibrium of mind and body. Researchers have reported a wide variability of swallowing pathophysiologies and causations, further widened by the continual evidence releases on increasing swallowing complexity. Clinicians are alarmed at this fact and an inconvincible hesitation remains in combating the complexity of the prevailing disease conditions. Acquiring and applying insights, which are authentic and standard is a solution. This is invariably emphasized because, to make effective treatment decisions targeting function restoration, clinician's ability to accurately diagnose the impairment is utterly vital (Vose, Kesneck, Sunday, Plowman, & Humbert, 2018).

Historically, the focus of research was largely on the use of compensatory maneuvers to prevent aspiration while swallowing. Compensations were employed in various aspects of feeding: postural compensations such as head manipulations, manipulation of oral structures, along with shifts in body position, bolus compensations like altering the viscosity, volume, consistency and/or temperature of food has been shown as promising methods for improved swallow safety and efficient oral intake. In addition, a number of exercise protocols have been proposed targeting the range of motion, increasing volitional swallowing effort, stimulating the sensory system to help improve swallowing function (Burkhead, 2007).

Unlike compensatory strategies, the goal of exercise protocols is to maximize the safety of oral intake by enhancing the physiological parameters of the swallowing system. Literature searches have documented promising outcomes of exercise-based approaches for dysphagia rehabilitation. For example, Shaker et al used head lift exercises, which are now termed as “Modified Shaker’s exercises” to strengthen the submental muscles and found improved upper esophageal sphincter opening and laryngeal excursion during swallow (Shaker et al, 1997, 2012). Crary et al studied the effects of surface electromyography (sEMG) biofeedback in 25 patients with chronic dysphagia post stroke and treatment for head/neck. They found significant increase in functional oral taking in of food and liquid, thereby lowered costs of management (Crary, Carnaby, Groher, & Helseth, 2004). Robbins et al studied a progressive 8-week isometric lingual strengthening program and found significant change in isometric and swallowing pressures, lingual volume and airway protection in stroke patients with dysphagia (Robbins et al, 2007).

Following life conservation and medical clearance, management of dysphagia solely leans on rehabilitative approaches. Langmore and Pisegna stated that, “Rehabilitative exercises are those meant to change and improve the swallowing physiology in force, speed or timing, with the goal being to produce a long-term effect, as compared to compensatory interventions used for a short-term effect” (Langmore & Pisegna, 2015, p.222). Also, researchers have stated that rehabilitative exercises constitute retraining of the neuromuscular systems to retrieve the neuroplasticity through the exploitation of muscular system imposing intense and persistent training to rewire and repattern the neural innervations of the muscle or muscle groups in question (Clark, 2003).

Review of physical rehabilitation and exercise science literature suggests that distinctive training methods and strategies should be employed to elicit differential changes in strength, endurance, speed, and the like. A clear understanding of the muscular functioning and neural plasticity is important for constructing management plans to maximize peripheral and central adaptation for lasting improvement in swallowing (Burkhead et al, 2007).

Types of muscles

Fundamental knowledge of muscle constitution and neuromuscular function is necessary to understand movement and exercise. Muscular groups are composed of hierarchically arranged fibers that are divided into myofibrils, parallelly arranged in bundles to form a muscle fiber. Myofibrils are further subdivided into sarcomeres, called the "workhorse of contraction" (Burkhead, 2009, p.43). Sarcomeres contain myofilaments working on two contractile proteins: actin and myosin, which when activated results in muscle contraction.

Strength (amount of force produced) and endurance (response over time) are determined by the muscle make up, its fibre composition. In every muscle and muscle group, various fibre types are present, with a predominance of a specific type in a given muscle. Generally, skeletal muscle fibres can be classified into fibre types, namely, Type I and Type II. The bio-potential (for. e.g. force generating capacity) of the muscle is based on the type of fibre. Type 1 fibres are relatively smaller in diameter and thus generate minimal force, while type II fibres produces greater force due the largeness in size. Thus, Type II fibres are more fatiguable, which makes them appropriate for quick, forceful movements. Contrarily, Type I fibres are slow-twitching, low-force and are suitable for long-enduring activities (Burkhead, 2009). Type II fibres are classified into Type IIa and Type IIb. Type IIb fibres are capable of generating greater force, that it becomes fatigued rapidly. Type IIa fibres have features of both the Type I and Type IIb fibres, which makes them extremely adaptable due to mixed contractile properties. Uniquely, muscles of mouth, pharynx and larynx contain hybrid muscle fibres in addition to the customary Type I, IIa, IIb fibres.

Muscles of mastication with reference to tongue and lip musculature

Masticatory and deglutitive muscles possess special fibre composition not like any other skeletal muscle. The array of actions that these muscles undertake in functions like respiration, phonation, resonation, and most importantly, deglutition justifies the fact that form follows function, considering the special composition of fibres that they possess. Also, the demand on these muscles may switch briskly from slow tonic contractions for functions like laryngeal safety and respiration, to quick low-force movements of speech and swallowing (Kent, 2004).

Tongue: Tongue is the major propulsion organ of the stomatognathic system, acting by the coordinated elevation of the anterior, middle, and posterior portions. Through the entire oral and pharyngeal phases of swallow, the tongue remains active, propelling the bolus through the oral cavity, the oropharynx, and pharynx toward the esophagus (Stierwalt & Youmans, 2007).

Kent (2004) gives an insightful review emphasizing the uniqueness of the oropharyngeal muscle system and the way it outstands structurally and functionally from other muscle groups and strikingly, its motion is not about a joint. Instead, its characteristic action is achieved by composite contraction patterns driven by specially aligned intersecting fibres. The genioglossus, which forms the tongue dorsum, best illustrates this functional uniqueness. The anterior tongue contains largely Type I and IIa fibres (Oh, 2015), which produce low force, high enduring movements. This is favourable for stereotypic, low-force movements required for food manipulation when chewing and aggregating food particles to form a cohesive bolus. In the posterior region, rapid-contracting Type II fibers, are found performing writhing movements to propel the bolus during swallowing. Fiber-specific adaptations in muscle structure occur as a resultant of timed maximal or absent activity, determined by the type, duration and intensity of activity (Kent, 2004).

Lingual strength has been examined in a number of patient groups with Parkinson disease, head and neck maliganancies, muscular dystrophy, and stroke. Acute neurological impairments, such as stroke and brain injury, and other progressive impairments are found to co-occur with increased incidences of swallowing impairment (Smaoui, Langridge & Steele, 2019).

Lips: Labial function is inevitable in everyday routines such as includes facial expression, articulation, food consumption and also swallowing capacity, indirectly. Lip closure employs majorly the orbicularis oris, a complex skeletal muscle. Labial muscles are particularly functional in the oral phase of swallowing, indirectly influencing feeding, socializing, cortical activity and even sleep, in ridding with halitosis (Wong et al, 2020).

Ibrahim et al, in 2013, studied the effects of lip strengthening exercise regime using lip trainer for 14-24 weeks on labial closure strength in healthy participants and found that there was a significant increment in labial closure strength at the end of 14 weeks of exercise (Ibrahim, Arifin, & Rahim, 2013).

Fujiwara et al studied 66 healthy Japanese women who went through 7 days of lip strengthening training using oral screens changes were measured across the duration at baseline, 6th and the 8th day and they found a significant increase of lip strength over time (Fujiwara, Tokura, Tome, & Kitai, 2016).

Training effects of lip strength and endurance were studied in non-healthy participants and promising results have been reported. Earlier, a retrospective study by Hagg and Anniko in 2008 investigated if there are any changes in the lip force in stroke patients who were using oral screens for about 5-8 weeks. They found that lip force significantly improved after treatment, resulting in significant amelioration of facial paresis (Hägg & Anniko, 2008). Later in 2010, the same researchers studied prospectively the effect of labial force on swallowing capacity after a period of training with oral screen. They observed a significant correlation between labial force and swallowing in stroke patients but not in healthy participants and concluded that physical labial strengthening may be effective in treating oropharyngeal dysphagia (Hägg & Anniko, 2010)

In their single case study, Perry and collegues examined the eficiency of an 8-week lip closure–strengthening exercise regime with biofeedback in a recipient of full facial transplantation one year post surgery. Exercise was given 60% of maximum strength and the results revealed improved lip strength, lip movement velocity and the range of motion while speaking. Also, patient-reported improvements in straw-drinking and facial expression during communication were also recorded (Perry et al, 2017).

While examining the effects of lip closure training (LCT), Takamato and collegeues found that enhanced maximal lip closure force facilitated reduction in eating duration, reduced food spillage, and daytime sleeping. Moreover, prefrontal cortical activity significantly increased during lip closure, which in turn significantly correlated with the raised maximal lip closure force post intervention. These results proved that LCT can be of great use in elderly individuals with deteriorated eating/oral and cognitive functions (Takamoto et al, 2018).

Strength training principles

Exercise drills that do not exert the neuromuscular system beyond the level of routine function will not incur adaptations. “By challenging the system beyond typical use, adaptations occur to accommodate the increased demand.” (Burkhead, Sapienza, & Rosenbek, 2007, p.255). Three broad themes of exercise principles are intensity, specificity, and transference. Intensity comprises the volume, load, and duration of the stimulus of the exercise. Specificity denotes the amount of the exercise task exacting with the intended outcome. Transference is addressed in the context of enabling cross-training and nonspecific training to eventually improve overall function.

Swallowing is a submaximal muscular activity, which implies that the muscle strength produced to successfully accomplish the activity is much lower than the maximum force that can be generated by the muscles in question. “The proportion of potential of force-generating capacity in relation to the effort required to perform a certain task is known as functional (or physiologic) reserve.” (Rogus-Pulia, & Connor, 2016, p.301) Lesser the functional reserve the muscle contains to perform an action, quicker will be the muscle fatigue and greater will the self perceived effort be (Buchner & de Lateur, 1991).

Effects of Training and Detraining

Initial changes during strength training program may be attributed better to the response of the nervous system to muscle activation than to actual structural alterations. As training progresses, performance is enhanced due to recruitment of more number of newer motor units or due to enhanced force and co-ordination in existing motor units. Eventually, it is morphological changes that bring about changes in strength of muscle groups rather than neural contribution (Burkhead et al, 2007).

In response to exercise, muscle groups undergo two types of structural adaptations:

- *Type shift:* The contractile features of the muscle fibres shift to the slower long-enduring phenotype (Type I).
- *Hypertrophy (enlargement of the muscle fibre):* It is the morphological adaptation that modifies the actual force-generating potential of a muscle and is generally the preliminary objective of strength training.

The above mentioned morphologic changes happen at different times over the training duration. Exercise science literature shows that type shifts (along with neural adaptations) contribute primarily for initial improvements, prior to any muscular hypertrophy. To count that a predominant variation has occurred in performance, a muscle can sufficiently hypertrophy within even five weeks of strength training (Burkhead et al, 2007; 2009). Hamdy et al. reported that brain reorganization happened at the cortical level in patients who displayed recovery in swallowing (Hamdy, Rothwell, Aziz, & Thompson, 2000).

Swallowing maneuvers with special note on effortful swallowing

Swallowing maneuvers are used to rehabilitate oro-pharyngeal dysphagia. One of the maneuvers, effortful swallowing can be used both as a compensatory maneuver and as a strength training exercise to improve swallowing and eliminate pharyngeal residue (Molfenter, 2018). Authors refer to effortful swallowing as *“volitional manipulation of oropharyngeal phase of swallowing”* (Nekl, 2012, p. 254). The maneuver involves the tongue to be pushed firmly against the palate in an upward-backward motion and pressing the throat muscles and swallowing as hard as possible (Park, Oh, Yoon, & Park, 2019).

The effortful swallow was originally advanced as a compensatory technique to assist the progress of bolus flow via the pharynx, increasing the intrabolus pressure, by increasing the contact of the base of the tongue (BOT) with the posterior pharyngeal wall (PPW) during swallowing (Pouderoux & Kahrilas, 1995). This is expected to subsequently improve bolus clearance in the vallecular regions (Kahrilas, Lin, Logemann, Ergun, & Facchini, 1993; Pouderoux & Kahrilas, 1995). The initially devised instruction for eliciting an effortful swallow, “as you swallow, squeeze hard with all your muscles” (Logemann, 1998, p. 221), facilitates active oral and pharyngeal muscle actions. The volitional aspect of a “hard” swallow serves to increase clearing pressures, particularly in the mid-tongue region in healthy individuals (Pouderoux & Kahrilas, 1995). In addition, tongue base to pharyngeal wall pressures and the time of their contact increases in comparison to typical swallowing, and there is less pharyngeal residue, as seen in dysphagic with oncologic comordities (Garcia, Hakel, & Lazarus, 2004; Lazarus, Logemann, Song, Rademaker, & Kahrilas, 2002). However, interestingly, the effortful swallow, nowadays, is seemingly manifested as a therapeutic or rehabilitative technique considering its role in modifying the swallowing physiology, exclusively by exerting the musculature, which none of the other maneuver accomplishes (Büllow, Olssen, & Ekberg, 1999, 2001, 2002; Lazarus et al., 2002; Pouderoux & Kahrilas, 1995).

Unlike normal swallowing, the effortful swallow causes heightened oral and pharyngeal pressure including clearing pressure and propulsive force of tongue (Coulas, Smith, Qadri, & Martin, 2009) and decreased upper esophageal sphincter exertions over long duration of swallow. Also, effortful swallow produces immediate alterations in the biomechanics of swallow in the following front: increased tongue-base retraction, early and maximum extent of superior hyoid excursion, longer duration of maximum hyoid excursion, expanded contact duration between tongue base and posterior pharyngeal wall (Lazarus et al., 2002), maximum vestibule closure time in larynx, greater extent and time of epiglottic tilt (Jang, Leigh, Seo, Han, & Oh, 2015), increased time of UES opening (Hind, Nicosia, Roecker, Carnes, & Robbins, 2001), improvising the airway protection, improved clearance of vallecular residue (Jang et al., 2015). It mainly aids in reducing the depth of laryngeal penetration and facilitates swallowing efficiency (Hind et al., 2001), lengthened airway closure, and reduced bolus residue functionally enable the effortful swallow to augment safe bolus propulsion thereby decreasing the risk of aspiration (Nekl et al., 2012).

Prompted by the Videofluoroscopic swallowing studies, the first researches emerged on the effects of effortful swallow maneuver. Presently, assorted authors have worked on unraveling the benefits of effortful swallow in terms of swallowing physiology.

The first studies addressing the effects of the effortful swallow maneuver were prompted by observations of videofluoroscopic swallowing studies (VFSSs). Currently, several authors have shown additional effects of the effortful swallow on swallowing physiology in controlled studies (Fritz et al., 2014; Huckabee, Hiss, Barclay, & Jit, 2005; Jang et al., 2015). However, a systematic review that particularly investigates the effects of the effortful swallow maneuver is not available for providing clinical guidance and understanding in the present literature (Bahia & Lowell, 2020).

Several researchers have unveiled the supplementary effects of the effortful swallow on swallowing physiology in controlled studies (Molfenter, Hsu, & Lazarus, 2018; Witte, Huckabee, Doeltgen, Gumbley, & Robb, 2008), approving its role as an effective rehabilitative maneuver, instead of just regarded as a compensatory technique. Thus, owing to its multiple physiologic impacts and ease in elicitation, this maneuver is aopted in clinical practice on a broad scale (Bahia, 2020; Vose, Kesneck, Sunday, Plowman, & Humbert, 2018).

Physiological changes in the pharyngeal phase

High-resolution manometry studies showed higher peak pressure in upper pharynx, velopharynx, hypopharynx while performing a, effortful swallow (Takasaki, Umeki, Hara, Kumagami, & Takahashi 2011). Also, standard manometry studies have shown increased pressure over the epiglottis and mesopharynx (Huckabee & Steele, 2006). Pressure duration revealed conflicting results across studies (Hiss & Huckabee, 2005; Takasaki et al., 2011; Witte et al., 2008).

Contrastingly, few researchers were in agreement in reporting lengthened laryngeal closure time during the effortful swallow (Hind et al., 2001; Molfenter et al., 2018). Also, longer pharyngeal phase events have also been shown (Molfenter et al., 2018). Larger and prolonged epiglottic tilt was found to co-occur with effortful swallow maneuver (Jang et al., 2015).

Physiological changes in the upper esophageal sphincter

UES opening duration was found to be differing across various studies. Few studies found lower peak pressure in the UES while performing the effortful swallow in comparison to normal swallowing (Huckabee et al., 2005; Huckabee & Steele, 2006). On the contrary, some studies showed greater peak pressure occurring along with effortful swallows (Takasaki et al., 2011). Also, greater total pressure within the UES was also indicated by Hoffman et al. in 2012.

Physiological changes in the esophageal phase

Consistently, increase pressure was reported during the effortful swallow over middle and the lower esophagus (Lever et al., 2007; Nekl et al., 2012). However, absent change in pressure was found in the proximal regions during the effortful swallow using perfusion manometry (Lever et al., 2007). However, Nekl et al. (2012) conflictingly found heightened pressures over the entire esophagus.

LES pressure variations have also been investigated in association during the effortful swallow but were found to be evident gender-specifically. Few pertinent studies found that the effortful swallow reduced the susceptibility of incomplete bolus clearance (Nekl et al., 2012). More studies are warranted in this regard for better understanding.

Effect of effortful swallow on the oral phase

Various studies found that tongue to palate maximum pressure generation was greater during the effortful swallow in comparison with normal swallowing at all the sensor locations across different ages. Pressure onset time variations and duration in effortful swallows were also reported to be different from normal swallows. Anterior tongue-to palate contact pressure duration was found to be long. In some studies total pressure duration was found to be longer in the middle region of tongue (Steele & Huckabee, 2007). In addition, there was longer pressure rise time in the anterior and middle region of palate on an effortful swallow. Age discrepancies were also found, with elderly population showing lengthier rise times than younger adults in the anterior region of palate, though not in the middle region (Hind et al., 2001; Lever et al., 2007).

Applications of effortful swallowing in lip/tongue strengthening

Tongue weakness is proven to be one of the predicting signs for dysphagia (Stierwalt & Youmans, 2007). Researchers have found that reduced lingual strength showed significant relation to aspiration (swallowing safety) in healthy older adults (Molfenter, 2018). Many studies have been conducted on tongue strengthening procedures, providing evidences for tongue strength and fatigability measures. Many of the studies report on training effects of lingual strength training exercises. Also, tongue has been proven to display task specific training effects, i.e., strength, endurance, and power in accordance to the approaches of training (Oh, 2015). Pertinent training effects include lingua-palatal pressures on the production of non-effortful and effortful swallows, and maximum isometric pressure (MIP) generated by the lips and tongue, also known as strength and fatigability of the lips and tongue measured in terms of endurance (Clark & Shelton 2014). Specifically, lingual strength may be evaluated out by the pressing of the tongue with maximal force against a resistor like palate, called as isometric tongue strength, or it can be measured during swallowing (Todd, Lintzenich, & Butler, 2013), a sub-maximal pressure task.

During the process of swallowing, at the oral stage, the anterior portion of tongue squashes the food against the hard palate for transporting it to the tongue base. The posterior tongue reaches to press the posterior pharyngeal wall to achieve velopharyngeal closure. Lip works for the closure of the oral cavity, preventing anterior spillage of the bolus. In all these functions, tongue and lips suffers pressurization from the adjacent structures. Since tongue presses against the bony hard palate, which acts as a resistor (Park et al., 2019), it is as good as a resistance exercise. This indicates that even a normal swallowing process would impart some change in the tongue strength over a considerable duration (Kays, Hind, Gangnon, & Robbins, 2010). Since lips constantly play role in maintaining the oral-cavity seal, each lip is also offered with resistance by the other, which result in strengthening of the lip musculature.

However, in modified swallowing procedures like the effortful swallowing, an overload is exerted on the stomatognathic structures. Overload refers to the taxing of a muscle beyond its normal use. It is usually offered by resistance exercises. In previous studies, effortful swallow was found to exert highest amount of pressure on the tongue relative to normal swallowing of thin as well as semisolid boluses (Witte et al., 2008), which is probably due to repetitive resistance offered by the hard palate against the tongue (Park & Kim, 2016). Since effortful swallow exerts greater pressure on tongues and lips, it is hypothesized that it will lead to greater training effects on tongue and lips than would normal swallowing process. Approvingly, studies have shown that increased tongue – palate pressures during effortful swallows facilitates the increment in pharyngeal pressures and quickens the propagation of the pharyngeal pressure wave (Huckabee & Steele, 2006).

Also, resting on the statement of Humbert and German (2013) that, “motor accuracy can be ensured by neural modulation as a result of input obtained from peripheral sensory receptors and descending pathways from the cerebral cortex, sub-cortex, and cerebellum” (Humbert & German, 2013, p. 4), Hoffman et al asserted that, in like manner, effortful swallowing and its resultant changes in motor timing and force are known to have impacts on neuro-physiological adaptability (Hoffman et al., 2012).

Training effects of effortful swallowing

Recent studies unveil useful evidences that effortful swallowing maneuver can not only be used as a compensatory strategy, but as a potential rehabilitative technique as well. This is due to the training effects imparted to the muscle groups being involved in the maneuver, when administered systematically through an exercise regime.

According to Langmore and Pisegna in 2015, the criteria for determining the working of an exercise is problematic especially for those studies that have focused on "swallowing" exercises. The swallow "manoeuvres", always show an immediate or compensatory effect. It will bring about alterations to the swallow immediately because of the greater effort, holding it out longer, or holding the breath earlier. However, it is rightly pointed out that if the swallow manoeuvre is trained with the goal of making permanent positive changes in swallow, then it can be called an exercise (Langmore & Pisegna, 2015).

Researchers in the earlier studies investigated training effects of tongue under various strength training exercises: A study in healthy subjects of ages between 20-29 years made comparison of the effects of two types of tongue strengthening exercise regime- tongue strengthening using tongue depressor and tongue strengthening with the IOPI and reported significant increment in mean maximal tongue strength compared to the baseline after an 1-month training period (Lazarus, Logemann, Huang, & Rademaker, 2003).

One study provided encouraging results that after the period of an 8-week progressive lingual resistance training, increased isometric tongue strength along with a carried over enhancement in swallowing function was seen in healthy elderly population. The researchers found significant raise in peak isometric lingual pressure way early, in the 4th week of the commencement of the training regime (Robbins et al., 2005).

Research literature has also documented differential training effects on anterior and posterior tongue. Kim et al. (2017) reported that tongue strength increased to about

9.2 kPa in the anterior tongue and to 11 kPa in the posterior region as a result of a period of tongue resistance training in patients with post-stroke dysphagia (Kim et al., 2017). A recent study investigated the effects of tongue pressing exercise for a period of 8 weeks, applied to the anterior tongue in eleven healthy adults within the age range, 20.6±1.2 years. The exercise intensity was gradually increased over duration and the results were obtained. It was found significant increases in both anterior and posterior maximum tongue pressures while the strength training exercise targeted only on anterior tongue muscles. This shows the carry over effect (Yano et al., 2019).

Clark and Shelton in 2014 conducted the very first study reporting the training effects of effortful swallow training. They investigated the pre test and post test tongue strength changes after a period of high effort lingual-elevation exercises paired with effortful swallow training in healthy adult population. A well-established paired effect of lingual elevation exercise and effortful swallow training on tongue strength was found (Clark & Shelton, 2014). Park and Kim in 2016 showed an increment in tongue strength of 8.1 kPa in healthy older adults after a 4-week period of tongue pressing effortful swallow training (Park & Kim, 2016). Another recent study reported significant increase in anterior as well posterior tongue strength after 4-week period of effortful swallow training in patients with post-stroke dysphagia (Park et al., 2019).

Lip strength is also related to neurologic conditions and general swallowing physiology but is not as well investigated as is lingual strength. Evidences show that lip activity is more during straw drinking when compared with other drinking conditions. Clark and Shelton in 2014 studied the changes in lip strength after a training period of discrete sips from high-resistant straws and showed improved lip strength. They speculated that drinking out of straw may contribute to the overload on the labial muscles and that strength gains would be seen subsequent exercise programs with high-effort sips from straws (Clark & Shelton, 2014). Studies that assessed the lip strength as a consequence to effort swallow training are sparse.

Swallowing capacity and strengthening exercises

Literature provides evidences for improved swallow capacity associated with improved oral function measures. A study done by Kim and colleagues in 2017 reported that tongue to palate resistance training (TPRT) in patients with post-stroke dysphagia resulted in significant increment in lingual strength and swallowing function simultaneously (Kim et al, 2017). Recent studies have shown approving findings for lingual strengthening trainings in enhancing tongue strength and endurance in healthy and disordered populations, which has led to the raising adoptions of lingual resistance training programs in swallowing management. However, if betterments occur in swallowing function remains obscure (Smaoui et al., 2019). However, Hagg and Anniko in 2010 had reported a significant correlation between lip force and swallowing capacity in adults with stroke. He concluded by stating that pathological lip function will greatly influence swallowing capacity in stroke patients with oropharyngeal dysphagia. These results support that lip muscle training may be beneficial in treating dysphagia. Till date, no study has reported the isolated training effects on tongue and lips and changes in swallowing capacity after an effortful swallowing training regime which emphasizes the need to study on that regard.

Final comments

There is a good body of literature over the decades that propounds that isometric exercises involving maximal pressure on tongue have convincing effect on the oral musculature, especially tongue, with positive functional outcomes in swallowing such as adequate feeding, improved efficiency in swallowing and appropriate social eating routines (Takamoto et al., 2018).

Yet, studies irresistibly lack for satisfactory evidences which would shed light on the effectiveness of strength training exercises in question, the magnitude of its effect, and the appropriate guidelines to adhere to such a strength-training exercise at the clinical level. Thus it is pivotal to understand how the effortful swallow contributes to swallowing physiology (Bahia & Lowell, 2020).

It is crucial to summon into mind that lip or tongue strengthening exercises need not necessarily be considered in exclusion. Deglutition, in its entirety, is a complex synchronized process, encompassing multiple simultaneous events. So, the effects of lip and tongue strengthening exercises affect the swallowing functions and not supposedly tongue alone. On that note, applying strength training on tongue musculature has simultaneous effects on other swallowing related measures. This leads to a curiosity to study the measures of lip and tongue function in effortful swallow conditions.

CHAPTER III

METHOD

The present study aimed to investigate the effects of a period of effortful swallow regime on isometric lingual strength and endurance, labial strength and endurance and swallowing capacity in young adults with normal swallowing. A single group time series study design was adopted for the present study.

Participants

A convenient sample of ten healthy female volunteers between the age of 18 and 25 years (mean age = 21.5 years) were the participants of the study. All of them were recruited from the student groups of AIISH, from the batches of 1st B.Sc and 1st M.Sc. Prior to enrolment in the study, the participants (n-=20) were screened for potential speech and swallowing issues by standard assessment procedures. However, of the 20 participants recruited for the study, ten individuals were excluded from the study due to practical issues in clinician monitoring. A questionnaire World Health Organization Disability Assessment Schedule-Second Version (WHODAS 2.0), a 12-item short version based on International Classification of Functioning Disability and Health (ICF) which was developed by WHO in 2010 was completed by each volunteer through interview mode. This questionnaire provides a profile of functioning across six activity domains (i.e., cognition, mobility, self-care, getting along, life activities, and participation). This was to exclude volunteers with any dysfunction in any of the six aforementioned domains. Also, a thorough informal assessment was carried out to preclude out cognitive, communicative, sensori-motor, neurological, psychological issues.

Weight, height, and gender were recorded which were run for the calculation of body mass index (BMI) for the purpose of identifying potentially obese (i.e., BMI > 40) volunteers. According to ICD 11, Class 3 obesity, formerly called morbid obesity (BMI of greater than 40) is associated with a high prevalence of asymptomatic esophageal motility disorders (Jaffin, Knoepflmacher, & Greenstein, 1999). For this reason, volunteers with a BMI greater than 40 were excluded from participation in the study.

All participants were non-smokers and were not regular consumers of alcohol. Volunteers who reported previous history of oral function difficulty and swallowing difficulty were excluded from participation in the study. None of the participants exhibited prior or existing swallowing problems or any previous surgery in the head, neck, throat or esophagus (Pitts, Stierwalt, Hagerman, & Lapointe, 2017). No history of medically documented esophageal dysmotility, food allergies, eating disorder and altered stomatognathic functions were present. Also, participants with neck pain or neck surgery, palato-dental prosthesis usage, significant malocclusion and facial asymmetry were excluded from the study. Those with parafunctional oral habits like bruxing, clenching, or tongue thrusting were also excluded.

Participants were informed about the duration, the objectives and the pattern of the study process after which a written informed consent was obtained from each volunteer. The study complied with current ‘Ethical Guidelines for BioBehavioral Research Involving Human Subjects’ of AIISH.

Instrumentation

Measures of lingual strength and endurance, labial strength and endurance were obtained using Iowa Oral Performance Instrument (IOPI), version 2.2. This was developed by Robin and Luschei in the speech department at the University of Iowa in

1992 (Luschei, 2001). The IOPI, which has been used extensively in clinical practice and research over the past 15 years, is a portable device that uses a nickel-sized air-filled pliable plastic bulb. This oblong bulb is made of soft rubber and is approximately 3.5 cm long and 4.5 cm in diameter with an approximate internal volume of 2.8 ml (Solomon, Clark, Makashay, & Newman, 2008). The bulb is connected to a hand-held instrument via an 11.5-cm-long clear plastic tube to measure peak pressure [in kilopascals (kPa)] exerted on the tongue bulb. It contains pressure-sensing circuitry, a peak-hold function, and a timer. Currently it is one of the most commonly used measurement techniques available to objectively measure tongue strength and endurance. According to a review by Adams et al. in 2013, IOPI is an effective evaluation device which is relatively inexpensive and capable of providing objective measures of tongue strength and endurance rather than only relying on the speech-language pathologist's clinical assessment, especially when multiple staffs are making assessments. This evidence is strongest for strength measurements and is best established for measurements of tongue strength in particular (Adams, Mathisen, Baines, Lazarus, & Callister, 2013). Researchers have used this device in many studies to measure tongue strength and endurance with excellent inter-rater reliability.

When strength is applied to the bulb, the liquid crystal display panel displays the strength value in kilopascals (kPa). The voltage recorded is transformed to kilopascals (kPa) of pressure by multiplying the microvolts 50.9 in accordance with the standard calibration procedure. Biofeedback is relayed to the user through a numerical display (in kPa) and through a series of lights changing from red to green to indicate successful achievement of the target pressure. The IOPI is capable of making static measures as well as dynamic measures over time (Stierwalt & Youmans, 2007).

Lip and tongue strength can be calculated as a measure of the maximum pressure produced within a standard-sized air-filled bulb. The IOPI can also be used to assess fatigability of lips and tongue in terms of a parameter called endurance, which is inversely proportional to fatigability. Low endurance values are an indicator of a high fatigability. Endurance is measured with the IOPI by quantifying the length of time that a patient can maintain 50% of his or her maximum pressure. This procedure is conducted by setting the target value in the Target Mode to 50% of the patient’s maximum pressure and timing how long the patient can hold the top (green) light on. The timing is displayed in seconds on the device.

Procedure

A rapport with the volunteering participants was established prior to the data collection process. Participants were thoroughly informed about the length of the effortful swallow training in pursuance of intellectual readiness for consistent adherence to the six-week long regimen. Participants were given a demographic data sheet and the WHO-DAS 2.0 questionnaire (see appendix) to fill up and then were led further into the measurement process.

Measurement of lip strength and endurance

Lip strength (inter-labial compression) was measured by placing the bulb between the upper and lower lips (at tubercle of upper lip and groove of lower lip) at the middle. This placement has been planned based on the method used by Solomon and collegues (Solomon et al., 2008), so that the pressure exerted gets distributed evenly across the entire surface of the tongue bulb to provide accurate pressure readings. Encouraged trials were elicited following the procedure which is as follows:

Baseline strength measurement

- ✓ Participants were instructed to press the bulb between the lips with maximum effort for 2-3 seconds.
- ✓ Three trials of strength were elicited and the highest generated pressure was taken as the maximum lip strength (P_{max}) expressed in Kilopascals (kPa), provided that the mean value of each of the three sets did not differ by more than five percent.
- ✓ Approximately 30 seconds of rest was given between trials.

Baseline endurance measurement

- ✓ Subjects were asked to press the IOPI bulb between the lips to sustain the illumination of the middle green LED on the lights array “for as long as possible”.
- ✓ The target pressure for each of the baseline endurance measures, defined as 50% of the P_{max} obtained during the preceding lip strength assessment, and the middle LED on the IOPI was programmed to represent the target value.
- ✓ Lip endurance was considered as the duration for which the 50% of the P_{max} could be maintained, expressed in seconds.

Each participant completed three baseline measures of lip strength and endurance with a 20-minute rest period between the measures.

Measurement of tongue strength and endurance

Anterior tongue strength was assessed with the tongue bulb positioned longitudinally 10 mm posterior to the tip of tongue along the hard palate (Robbins et al., 2007), posterior to the alveolar ridge. Posterior tongue strength was assessed with the tongue bulb positioned 10 mm anterior to the posterior-most circumvallate papilla by the posterior border of the hard palate (Kim et al., 2017). Encouraged trials were elicited following the procedure which is as follows:

Baseline strength measurement

- ✓ Participants were instructed to press the bulb against the palate with maximum effort for 2-3 seconds.
- ✓ Three trials of strength were elicited and the highest generated pressure was taken as the maximum tongue strength (P_{max}) expressed in Kilopascals (kPa), provided that the mean value of each of the three sets did not differ by more than five percent.
- ✓ Approximately 30 seconds of rest was given between trials.

Baseline endurance measurement

- ✓ Subjects were asked to press the IOPI bulb against the palate to sustain the illumination of the middle green LED on the lights array "for as long as possible".
- ✓ The target pressure for the baseline endurance measures, defined as 50% of the P_{max} obtained during the preceding tongue strength assessment, and the middle LED on the IOPI was set to represent this target value.
- ✓ Tongue endurance was considered as the duration that 50% of the P_{max} could be sustained, expressed in seconds.

Each participant completed three baseline measures of tongue strength and endurance with a 20-minute rest period between the measures.

For both measures (lip and tongue), a piece of tape was used to mark the meeting point of the lips with the connective tubing that runs between the IOPI device and the intra-oral bulb. The investigator provided consistent, verbal encouragement to motivate subjects to put in their maximal effort for each trial. Subjects were instructed to breathe through the nose and to make attempts to suppress any spontaneous swallows during the endurance trials. The IOPI device was washed in running water, dipped in Savlon/Dettol solution for two minutes and then washed again in running water, before and after every use. Also, the instrument was calibrated once in a month as recommended by the manufacturer, to ensure accuracy in measurement by adhering to the procedure provided in the manual.

Measurement of swallowing capacity

The swallowing can be assessed for its capacity using information on the volume swallowed, the number of swallows and the time taken. Using the above information, three quantitative indices can be calculated, viz. average volume per swallow (ml), average time per swallow (s) and swallowing capacity (ml/s). These indices might be useful in screening those at risk of dysphagia or its complications, and in monitoring (Hughes & Wiles, 1996).

The swallowing capacity, in this study was measured using 100 ml water swallow test. Each participant, seated in comfort, was asked to drink 100 ml of water from a beaker as quickly as and comfortably as possible (Hughes & Wiles, 1996). The participants were observed from the side, their swallowing was video recorded, and the number of swallows used was counted by observing the movements of the thyroid cartilage. All participants were able to hold the beaker of water to their own mouth. A stopwatch was started at the commencement of the swallow with the cup touching the participant’s lower lip and ending when the larynx came to rest for the last time. Studies have proven that the final laryngeal movement usually co-occurs with other events such as phonation, exhalation, or mouth opening.

The total time taken by the participant to swallow and the total number of swallows was obtained. For the total number of swallows, the number of hyolaryngeal elevations associated with the swallows was calculated. Every one elevation and one depression of hyolarynx was counted as one swallow. Participants were also told to ensure that there are no remains of liquid residue in the cup; hence to swallow full 100 ml. Volume per swallow, time per swallow, and swallow capacity were calculated on an offline basis.

- Volume per swallow = 100ml/total number of hyolaryngeal movements (ml)
- Time per swallow = Total time taken to swallow 100 ml/total number of hyolaryngeal movements (sec)

Swallow capacity = 100 ml/total time taken to swallow 100 ml (ml/sec)

Effortful swallow training protocol

Participants were recruited for a 6-week regime of trainer-monitored effortful swallow training with the dosage of 20 trials, 5 days per week, for consecutive 6 weeks. The treatment dosage was narrowed down after a thorough reviewing of literature regarding tongue and lip strengthening training studies, general motor-training and detraining effects of tongue and lip musculature studies. Robbins et al. in their study on lingual training exercises recommend a minimum period of 6 weeks for lingual strengthening effects to emerge from a training regime (Robbins et al., 2005). Very recently Park and colleagues in their study advised a minimum of 6-8 weeks of training for the muscles to get stimulated and strength increased (Park et al., 2019).

Since previous studies concluded that effortful swallowing maneuver renders the same effect on pharyngeal peak pressure and pressure duration in both saliva and water swallow, water bolus were taken for the present study (Witte et al., 2008). The type and amount of bolus taken were thin liquid (water) of 5 ml, taken for a convenient single swallow. For the effortful swallow trials, participants were instructed to swallow as hard as they can with all of the muscles in their mouth with unconstrained jaw (Stierwalt & Youmans, 2007) and to not use any of the abdominal muscles during the process. Each training session was carried out before meal-time, due to the reported reduction effects of strength and endurance measures after dining (Kays, Hind, Gangnon, & Robbins, 2010). Participants were made to sit upright in front of the trainer (Rosen, Abdelhalim, Jones, & McCulloch, 2018). The following instructions were given to elicit effortful swallow on the 5 ml water bolus: *"Squeeze hard with all your muscles as you swallow the given amount of water''* (Lazarus et al., 2002, p. 173). The methodology adopted for the current study is depicted as a flow chart in figure 3.1

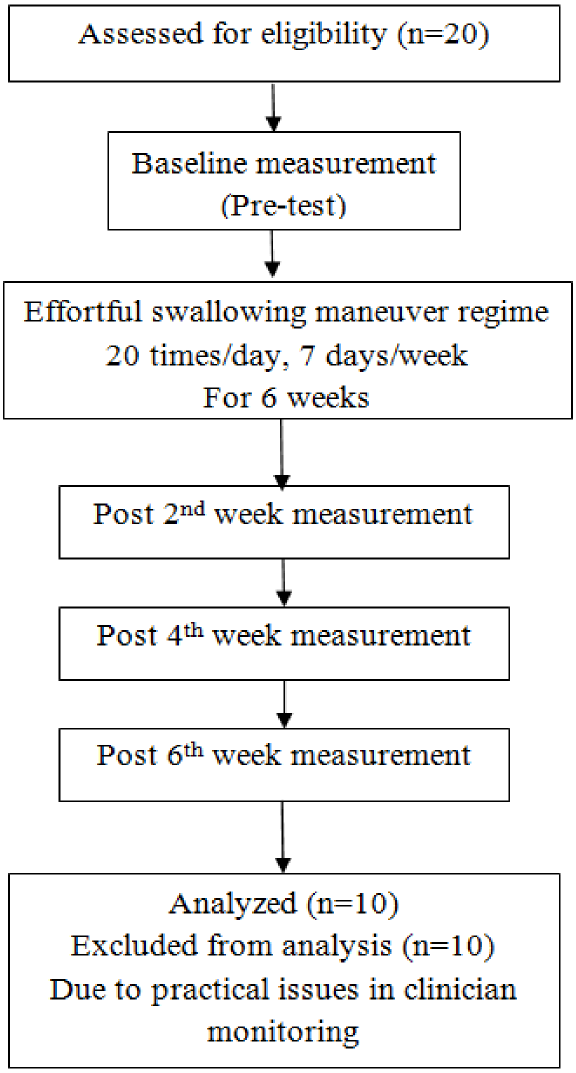

Figure 3.1 Flow chart of the adopted method for the study.

Training monitoring

Although the clinician had no direct means to verify the performance accuracy and the physiologic effects, correctness of the maneuver performance was confirmed by direct observation of the strong contraction of the oro-facial and supra-hyoid muscles. Additionally, palpation of the supra-hyoid muscles under the jaws intermittently confirmed effortful swallowing as per the recommendations (Park et al., 2019).

Training support

Participants were supervised and encouraged during the training. If there was fatigue of tongue or neck, participants were provided rest for several seconds.

Documentation

In addition, a daily log documenting exercise activity was maintained. Additional care was taken to ensure the optimal exercise dose in each participant. Factors that promote adherence to the training program were tabulated in detail.

Periodic assessments and post-test measurement

Lingual strength and endurance, labial strength and endurance and swallowing capacity were obtained periodically at the end of week 2, week 4 and week 6 (post-treatment) of the training period with IOPI using the same procedure aforestated.

Analyses

The seven dependent variables under investigation for this study were lip strength, lip endurance, anterior tongue strength, anterior tongue endurance, posterior tongue strength, posterior tongue endurance and swallowing capacity. IOPI measures and swallowing capacity were obtained manually from every participant over a period of six weeks in four time points (pre-test, post 2 weeks, post 4 weeks and post-test) and were preserved for analyses.

Statistical analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS v20.0 for Windows; SPSS Inc., Chicago, IL) software. Since an assessment of the normality of data is a prerequisite for the forthcoming statistical tests, the raw data were tested numerically with well-known tests of normality, the Kolmogorov-Smirnov and the Shapiro-Wilk test. The Shapiro-Wilk test rendered that swallowing capacity significantly deviated from normality, while the rest of the other six measures adequately met normality assumptions; therefore, parametric statistics were used to analyze the data obtained for these six swallow related parameters. Nonparametric statistics were used to investigate swallowing capacity because data obtained for these variables did not follow a normal distribution. Prior to statistical analyses, the values obtained for each dependent variable were averaged to produce a mean score for each time point (pre-test, post 2 weeks, post 4 weeks and post-test) of the exercise duration for n=10.

For strength and endurance of lip and tongue, a one-way repeated measure ANOVA was performed to examine the mean differences over time. A p-value of ≤ 0.05 was regarded as statistically significant. Also, to measure the interaction of the anterior and posterior tongue measures, a two-way repeated measure ANOVA was used with significance level set at $p=0.05$. For measures of swallowing capacity, a nonparametric Friedman test was used to investigate the significant differences over time. A p value of less than 0.05 was considered statistically significant. The results have been presented in the next chapter.

CHAPTER IV

RESULTS

The present study aimed to investigate the effects of a lingual, labial strength and endurance measures after a 6-week period of controlled effortful swallowing regime by estimating the changes in strength and endurance measures of lips and tongue occurring over the course of the effortful swallowing regime in young adults with normal swallowing, and further exploring any interaction between the anterior tongue and posterior tongue in strength and endurance measures. The study also aimed at assessing any change in swallowing capacity after the 6-week regime.

Description of Overall Findings

Of the 20 participants recruited for the study, ten individuals were excluded from the study due to practical issues in clinician monitoring as intended initially. The remaining ten participants underwent the 6-week effortful swallowing experience regime. Swallowing related measures like lip strength (LS), anterior tongue strength (ATS), posterior tongue strength (PTS), lip endurance (LE), anterior tongue endurance (ATE), posterior tongue endurance (PTE) and swallowing capacity (SC) were obtained from the participants at four time points, namely, pre-test [baseline] (1), post 2 weeks (2), post 4 weeks (3), post 6 weeks [post-test] (4) over the period of six weeks.

Measures of lips and tongue function from the participants are tabularized below starting with descriptive statistics, followed by analyses that divided the measures into subgroups in terms of the parameters measured; namely, lip strength, lip endurance, anterior tongue strength, etc. to determine the potential outcome of the exercise regime over time. Precisely, for tongue measures, respective analyses are followed by the presentation of parallel analyses conducted to find the interaction between ATS and PTS, ATE, and PTE. Finally, the non-parametric test results are tabulated to display the changes in swallowing capacity over the period of the exercise regime.

Analyses of results show that the 6-week effortful swallowing exercise regime significantly affected strength and endurance measures in the anterior tongue, posterior tongue, and lips with respect to the baseline measures ($p>0.05$), although swallowing capacity showed only minimal changes.

Normality testing

To check the study sample for normality, the Shapiro-Wilk test of normality was carried out. According to this test, the closer the test statistic (W) is to one, the normal the sample is. It was found out that all parameters were normally distributed with $p>0.05$, except for SC, where its data at two time points, pre-test (p=0.0.35) and post 6 weeks ($p=0.040$) deviated significantly from normality.

Inferential statistical analyses

In order to test the hypothesis that effortful swallowing exercise affected the strength and endurance measures, one-way repeated measures ANOVA was performed and pairwise comparisons were run to trace the change over the course of the regime. Two-way ANOVA was used to detect any interaction that could be present between the anterior and posterior tongue, i.e. between ATS and PTS, and between ATE and PTE.

To test the hypothesis that effortful swallowing exercise had an effect on swallowing capacity, Freidman test was performed and Wilcoxon signed ranks test was done to find the pattern of change over the course of the regime. The results of the findings are recounted under the forthcoming headings.

Lip Measures

Lip Strength

Isometric lip strength and endurance measures were obtained from the 10 healthy participants over the period of 6 weeks at four time points. The mean and standard deviation of lip strength (LS) at each time point is tabulated below (Table 4.1). It can be noted that the means showed a growing trend with time.

Table 4.1

Descriptive Statistics of Lip Strength (LS)

Time points	Dependent Variable	Mean (kPa)	Std. Deviation
1	Pre-test (baseline)	32.20	6.53
2	Post 2 weeks	33.10	7.77
3	Post 4 weeks	36.20	6.34
4	Post 6 weeks (post-test)	39.80	5.07

A one-way repeated measures ANOVA was carried out to compare the effects of the effortful swallowing exercise on LS, measured at four time points, pre-test, at the end of 2 weeks, 4 weeks and 6 weeks (post-test) of the 6-week exercise regime. It revealed statistically significant increase in the mean values at the end of the 6-week period of controlled effortful swallowing regime, $F(3,27) = 12.43$, $p = 0\ .000$, $\eta^2_p = 0.58$. Bonferroni corrected multiple comparisons were done post hoc, which showed that significant changes in LS happened after the 4th week of the exercise regime (p=0.03). The result of Bonferroni test has been depicted in table 4.2.

Table 4.2

Results of Bonferroni Pairwise Comparisons

Swallowing-related Variables	***p* – values of combinations of time points**					
	2 vs. 1	**3 vs. 1**	**4 vs. 1**	**3 vs. 2**	**4 vs. 2**	**4 vs. 3**
LS	1.000	0.144	0.005*	0.319	0.025*	0.003*
LE	0.058	0.010*	0.001*	0.157	0.005*	0.004*
ATS	1.000	0.135	0.032*	0.121	0.009*	0.005*
ATE	0.110	0.052	0.011*	0.150	0.018*	0.006*
PTS	1.000	0.111	0.002*	0.025**	0.001*	0.000*
PTE	0.529	0.112	0.009*	0.082	0.002*	0.008*
SC†	0.208	0.235	0.027*	1.000	0.065	0.035*

†Comparisons based on Wilcoxon Signed Ranks Test
*Significant *p*- value ($p<0.05$)
**Note that in case of PTS, significant difference appeared after the 2nd week of regime.

The figure 4.1 shows the pairwise comparison of the mean differences of LS between the time points. Also, from table 4.2, it is clearly seen that the significant difference was present between time points 1 and 4, 2 and 4, and 1 and 3. This revealed that significant increase in LS occurred after the 4th week of the regime.

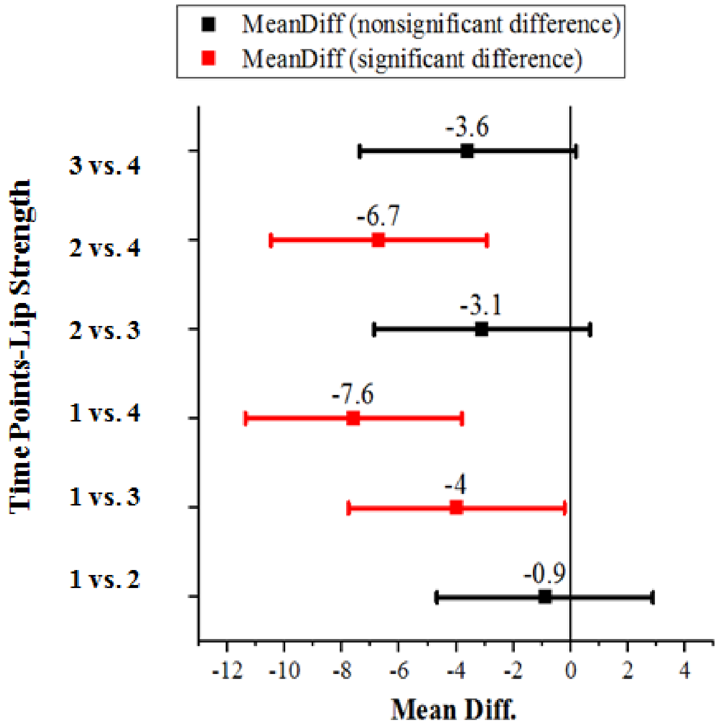

Figure 4. 1 Pairwise comparison of LS values using mean difference at various time points .

Lip endurance

The mean and standard deviation of Lip Endurance (LE) obtained from the group of 10 participants at each time point is tabulated below (Table 4.3). It can be noted that the mean values and standard deviation increased with time, which implies a great variability in the obtained measures.

Table 4.3

Descriptive statistics of Lip Endurance (LE)

Time points	Dependent Variable	Mean (seconds)	Std. Deviation
1	Pre-test (baseline)	43.60	26.43
2	Post 2 weeks	67.60	37.87
3	Post 4 weeks	78.30	37.48
4	Post 6 weeks (post-test)	91.10	41.15

One-way repeated measures ANOVA was carried out to compare the effects of the effortful swallowing exercise on LE, measured at four time points, pre-test, at the end of 2 weeks, 4 weeks and 6 weeks (post-test) of the 6-week exercise regime. The results revealed a statistically significant increase in the mean values after the 6-week period of controlled effortful swallowing regime, defined by the main effect, $F(3,27) = 21.90$, $p = 0.000$, $\eta^2_p=0.709$. Bonferroni corrected multiple comparisons showed significant changes in LE after the 4th week of the exercise regime ($p = 0.04$). The result of Bonferroni test has been depicted in table 4.2.

The figure 4.2 shows the pairwise comparison of the mean differences of LE between the time points. Also, from table 4.2, it is clearly seen that the significant difference was present between time points 1 and 2, 3 and 1, 4 and 1, and 4 and 2. This shows that significant increase in LE occurred after the 4th week of the regime.

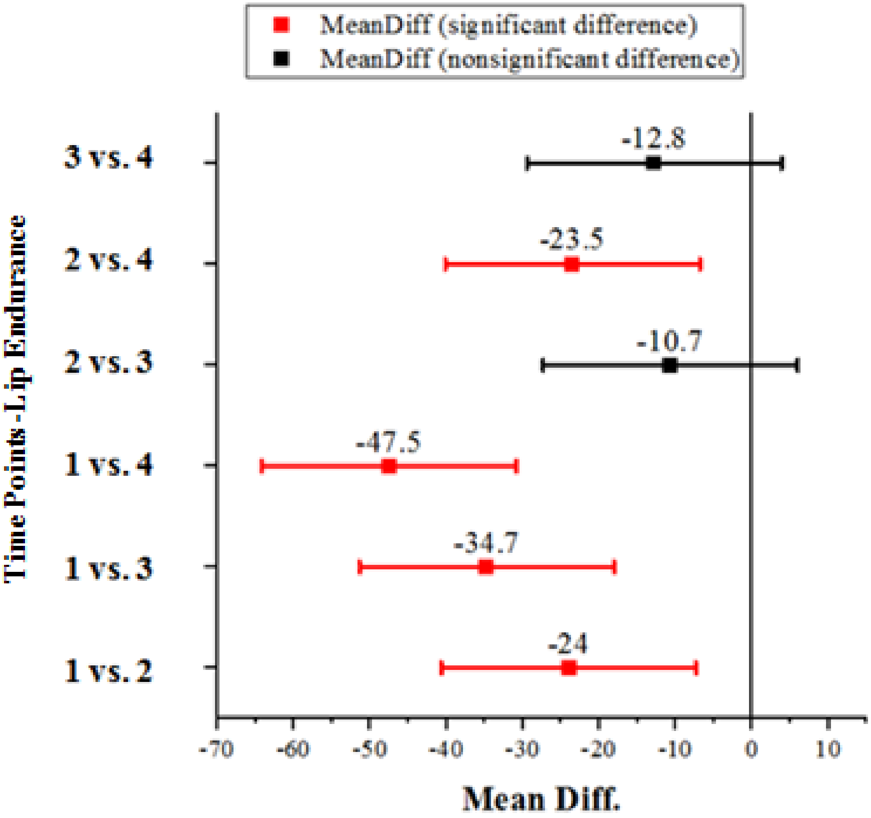

***Figure** 4.2* Pairwise comparison of LE values using mean difference at various time points.

It is also noteworthy from figure 4.2 that standard deviations of LE at the four time points overlap substantially. This implies that statistical significance is at threat considering the overall regime course. Yet, the mean of the pre-test and post- test scores shows statistically significant positive difference with comparatively less overlap in the standard deviations.

Tongue Measures

Anterior Tongue Strength and Posterior Tongue Strength

The mean and standard deviation of Anterior Tongue Strength (ATS) and Posterior Tongue Strength (PTS) obtained from the group of 10 participants at each time point is tabulated below (Table 4.4). It can be seen Note that the mean values of ATS and PTS showed a growing trend with time.

Table 4.4

Descriptive statistics of Anterior Tongue Strength (ATS) and Posterior Tongue Strength (PTS)

Time points	**Dependent Variable**	**Anterior Tongue Strength**		**Posterior tongue strength**	
		Mean (kPa)	**S.D**	**Mean (kPa)**	**S.D**
1	Pre-test (baseline)	41.30	11.49	39.20	10.88
2	Post 2 weeks	44.70	12.18	41.30	8.67
3	Post 4 weeks	48.50	10.23	45.80	8.47
4	Post 6 weeks (post-test)	52.70	9.39	50.80	8.87

One-way repeated measures ANOVA were performed to compare the means. The results showed statistically significant increment in ATS and PTS, defined by the main effects, $F(3,27) = 9.015$, $p = 0 .000$, $\eta^2_p=0.500$, and $F(3,27) = 15.618$, $p = 0.000$, $\eta^2_p=0.634$, respectively. Bonferroni corrected multiple pairwise comparisons was carried out for the mean values of for ATS and PTS between all possible combination of time points. The results revealed a significant increase in ATS after the 4th week of the regime (p = 0.005) (Figure 4.3) and in PTS from 2nd week of the regime (p =0.025) (Figure 4.4).The results of the Bonferroni test for the ATS and PTS has been depicted in table 4.2.

The figure 4.3 shows the pairwise comparison of the mean differences of ATS between the time points. From table 4.2, it is clearly seen that a significant difference was present between time points 4 and 1, 4 and 2 and 4 and 3. This revealed that a significant increase in ATS occurred after 4th week of the regime with minimal changes post 2 weeks (Figure 4.3).

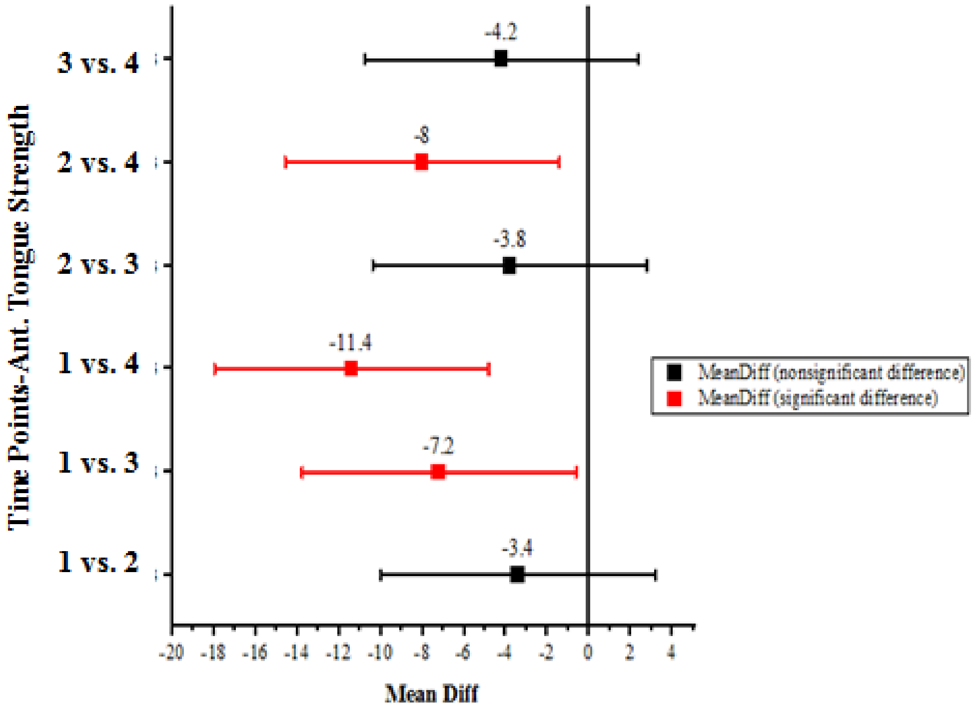

Figure 4.3 Pairwise comparison of ATS values using mean difference at various time points.

The figure 4.4 shows the pairwise comparison of the mean of PTS at each time point. It was seen that a significant difference was present between time points 4 and 1, 4 and 2, 4 and 3, and 3 and 2. This revealed that a significant increase in PTS occurred after 4th week of the regime with minimal changes after the 2nd week.

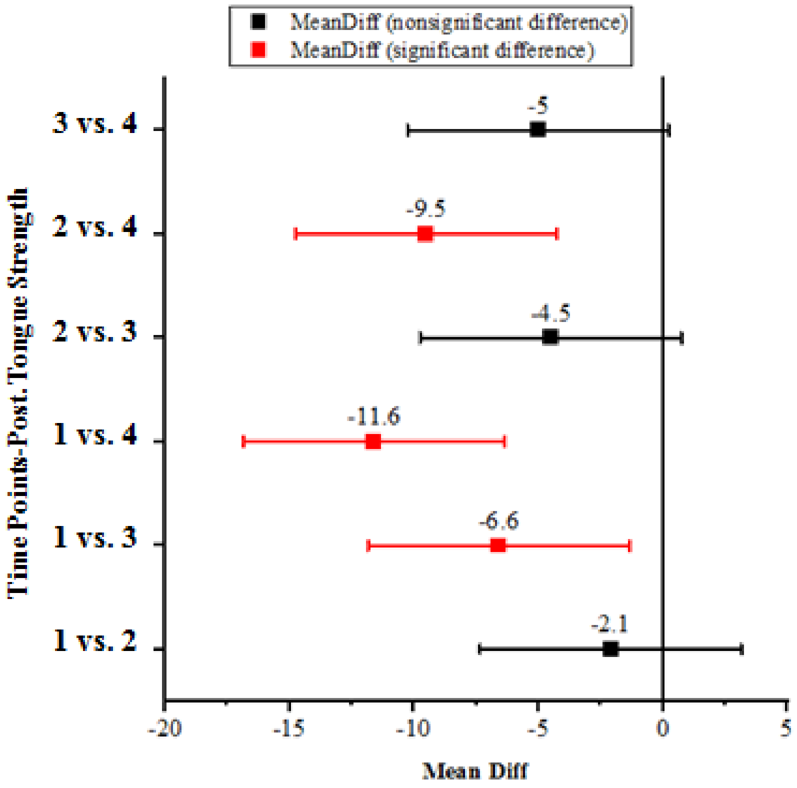

Figure 4.4 Pairwise comparison of PTS values using mean difference at various time points.

Interaction between ATS and PTS

It is of interest to examine the interaction between anterior and posterior tongue measures because previous investigations have shown an increase in posterior tongue strength with strengthening exercises applied only to the anterior tongue (Yano et al., 2019).

To test the hypothesis that there was no significant interaction between ATS and PTS, a two-way ANOVA was performed. It revealed that there was a significant main effect in both ATS and PTS over time (p = 0.000). However, there was no significant interaction between ATS and PTS measures over the 6-week effortful swallowing regime (*p* = 0.956) (Figure 4.5). Furthermore, figure 4.5 showed no significant difference in increment between ATS and PTS (*p* = 0.253).

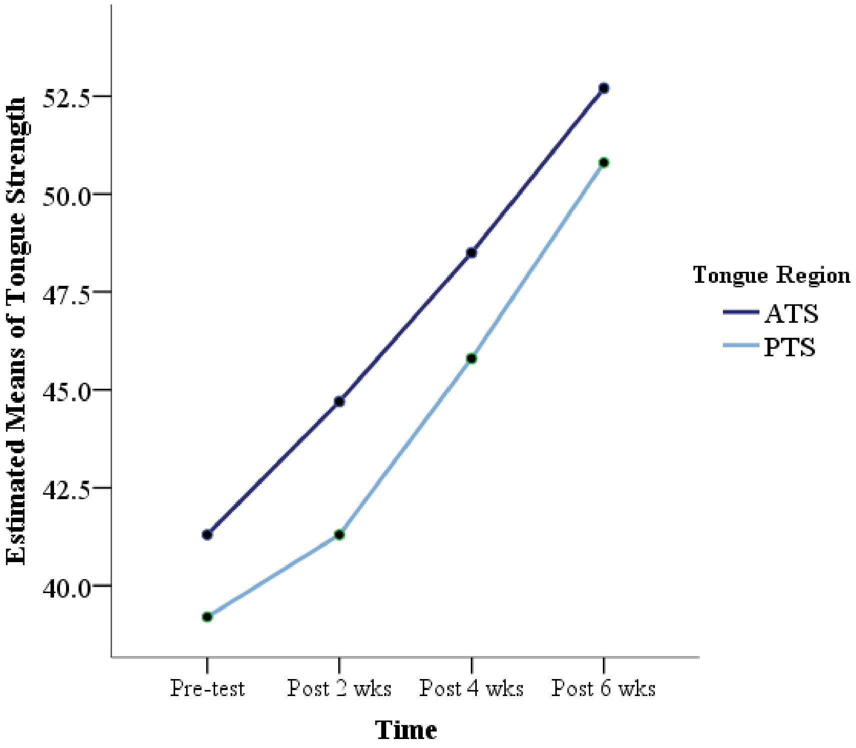

Figure 4.5 Growth of ATS and PTS at different time points. Note that there is no overlap of the mean values across time. However, the lines converge asymptotically.

Anterior Tongue Endurance (ATE) and Posterior Tongue Endurance (PTE)

The mean and standard deviation of ATE and PTE obtained from the group of 10 participants at each time point is tabulated below (Table 4.5). It can be noted Note that the mean and standard deviation of ATE and PTE increased with time.

Table 4.5

Descriptive statistics of Anterior and Posterior Tongue Endurance (ATE and PTE)

Time points	**Dependent Variable**	**Anterior Tongue Endurance**		**Posterior Tongue Endurance**	
		Mean (sec)	**S.D**	**Mean (sec)**	**S.D**
1	Pre-test (baseline)	13.40	4.55	8.90	2.64
2	Post 2 weeks	19.10	11.10	11.80	5.16

3	Post 4 weeks	24.60	16.13	14.70	6.63
4	Post 6 weeks (post-test)	29.70	16.31	18.10	6.52

One-way repeated measures ANOVA showed statistically significant increment in ATE and PTE, defined by the main effects, $F(3,27) = 6.633$, $p = 0.002$, $\eta^2_p=0.424$, and $F(3,27) = 13.959$, $p = 0.000$, $\eta^2_p=0.608$, respectively. Bonferroni corrected multiple pairwise comparisons were made between pairs of time points. The results showed significant increase in ATE and PTE after the 4th week of the regime, given by ($p = 0.006$) and ($p =0.025$) respectively. The results of Bonferronni test has been depicted in table 4.2

The figure 4.6 shows the pairwise comparison of the mean differences of ATE between the time points. From table 4.2, it was clearly seen that the significant difference was present between time points 4 and 1, 4 and 2, and 4 and 3. This revealed that a significant increase in ATE occurred after 4th week of the regime.

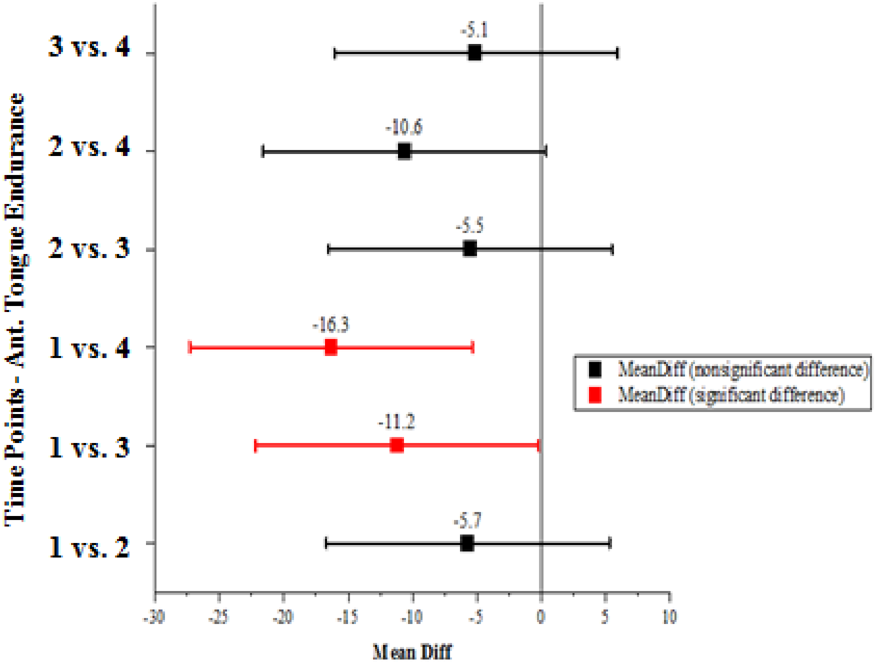

Figure 4.6 Pairwise comparison of ATE values using mean difference at various time points.

The figure 4.7 shows the pairwise comparison of the mean difference of PTE between the time points. From table 4.2, it was seen that a significant difference was present between time points 4 and 3, 4 and 2, and 4 and 1. This revealed that a significant increase in PTE occurred after 4th week of the regime.

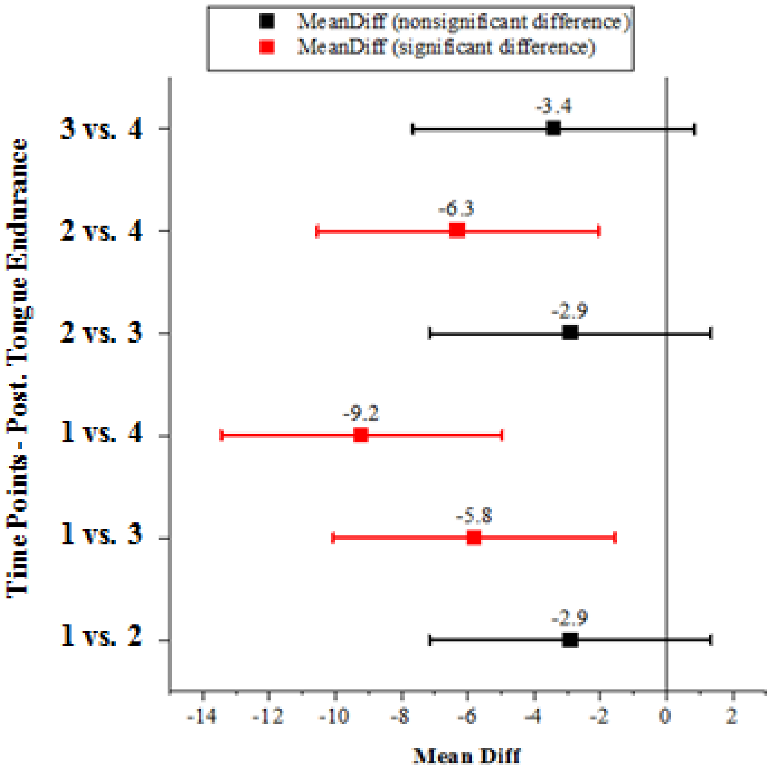

Figure 4.7 Pairwise comparison of PTE values using mean difference at various time points.

Interaction between ATE and PTE

To test the hypothesis that there was no significant interaction between ATE and PTE, a two-way ANOVA was performed. The results showed that there was a significant main effect in both ATE and PTE over time (p = 0.000), but there was no significant interaction between ATE and PTE measures in any of the time points (p = 0.956). However, there was a significant difference between the growth of ATE and PTE over the time flow (p = 0.009) (Figure 4.8). Notably, a comparison of the p values of ATE and

PTE showed that the increase in ATE was more significant than the increase in PTE on completion of the exercise.

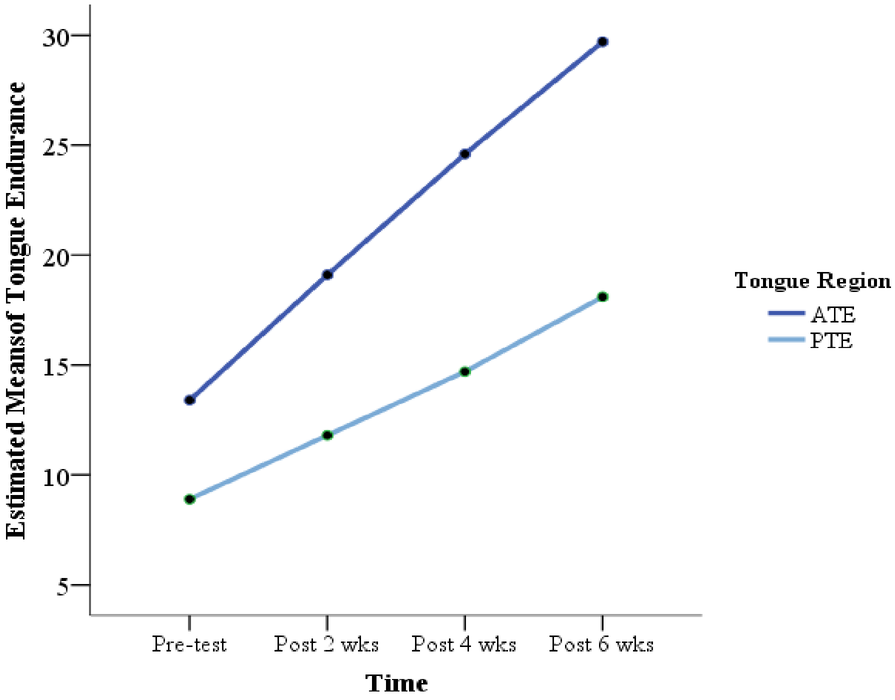

Figure 4.8 Growth of ATE and PTE at different time points. Note that there is no overlap of the mean values across time.

Swallowing Capacity

The mean and standard deviation of swallowing capacity (SC) obtained from the group of 10 participants at each time point is tabulated below (Table 4.6). It can be noted that the mean value increased from time point 1 to 2. However, at the end of the fourth week, there was a small decrease followed by a further increase at the end of the sixth week.

Table 4.6

Descriptive statistics of Swallowing Capacity

Time points	Dependent Variable	Mean (ml/sec)	Std. Deviation
1	Pre-test (baseline)	22.43	5.71
2	Post 2 weeks	25.83	7.46
3	Post 4 weeks	25.17	7.14
4	Post 6 weeks (post-test)	32.17	11.81

Non-parametric Friedman test was carried out to compare the effects of the effortful swallowing exercise on SC, measured at four time points, Pre-test (baseline), post 2 weeks, post 4 weeks and post 6 weeks(post-test) of the 6-week exercise regime. There was a statistically significant difference in the mean values of SC after the completion of the 6-week regime. The results rendered a Chi-square value of 8.36, which was significant ($p = 0.039$).

Post hoc Wilcoxon signed-rank test was conducted, which showed significant difference in SC between time point 1 and time point 4 (/z/ = 2.21, $p = 0.03$) and between time point 3 and time point 4 (/z/= 2.11, $p = 0.04$). Thus, the results implied that a statistically significant improvement occurred in SC after the 4th week of the exercise regimen, though negligible changes were seen before 4th week. The means of SC at each time point has been depicted in the figure 4.9.

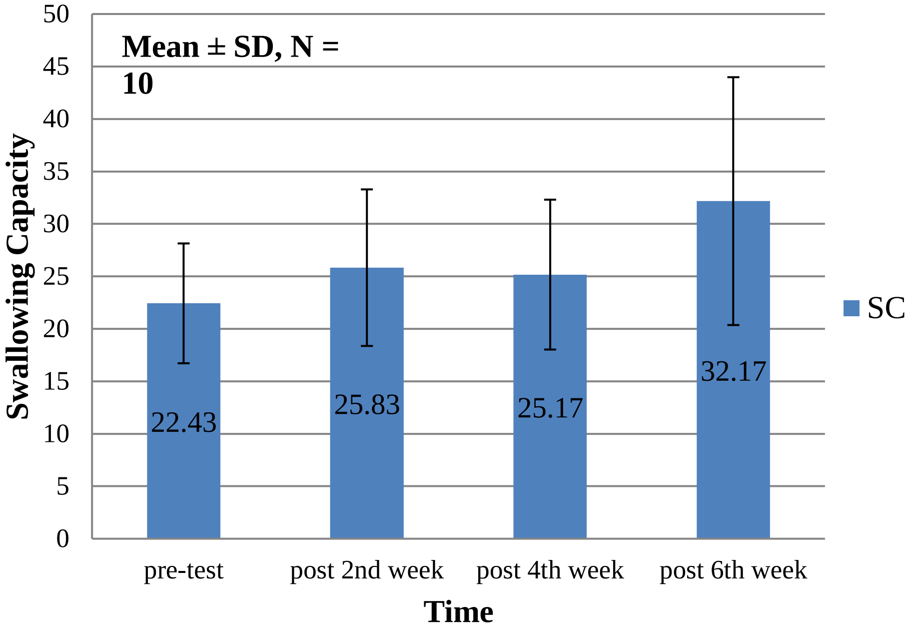

Figure 4.9 Means of SC at each time point showing increase according to the flow of time over the 6-week effortful swallowing regime. The 95 percent confidence intervals are shown by the error bars.

To summarize, the analysis showed significant positive results for Lip strength and endurance measures, Anterior and posterior tongue strength and endurance measures with consistent growth patterns over time. Comparatively, reduced yet statistically significant increase is found in swallowing capacity although a consistent growth trend is not seen. However, interaction between anterior and posterior tongue strength measures and between anterior and posterior tongue endurance measures does not show statistical significance as expected. The next chapter of this paper provides coherent discussions which can serve for a better understanding of the results of the statistical analyses.

CHAPTER V

DISCUSSION

Effortful swallowing is a maneuver profoundly scrutinized in literature, especially in terms of its rehabilitative scope. Studies have given positive expression in adopting this technique as a therapeutic source in the clinical ambience. However, there still are unattended areas not limited to swallowing capacity, anterior and posterior tongue interaction, changes in lip measures etc., for which literature has not provided sufficient evidences. The present study attempted the best to inquest into few of the missing information and contributes to fill the tarrying lacuna for future researchers.

The purpose of the study was to identify the main effects in the swallowing-related measures, namely, lip strength, lip endurance, anterior tongue strength, anterior tongue endurance, posterior tongue strength, and posterior tongue endurance in young adults on completion of a 6-week period of controlled effortful swallowing regime and to examine the course of the changes that happened by continued monitoring at four different time points, pre-test, post 2 weeks, post 4 weeks and post 6 weeks (post-test). Also, exploration of any interaction between anterior tongue and posterior tongue in terms of strength and endurance was also an intended objective. Overarching aim was to probe into the transferability of effects of effortful swallowing as a strengthening technique to lip functions, which is unreported till date and applicability of the observed results, if ever, to the population with dysphagia.

The study showed that all the seven variables achieved increases on completion of the exercise regime. However, it identified varied patterns of results with respect to each variable. The results are interesting in that a single maneuver has caused improvements in varied aspects of swallowing.

Earlier studies have shown that direct application of pressure over the lip and tongue, exerting its musculature using tongue depressor, IOPI, oral screens, certain training strategies such as tongue-to-palate resistance training (TPRT) (Kim et al., 2017) or the use of other therapeutic devices, for example, Madison Oral Strengthening Therapeutic (MOST) device (Juan et al., 2013) have provided convincing results in the literature in improving lip and tongue strength and endurance measures and thereby swallow efficiency.

Previous studies have largely examined healthy elderly population (age range=70-89 years) (Robbins et al., 2005) and elderly individuals (age range=42-93 years) with dysphagia (Kim et al., 2017; Park et al., 2019; Robbins et al., 2005; Robbins et al., 2007; Steele et al., 2013). Very few researchers have reported the effect of tongue strengthening exercises in young healthy population (Clark & Shelton, 2014). Moreover, specific effects of an effortful maneuver regime on tongue and other swallowing related measures lacked scrutiny among the research bodies. Certainly, lip measures remained understudied over a long period in the history.

Also, intervention for the treatment groups was not always limited to tongue interventions but included conventional dysphagia therapy techniques such as effortful swallowing, thermal tactile stimulation, facial massage, and compensatory maneuvers or range of motion exercises (Smaoui et al., 2019). These facts make the current study unique from other studies. Nevertheless, decent similarities can be drawn from the extant literature to enjoy better comparisons and validate the detected results.

Lip Strength and Endurance

The first objective of this study was to investigate the effects of effortful swallowing regime on lip strength and endurance. The exercise regime rendered significant main effects in strength and endurance measures which were time significant, i.e. the significance of change increased over the duration. The results were consistent with many of the previous studies (Fujiwara et al., 2016; Yoshizawa, Ohtsuka, Kaneka & Iida, 2016) although there was no report of lip strength training effects through effortful swallow regime in particular. Previous studies used a variety of tools like oral screens (Thüer & Ingervall, 1990), IOPI (Hee-Su et al., 2018; Park, Kim, & Oh, 2015) and lip trainer/strength fixation devices (Kaede et al., 2016). Also, strategies like, lip closure training (Fujiwara et al., 2016), resistance training (Hee-Su et al., 2018) etc., were found to be adopted for the studies reported in literature.

In the present study, significant training effect was found to show up after the 4th week of the effortful swallow regime. However studies report training effect appearing as early as 3rd week in healthy participants as a result of other resistance training protocols. Kaede and colleagues, in 2016, investigated the effect of lip–closing force in healthy young adults after a 4 week period of lip-closing training using a lip muscle strength fixation device called M patakara (Kaede et al., 2016). They found significant regional increase in lip closing force in the 3rd and 4th week of the training session when compared to the control group who received no treatment (Kaede et al., 2016).

Surprisingly, a few researchers reported that changes in lip strength were seen as early as the 8th day of the exercise program. Fujiwara et al. studied 66 healthy Japanese women who went through 7 days of lip strengthening training using oral screens. The changes were measured across the duration at baseline, 6th and the 8th day and they found a significant increase of lip strength over time (Fujiwara et al., 2016).

Ibrahim et al, in 2013, studied the effects of lip strengthening exercise regime using lip trainer for 14-24 weeks on labial closure strength in healthy participants and found that there was a significant increase in labial closure strength at the end of 14 weeks of training.

Researchers report that advanced changes not necessarily stand as lasting changes and almost all the authors have observed forthwith detraining effects even within one week post termination of the exercise. Such advanced changes may be allegedly due to the higher dosage involved in the strength training protocols. Moreover, the use of effortful swallowing maneuver as a strength training strategy in the present study makes it incomparable with other previous studies which have operated on other different exercise strategies.

Reports of lip endurance training effects in literature are very limited. Yoshizawa and colleagues used oral screen set at 80% of maximum strength to train 10 young men and 10 young women with lip incompetence for a period of 4 weeks. They found that lip strength and endurance improved gradually and significantly over the course (Yoshizawa et al., 2016).

Studies have measured that the mean maximum lip strength and lip endurance for young women were found to be 11.4±3.8 kPa and 22.4±21.7 seconds respectively (Jeong et al., 2017). These values are found to be much lower than the baseline measures obtained from the present study where the mean maximum lip strength is 32.20±6.5 kPa and endurance is 43.60±26.43 seconds. The reasons for the difference stems more likely from the ethno-cultural variations in the population studied. However, similarity in standard deviations of both the measures proves the broadness range of scores obtainable.

A threat that makes the measurement of lip functions liable to err is the likely assistance of other mechanism in generating the most extreme values. If the teeth had inadvertently aided lip pressure generation, scores would be spuriously high (Clark &

Solomon, 2012). This demands mindfulness in future examiners to watch participants closely during the assessment, especially when using IOPI.

Adequate and efficient lip closure has proven to shorten eating time, decrease food spill rates, and thereby decrease daytime sleeping. Also, on a wider scale, during lip closure, significant increase in prefrontal cortical activity is identified. In addition, the increase rate in the right dorsolateral prefrontal cortical activity after the intervention period was significantly correlated with the increase rate in the maximal lip closure force after the intervention period (Takamoto et al., 2018).

The findings of lip strength and endurance measures in the present study provide preliminary support to the literature on the efficacy and concurrent benefits of the effortful swallowing maneuver in the light of improving lip functions. However, since diverse techniques and tools were employed for training interventions, standardizing the measuring strategies and training equipment are reckoned to be imperative in the future clinical field.

Tongue Strength and Endurance

The second objective of this study was to investigate the effects of effortful swallowing regime on anterior and posterior tongue strength and endurance. The third objective was to explore any interaction between the anterior and posterior tongue in strength and endurance measures. The exercise regime rendered significant main effects in strength and endurance measures which were time significant. The results were consistent with many of the previous studies.

Researchers have suggested that separate assessment of physiological aspects of effortful swallowing be made for better understanding of the potential of the maneuver in addressing the targets that are paramount in establishing healthy and safe swallow (Bahia

& Lowell, 2020). On that note, this study tracks the changes in strength and endurance measures of anterior and posterior tongue distinctively, notwithstanding the obligation for parallel assessments to document the interaction of anterior and posterior tongue measures too.

As mentioned earlier, studies reporting tongue strength and endurance measures together are sparse. Studies reviewing the application of effortful swallowing as a rehabilitation technique in dealing with tongue and lip weakness and swallow inefficiency are rather sparse and a fortiori, there are only a handful of studies investigating the training effects of effortful swallowing on all the mentioned targets of the current study.

Earlier studies have extensively studied the training effects of tongue in terms of tongue strength and some studies of tongue endurance, regardless of its anterior and posterior region. Various tongue strengthening techniques were reported to be adopted, not limited to oro-myofunctional exercises (Ibrahim et al., 2013), isometric progressive resistance therapy (Juan et al., 2013), tongue-to-palate resistance training (Kim et al., 2017), isometric lingual strength training (McKenna, Zhang, Haines, & Kelchner, 2017), lingual resistance training (Smaoui et al., 2019), tongue pressing strength and accuracy training (Steele, 2013) etc. Also, instruments and other therapy approaches like IOPI, tongue depressor, McNeil Dysphagia Therapy Program (Crary et al., 2012) have been found to give positive results in some of the aspects of swallowing but are overlooked in the literature due to non-transferability to the entire swallow mechanism and a relatively weak study design.

Anterior Tongue Strength (ATS) and Posterior Tongue Strength (PTS)

In the present study, significant training effects on anterior tongue strength (ATS) and posterior tongue strength (PTS) were found. Although the prescribed exercise duration was six weeks, significant increase in ATS was observed in the 4th week and in PTS in the 2nd week of the effortful swallowing regime. Specific effects of one exercise protocol as target lacks adequate investigation as the literature reports training effects of multiple exercises applied together on a single experimental group. This makes it scientifically difficult to analyze the effects of a particular technique in question. With that mentioned, training effect of effortful swallowing maneuver on tongue strength is investigated less, with respect to distinctive changes in anterior and posterior tongue regions.

Clark and Shelton studied the effects of 4-week modified effortful swallow training (augmented with lingual elevation and high effort sips) and found greater than control group but non-significant increase in anterior lingual palatal pressures and anterior tongue maximum isometric pressure (MIP) in healthy adults (Clark & Shelton, 2014).

Park et al, in 2019, in their randomized controlled trail, studied the effects of a 4-week effortful swallowing training on tongue strength, separately on anterior and posterior tongue region in 12 stroke patients with dysphagia. They found significant increase in anterior and posterior tongue strength post training (Park et al., 2019).

A few of the studies have studied the effects of effortful swallowing in combination with other training techniques in dysphagia population. Park et al, in 2012 investigated the effects of effortful swallowing training combined with electrical stimulation in stroke patients with dysphagia. They reported significant increase in the hyoid elevation and greater but non-significant increase in UES opening after 4 weeks of training although no report on the effect of tongue musculature were observed (Park, Kim, Oh, & Lee, 2012).

From the aforementioned studies, significant changes both in anterior and posterior tongue were found to occur after 4th week of the exercise regime in both healthy and non-healthy groups. This partially conforms to the results of the present study with respect to anterior tongue strength which also showed significant increase after the 4th week.

However, posterior tongue strength showed significant increase as early as the 2nd week of the regime. Such an earlier increase may be because the study involves healthy and young adults undergoing the regime. In young, healthy population, the tongue function is indisputably sound and intact and hence, application of strength training will effortlessly produce phenomenal effects on the structures of target (Langmore & Pisegna, 2015). Moreover, effortful swallowing intrinsically imparts greater pressure on the base of the tongue and the posterior pharyngeal regions (Doeltgen, Ong, Scholten, Cock, & Omari, 2017; Takasaki et al., 2011) which implies that posterior tongue regions are exerted more than anterior tongue region (unless voluntary pressure is applied) when an effortful swallow is performed. These findings favourably explain the early changes happening in the posterior tongue strength.

The present study stands peerless that it investigates the effect of anterior and posterior tongue strength separately after an effortful swallowing regime. Considering the normative values, the combined values (not specific to anterior and posterior tongue) of mean maximal tongue strength for young women was found by different researchers to be 32.1±7.9 kPa (Jeong et al., 2017), 47 kPa (Vanderwegen, Guns, Van Nuffelen, Elen, &

De Bodt, 2013) in different ethnicities. These values roughly match with the baseline values found in the present study, where the mean maximum anterior tongue strength and posterior tongue strength are 41.3±11.5 kPa and 39.2±10.9 kPa respectively, which may show that tongue strength measures are quite resistant to ethno-cultural variations.

Though the available evidence is meagre, foundational insights are provided by the above-mentioned studies. These include the possible changes on tongue that can be expected after an exercise regimen, like effortful swallowing maneuver, in this case. The studies have well confirmed the effects of strengthening exercises on tongue strength, though not the differential effects on anterior and posterior tongue regions. Mindfulness is warranted that there are no parallel studies to compare the results with the obtained results.

Interaction effects

Only one study has investigated the interaction effects between anterior and posterior tongue strength measures after a lingual strengthening exercise program. Yano et al, in 2019, recruited eleven healthy participants for tongue pressing strength training targeting the anterior tongue for 8 weeks. They examined if training to the anterior tongue resulted in changes in the posterior tongue. The results showed significant increase in Maximum Tongue Pressure (MTP) in both anterior and posterior tongue after the 8-week training, confirming the presence of interaction effects.

But, the present study failed to display any interaction effects between anterior and posterior tongue strength measures. However, referring back to figure 4.5, it is found that the ATS and PTS curves asymptotically converge as the time increases. This gives a valuable notion that the measures perchance interact if training and observation are lengthened in terms of duration or if the sample size is increased. Conformingly, earlier studies have shown significant interaction only after the 8th week. This calls for a study design with longer exercise duration to trace the asymptotic growth of the values and also the point of convergence which will provide adequate understanding on the amount of training necessary to evoke interaction and carried over effects between the anterior tongue and posterior tongue.

Anterior Tongue Endurance (ATE) and Posterior Tongue Endurance (PTE)

In the present study, significant training effects on anterior tongue endurance (ATE) and posterior tongue endurance (PTE) were found on completion of the effortful swallowing regime. Although the prescribed exercise duration was six weeks, significant increase in ATS and PTS was observed in the 4th week of the effortful swallowing regime.

In the current literature, there is no single study investigating the effects of tongue endurance measures after an effortful swallowing regime.

To mention one of the very few of the studies related to tongue endurance measurement, Clark investigated the specificity training of with respect to a four exercise parameters for the lingual musculature in twenty five healthy individuals. The participants underwent 4 weeks of lingual exercise targeting on the parameters, strength, endurance, speed and power. He found that tongue endurance training did not improve performance of tongue endurance, concluding that specificity of endurance was not statistically significant (Clark & Solomon, 2012).

Comparing ATE and PTE, PTE showed the greatest significant increase on completion of the effortful swallow regime, which signifies again the additional influence of effortful swallow on the posterior tongue in relation to the anterior tongue. In the present study, the mean maximum ATE and PTE measured at baseline is 13.4±4.6

seconds and 8.9±2.6 seconds respectively. These values are much lower than the established normative values of the combined tongue endurance, 26.9 seconds (Vanderwegen et al., 2013), 20.8±13.5 seconds (Jeong et al., 2017) obtained from different ethnocultural groups. This disparity could be due to measuring errors or contributed by ethnic factors.

Although significant, endurance measures show overall flat curves relative the strength measures. Note that, in regard to tongue endurance measures, as the achievable strength increases over the exercise course, the 50% adjustment of maximum strength for endurance measurement increases according to the methodology of the study. This makes the endurance target dynamic though the strength values remains undisturbed. Thus as strength increases, there is no surprise that the endurance values remain unchanged. But in the present study, endurance values showed significant increase over the course. Also, according to recent studies, regardless of training, endurance remains almost stable throughout life (Vanderwegen et al., 2013).

Interaction effects

No study in the entire literature has investigated the effects of interaction between ATE and PTE measures over the course of any strength training exercise, let alone the effortful swallow regime. Unlike strength measures (ATS and PTS), it can be seen that from figure 4.8, ATE and PTE does not show any sign of convergence, but a sharp divergence along with increase in time! This may probably connote that there is zero interaction between ATE and PTE regardless of the exercise duration. Best explanation for this trend can be drawn from the fundamentals of muscle physiology. The type of muscle constituting the anterior and the posterior tongue is entirely different. Anterior tongue is composed majorly of fast –twitching, quick adapting Type 2 muscle fibres and posterior tongue is made of easy-fatiguing, slow twitching Type 1 fibres. More precisely, anterior tongue comprises a mixture of Type 1 and Type 2a muscle fibres which enables anterior tongue for exhibiting low forceful but high enduring movements, necessarily designed for efficient feeding (Oh, 2015).

Now, put simply, anterior tongue possesses potential to achieve greater scores in both strength and endurance (Type 1+Type 2a) whereas posterior tongue is less adaptable and can achieve better values in endurance (Type 1) measures (Kent, 2004). This muscle physiology pattern is par excellence the pattern obtained in the strength and endurance measures of anterior and posterior tongue. Thus is the divergence between the ATE and PTE curves.

Greater the understanding of muscle physiology before planning rehabilitative programs is, better facilitated is the progress of the exercise in accomplishing the targets.

Worth mentioning, differences are likely to occur among the comparable values of tongue measures (strength and endurance) in different studies, because other tongue strengthening exercises exert anterior tongue region to a greater extent, unlike the effortful swallowing maneuver whose primary target is the posterior tongue muscles.

Swallowing Capacity (SC)

The fourth objective of this study was to assess any change in swallowing capacity after the 6-week period of effortful swallowing regime. The exercise regime rendered significant main effects in swallowing capacity measures which were not time significant. Significant increase appeared only after the 4th week of the regime.

There are no parallel studies in the literature to assess the consistency of the obtained results. However, other aspects of swallowing like durational factors, swallow safety have been adequately reported in the literature in the context of lingual strengthening exercises.

Tongue strengthening exercises influencing swallow function is not any unusual phenomenon is the literature. Over the years, lingual resistance training has been proposed as an intervention to improve decreased tongue pressure strength and endurance in patients with dysphagia. Alterations in swallowing physiology were reported largely in terms of temporal measures observed in instruments like VFSS such as oral transit time, pharyngeal time, oral clearance duration and the like (Park, Kim, & Oh, 2015), in terms of swallowing safety which was found to improved by the scores of Penetration Aspiration Scale (PAS) (Steele et al., 2013) an also in terms of swallowing efficiency. Standardized rating scales were employed in order to quantify the improvement post lingual training regime (Robbins et al., 2007). However, little is known about the impact of lingual resistance training on swallow capacity (Smaoui et al., 2019).

In an isometric lingual strength training program applied to 10 healthy older adults for 8 weeks, Robbins et al found that, lingual strengthening produce significant increase in not just lingual pressures and volumes but also showed promising evidence for improved swallow function (Robbins et al., 2005).

Functional outcomes were also commonly reported to be improved after a lingual training program. Carnaby, Hankey, and Pizzi in 2006, compared the effects of standard low-intensity intervention, standard high-intensity intervention and usual care for a period of 1 month in 306 patients in three groups with dysphagia post acute stroke and found significant decrease in swallowing induced medical complications and non-significant reduction in mortality post the exercise. They also found 32% of the participants returning to normal diet, showing functional swallow without any swallowing issues

(Carnaby et al., 2006). Another study by Carnaby-Mann and Crary showed significant improvement patient perception of swallowing ability, functional oral intake and weight gain in a group six patients with chronic pharyngeal dysphagia after completing a 15-day protocol of effortful swallow combined with Neuromuscular Electrical Stimulation (NMES) (Carnaby-Mann & Crary, 2008).

There are no studies reporting swallowing capacity as a sequela of effortful swallowing regime in healthy participants. This is mainly because swallowing capacity is not regarded as a powerful and sensitive tool in assessing swallowing function. Yet, this present study can be give valuable insight since the result is in accord with the long-standing fact that lingual strengthening has positive influence on swallowing function. Though swallowing capacity is not a powerful and sophisticated measure, it can function as an easy, immediate and quick office tool to represent the swallowing function at its best.

CHAPTER VI

SUMMARY AND CONCLUSION

A thorough review of the literature revealed great lacunae in dysphagia science, especially with respect to its management. Practitioners had long been embracing conventional compensatory techniques and oral-motor training in swallowing therapeutics. Researchers have also remarked the lack of certainty in efficacy of dysphagia intervention among clinicians and scientists. Campbell-Taylor put forth his pessimistic conclusion about the hazards of ineffective interventions and lack of training among the clinicians while stating the need for vigorous manpower development (Campbell-Taylor, 2008). In response to his interpretation, an assortment of researchers brought hopeful perspective by raising pivotal research questions to be addressed (Coyle et al, 2009). Events such as these stirred up the research for dysphagia management, rightly recognizing the pressing need for intervening in the field of intervention. In recent history, rehabilitative approach for therapy has gained commending responses in the field of swallowing therapy. This served as an impetus for the current study to inquire further.

The present study aimed at studying the effects of a compensatory swallowing maneuver, which is widely applied in dysphagia management called the Effortful Swallowing Maneuver on seven swallowing related measures, namely, lip strength (LS), lip endurance (LE), anterior tongue strength (ATS), anterior tongue endurance (ATE), posterior tongue strength (PTS), posterior tongue endurance (PTE), and swallowing capacity (SC). The notable fact is that the effortful swallowing maneuver was used under the guise of a rehabilitative technique in improving the above-mentioned measures over a period of six weeks. A single group time series designed was adopted and a convenience sample of ten healthy participants underwent the 6-week controlled effortful swallowing regime using water bolus. All the parameters showed significant main effects with respect to time, although interaction effects between parameters showed non-significance. The study also identified the time points at which significant improvement could be noticed over the regime. Although the improvement followed a linear course, significant change became tangible at the 4th week of the regime for most of the parameters. The results were appreciable and in par with the reported literature.

The effortful swallow maneuver has positive evidences and approval among the clinical fraternity and the research bodies to be employed as a successful rehabilitative approach. The present study adds to the literature the fact that, effortful swallowing, if adopted in a controlled manner, can entertain influence on most of the structures in the swallowing mechanism. This study attempted to create evidences regarding the long-term training effects of effortful swallowing regime on tongue and lip musculature. The latter in particular, has emerged to be a basic research trial in the literature, as lip functions post effortful swallowing regime has never been enquired. Also, promising results have been obtained with respect to swallowing capacity in the current study.

Having known the benefits of effortful swallowing maneuver, it is meaningful to apply the technique in clinical set up. Researchers have recommended the use of biofeedback along with effortful swallow in rehabilitating oropharyngeal dysphagia (Felix, Corrêa, & Soares, 2008). Also, investigations should be done on standardizing the instructions to elicit the effortful swallow maneuver based on the functional and physiological effects of the maneuver (Bahia & Lowell, 2020).

Advantages of the study

Unlike other studies, this study has adopted a time series design that has aimed at tracking the improvement in the dependent variables over the 6 week course. This provides multiple values which allow for better comparisons and inferences.

While previous studies used non-bolus methods in lip and tongue strengthening trainings, it is advantageous that a water bolus was used for the study, because of the necessity to inevitably study the lip and tongue measures with respect to oral containment, bolus management and manipulation effectiveness as pointed out by Clark and Solomon in their study on orofacial strength (Clark & Solomon, 2012).

Klein and Jones point out that necessity in understanding to devise appropriate time windows and to recommend sufficient duration for the training in question in order to bring about changes at the re-organizational level in the brain so that improved functional outcomes can be met. For this, a training that adapts a rehabilitative approach is essential. This present study satisfies the rehabilitative requirements and goes in harmony with the recommendations of the earlier reviews (Kleim & Jones, 2008).

In addition, the present study conforms to the exercise standards described by reliable research articles basing their descriptions to principles of neuroplasticity (Kleim & Jones, 2008). The effortful swallow maneuver employed as a rehabilitative technique in this study is harmonious with the exercise principles described as follows.

The first and the second principles “use it or lose it” & “use it and improve it” respectively are actualized when the participants engage all the muscles of swallow in eliciting an effortful swallow along with the main targets of this study, the lip and the tongue muscles. The effortful swallow as a therapy technique, unlike other tongue strengthening techniques such as lingual resistance training, tongue pressing techniques, etc., ensures the exertion of muscles at all the phases of swallowing from lips to UES. This prevents lack of activity among the muscle groups in as much as failure to use the muscles of target makes the expected results questionable. The third principle, “specificity” is best applied through the effortful swallow maneuver, evident by the maximal use of lips and tongue, especially the posterior part in performing the effortful swallow. Studies have proven that the amount of exertion occurring in the base of tongue is significantly greater than that of a normal swallow or even other tongue strengthening exercises (Clark & Shelton, 2014; Coulas et al., 2009). The fourth principle is "transference" and is addressed well by the effortful swallow maneuver. This is supported by the studies which reported effects of effortful swallowing down till the esophageal sphincteric muscles and also functional aspects like swallowing efficiency and safety, let alone the tongue and lip muscles. Supporting studies are those which proved that effortful swallowing resulted in improved UES relaxation (Huckabee et al., 2005), longer pharyngeal pressure generation (Felix et al., 2008; Witte et al., 2008), longer hyoid excursion (Jang et al., 2015) and reduced risk for aspiration (Hind et al., 2001) and the like, although conflicting results should not be neglected. The fifth principle is called "intensity" and is tacitly evident in the study by the very instruction for the elicitation of the maneuver which says "swallow as hard as possible". The effortful swallow maneuver is sufficiently intense to exert the system beyond normal activity level resulting in larger adaptation effects. Warren and Fey emphasizes the necessity of checking the treatment intensity to avail effective treatment outcomes (Warren, Fey, & Yoder, 2007). The other principles like "repetition" and "time" are well appreciated in the present study by ascertaining that the participants undergo sufficient duration and dosage of training, that is, twenty swallows, every day for six complete weeks as recommended by previous investigators to satisfactorily await a change in lip, tongue muscles and the swallowing capacity.

Most of all, this study, being performed in healthy population can show possible firsthand benefits of effortful swallow, unadulterated by any disease condition, which can be foundational in informing the clinical fraternity of its pros and cons in applying this treatment strategy to individuals with dysphagia.

Limitations of the study

Although the study provided significant positive results and complied well with the established standards and the exercise principles, it is not devoid of limitations. Probing the source of the limitations and addressing them will provide the researchers a better direction for future investigations.

Significant positive results on almost all the dependent variables addressed in this study gives room for doubt in the methodology of the study. Since the present study has adopted a single group time series design, it is wise to take into account the single group threats. For this study, two single group threats can be applicable which can potentially contradict the obtained significance.

First threat is the instrument effect. The instruments used in measuring the variables for this study are the Iowa Oral Performance Instrument (IOPI) and the researcher herself. IOPI was used to measure the strength and endurance measures of lip and tongue and the researcher acted as the monitor and calculator in collecting values of swallowing capacity. Instrument effect is mainly induced by the inevitable variations in the instrument operation from one time to other during the collection of data. This threat is further maximized by the multiple data collection since time series design is the adopted methodology. Data was collected at pre-test (baseline), post 2nd week, post 4th week and post 6th week (post-test). Literature points out that instrumentation threats are more likely to occur when the “instrument” is a human observer. Also, as mentioned earlier, since researcher is one of the instruments, the manner of observation at each time point of data collection is largely vulnerable to alteration which can be attributed to multiple factors like health, mood, growing better in observation skills, etc.

Second threat is the practice/testing effect. This means that, when using an instrument (IOPI-in the present study) to collect data, practice obtained in using the instrument at the initial assessment/test will have influence on subsequent tests. This can increase the likelihood for false positive results.

Another limitation which is noteworthy is lack of adherence to the treatment (Clark & Shelton, 2014). Certainly, factors to promote adherence were inadvertently neglected that led to loss of participants. In this current study, major non-adherence confounds were lack of submission of exercise logs, intermittent failure to monitor the regime, lack of motivation in the participants group and some duration factors.

The other limitations include lack of control group, lack of randomization of the sample, small sample size (n=10), though a time series design, recruitment of healthy participants (convenience sample) instead of non-healthy individuals. An important point to notice is that the training effect could be higher in healthy people than non-healthy participants (Wong et al., 2020). This is because of the amount of neural deprivation or the structural aberration that stakes the normal swallowing mechanism. So, researchers should be conscious that the same results of the present study cannot be carried over thoroughly to the population who suffered stroke or any craniofacial anomalies presenting with dysphagia.

Also, the current study did not investigate the detraining effects of the effortful swallowing regime, which could have been a potential predictor of the efficacy and "generalizability" of the training protocol for clinical utility. Few studies have reported that detraining occurred in lingual strengthening exercises within one week of termination from the exercise (Kaede et al., 2016). This fact provides a future direction for a better study design.

These limitations are worth considering for scrutinizing the forthcoming research attempts for greater productivity. Controlled studies with larger sample sizes are needed to best serve the purpose of identifying an efficacious intervention program for patients with dysphagia. Also, while doing so, it is imperative to be mindful of the underlying statistical threats, adopting meaningful inclusion and exclusion criteria, use of sensitive instruments for measurement, factors promoting adherence to treatment, and lastly, effective duration of the training that are necessary to address both training and detraining effects.

Clinical Implications

The positive effects of effortful swallowing maneuver on lingual, labial measures and swallowing capacity show that it can be adopted for therapeutic application, particularly, in patients with oro-pharyngeal dysphagia. Thus, this maneuver can be used temporarily as a compensatory strategy in the commencement of swallowing therapy. And simultaneously, rehabilitative needs of the patients can be met by utilizing it in an exercise regime. Thus, effortful swallowing regime can serve for both immediate and long-term goals in dysphagia therapy. Immediate effects can be, not limited to, reduction in the risk for aspiration by prolonged tongue base and pharyngeal wall contact, facilitation of compensatory swallow and also to keep the muscles and structures in activity, since this maneuver is not a passive procedure, ensuring that they remain in use. Long-term effects can be manifold, such as strength training of the involved muscles, improved swallowing capacity, which directly influences feeding and social eating. All these long-term changes are indicators of cortical level reorganizations and adaptations.

Having been informed about the multi-component effects of effortful swallowing throughout the swallowing mechanism, it is implicit that the clinical realm can be well benefitted by the use of effortful swallowing as a “rehabilitative strength training procedure”. Future researches can be directed towards standardization of the technique, application on patient population, and meta-analysis of the established findings for better practice. Also, effects of eating habits, talkativeness on the efficacy of the effortful swallowing manoeuvres can serve as interesting research questions to probe into.

REFERENCES

Adams, V., Mathisen, B., Baines, S., Lazarus, C., & Callister, R. (2013). A systematic review and meta-analysis of measurements of tongue and hand strength and endurance using the Iowa Oral Performance Instrument (IOPI). *Dysphagia*, *28*(3), 350-369. doi.org/10.1007/s00455-013-9451-3

American Speech-Langauge-Hearing Association [ASHA] (2020). *Adult Dysphagia. Incidence and Prevalence.* Retrieved from https://www.asha.org/PRPSpecificTopic.aspx?folderid=8589942550&section=Incidence_and_Prevalence

Bahia, M. M., & Lowell, S. Y. (2020). A Systematic Review of the Physiological Effects of the Effortful Swallow Maneuver in Adults With Normal and Disordered Swallowing. *American Journal of Speech-Language Pathology*, 1-19. doi.org/10.1044/2020_ajslp-19-00132

Buchner, D. M., & de Lateur, B. J. (1991). The importance of skeletal muscle strength to physical function in older adults. *Annals of Behavioral Medicine*, *13*(3), 91-98. doi.org/10.1093/abm/13.3.91

Bülow, M., Olsson, R., & Ekberg, O. (2002). Supraglottic swallow, effortful swallow, and chin tuck did not alter hypopharyngeal intrabolus pressure in patients with pharyngeal dysfunction. *Dysphagia*, *17*(3), 197-201. doi.org/10.1007/s00455-002-0050-y

Bülow, M., Olsson, R., & Ekberg, O. (1999). Videomanometric analysis of supraglottic swallow, effortful swallow, and chin tuck in healthy volunteers. *Dysphagia*, *14*(2), 67-72. doi.org/10.1007/pl00009589

Bülow, M., Olsson, R., & Ekberg, O. (2001). Videomanometric analysis of supraglottic swallow, effortful swallow, and chin tuck in patients with pharyngeal dysfunction. *Dysphagia*, *16*(3), 190-195. doi.org/10.1007/s00455-001-0065-9

Burkhead, L. M. (2009). Applications of exercise science in dysphagia rehabilitation. *Perspectives on Swallowing and Swallowing Disorders (Dysphagia)*, *18*(2), 43-48. doi.org/10.1044/sasd18.2.43

Burkhead, L. M., Sapienza, C. M., & Rosenbek, J. C. (2007). Strength-training exercise in dysphagia rehabilitation: principles, procedures, and directions for future research. *Dysphagia*, *22*(3), 251-265. doi.org/10.1007/s00455-006-9074-z

Campbell-Taylor, I. (2008). Oropharyngeal dysphagia in long-term care: misperceptions of treatment efficacy. *Journal of the American Medical Directors Association*, *9*(7), 523-531. doi.org/10.1016/j.jamda.2008.06.001

Carnaby, G., Hankey, G. J., & Pizzi, J. (2006). Behavioural intervention for dysphagia in acute stroke: a randomised controlled trial. *The Lancet Neurology*, *5*(1), 31-37. doi.org/10.1016/s1474-4422(05)70252-0

Carnaby-Mann, G. D., & Crary, M. A. (2008). Adjunctive neuromuscular electrical stimulation for treatment-refractory dysphagia. *Annals of otology, rhinology & laryngology*, *117*(4), 279-287. doi.org/10.1177/000348940811700407

Carrau, R. L., Murry, T. (1999). Preface. *Comprehensive management of swallowing disorders.* Singular Publishing.

Clark, H. M. (2003). Neuromuscular treatments for speech and swallowing. *American Journal of Speech-Language Pathology*. doi.org/10.1044/1058-0360(2003/086)

Clark, H. M., & Solomon, N. P. (2012). Age and sex differences in orofacial strength. *Dysphagia*, *27*(1), 2-9. doi.org/10.1007/s00455-011-9328-2

Clark, H. M., O'Brien, K., Calleja, A., & Corrie, S. N. (2009). Effects of directional exercise on lingual strength. *Journal of Speech, Language, and Hearing Research*. doi.org/10.1044/1092-4388(2009/08-0062)

Clark, H. M. (2012). Specificity of training in the lingual musculature. *Journal of Speech, Language, and Hearing Research*. doi.org/10.1044/1092-4388(2011/11-0045)

Clark, H. M., & Shelton, N. (2014). Training effects of the effortful swallow under three exercise conditions. *Dysphagia*, *29*(5), 553-563. doi.org/10.1007/s00455-014-9544-7

Coulas, V. L., Smith, R. C., Qadri, S. S., & Martin, R. E. (2009). Differentiating effortful and noneffortful swallowing with a neck force transducer: implications for the development of a clinical feedback system. *Dysphagia*, *24*(1), 7-12. doi.org/10.1007/s00455-008-9157-0

Coyle, J. L., Davis, L. A., Easterling, C., Graner, D. E., Langmore, S., Leder, S. B., ... & Martin-Harris, B. (2009). Oropharyngeal dysphagia assessment and treatment efficacy: setting the record straight (response to Campbell-Taylor). *Journal of the American Medical Directors Association*, *10*(1), 62-66. doi.org/10.1016/j.jamda.2008.10.003

Crary, M. A., Carnaby, G. D., LaGorio, L. A., & Carvajal, P. J. (2012). Functional and physiological outcomes from an exercise-based dysphagia therapy: a pilot investigation of the McNeill Dysphagia Therapy Program. *Archives of physical* *medicine and rehabilitation*, *93*(7), 1173-1178. doi.org/10.1016/j.apmr.2011.11.008

Crary, M. A., Carnaby, G. D., Groher, M. E., & Helseth, E. (2004). Functional benefits of dysphagia therapy using adjunctive sEMG biofeedback. *Dysphagia*, *19*(3), 160-164. doi.org/10.1007/s00455-004-0003-8

Doeltgen, S. H., Ong, E., Scholten, I., Cock, C., & Omari, T. (2017). Biomechanical quantification of mendelsohn maneuver and effortful swallowing on pharyngoesophageal function. *Otolaryngology–Head and Neck Surgery*, *157*(5), 816-823. doi.org/10.1177/0194599817708173

Felix, V. N., Corrêa, S. M. A., & Soares, R. J. (2008). A therapeutic maneuver for oropharyngeal dysphagia in patients with Parkinson's disease. *Clinics*, *63*(5), 661-666. doi.org/10.1590/s1807-59322008000500015

Ferguson, D. D. (2005). Evaluation and management of benign esophageal strictures. *Diseases of the Esophagus*, *18*(6), 359-364. doi.org/10.1111/j.1442-2050.2005.00516.x

Ferreira, L. E. V. V. C., Simmons, D. T., & Baron, T. H. (2008). Zenker's diverticula: pathophysiology, clinical presentation, and flexible endoscopic management. *Diseases of the Esophagus*, *21*(1), 1-8. doi.org/10.1111/j.1442-2050.2007.00795.x

Fritz, M., Cerrati, E., Fang, Y., Verma, A., Achlatis, S., Lazarus, C., ... & Amin, M. (2014). Magnetic resonance imaging of the effortful swallow. *Annals of Otology, Rhinology & Laryngology*, *123*(11), 786-790. doi.org/10.1177/0003489414538607

Fujiwara, A., Tokura, K., Tome, W., & Kitai, N. (2016). Multidirectional lip-closing force in adult females after short-term lip training. *Journal of oral rehabilitation*, *43*(11), 833-839. doi.org/10.1111/joor.12430

Garcia, J. M., Hakel, M., & Lazarus, C. (2004). Unexpected consequence of effortful swallowing: case study report. *Journal of Medical Speech-Language Pathology*, *12*(2), 59-67.

Hägg, M., & Anniko, M. (2010). Influence of lip force on swallowing capacity in stroke patients and in healthy subjects. *Acta oto-laryngologica*, *130*(11), 1204-1208. doi.org/10.3109/00016481003745550

Hägg, M., & Anniko, M. (2008). Lip muscle training in stroke patients with dysphagia. *Acta oto-laryngologica*, *128*(9), 1027-1033. doi.org/10.1080/00016480701813814

Hamdy, S., Rothwell, J. C., Aziz, Q., & Thompson, D. G. (2000). Organization and reorganization of human swallowing motor cortex: implications for recovery after stroke. *Clinical science*, *99*(2), 151-157. doi.org/10.1042/cs0990151

Hee-Su, P., Jae-Young, P., Young-Hwa, K., Su, C. H., & Jeong, K. H. (2018). Effect of orbicularis oris muscle training on muscle strength and lip closure function in patients with stroke and swallowing disorder. *Journal of Physical Therapy Science*, *30*(11), 1355-1356. doi.org/10.1589/jpts.30.1355

Hind, J. A., Nicosia, M. A., Roecker, E. B., Carnes, M. L., & Robbins, J. (2001). Comparison of effortful and noneffortful swallows in healthy middle-aged and older adults. *Archives of Physical Medicine and Rehabilitation*, *82*(12), 1661-1665. doi.org/10.1053/apmr.2001.28006

Hiss, S. G., & Huckabee, M. L. (2005). Timing of pharyngeal and upper esophageal sphincter pressures as a function of normal and effortful swallowing in young healthy adults. *Dysphagia*, *20*(2), 149-156. doi.org/10.1007/s00455-005-0008-y

Hoffman, M. R., Mielens, J. D., Ciucci, M. R., Jones, C. A., Jiang, J. J., & McCulloch, T. M. (2012). High-resolution manometry of pharyngeal swallow pressure events associated with effortful swallow and the Mendelsohn maneuver. *Dysphagia*, *27*(3), 418-426. doi.org/10.1007/s00455-011-9385-6

Hoy, M., Domer, A., Plowman, E. K., Loch, R., & Belafsky, P. (2013). Causes of dysphagia in a tertiary-care swallowing center. *Annals of Otology, Rhinology & Laryngology*, *122*(5), 335-338. doi.org/10.1177/000348941312200508

Huckabee, M., Hiss, S., Barclay, M., & Jit, S. (2005). The relationship between submental SEMG measurement and pharyngeal pressures during normal and effortful swallowing. *Dysphagia*, *20*, 73. doi.org/10.1007/s00455-005-0008-y

Huckabee, M. L., & Steele, C. M. (2006). An analysis of lingual contribution to submental surface electromyographic measures and pharyngeal pressure during effortful swallow. *Archives of physical medicine and rehabilitation*, *87*(8), 1067-1072. doi.org/10.1016/j.apmr.2006.04.019

Hughes, T. A. T., & Wiles, C. M. (1996). Clinical measurement of swallowing in health and in neurogenic dysphagia. *QJM: An International Journal of Medicine*, *89*(2), 109-116. doi.org/10.1093/qjmed/89.2.109

Humbert, I. A., & German, R. Z. (2013). New directions for understanding neural control in swallowing: the potential and promise of motor learning. *Dysphagia*, *28*(1), 1-10. doi.org/10.1007/s00455-012-9432-y

Husaini, H., Krisciunas, G. P., Langmore, S., Mojica, J. K., Urken, M. L., Jacobson, A. S., & Lazarus, C. L. (2014). A survey of variables used by speech-language pathologists to assess function and predict functional recovery in oral cancer patients. *Dysphagia*, *29*(3), 376-386. doi.org/10.1007/s00455-014-9520-2

Ibrahim, F., Arifin, N., & Rahim, Z. H. (2013). Effect of orofacial myofunctional exercise using an oral rehabilitation tool on labial closure strength, tongue elevation strength and skin elasticity. *Journal of Physical Therapy Science*, *25*(1), 11-14. doi.org/10.1589/jpts.25.11

Jaffin, B. W., Knoepflmacher, P., & Greenstein, R. (1999). High prevalence of asymptomatic esophageal motility disorders among morbidly obese patients. *Obesity surgery*, *9*(4), 390-395. doi.org/10.1381/096089299765552990

Jang, H. J., Leigh, J. H., Seo, H. G., Han, T. R., & Oh, B. M. (2015). Effortful swallow enhances vertical hyolaryngeal movement and prolongs duration after maximal excursion. *Journal of oral rehabilitation*, *42*(10), 765-773. doi.org/10.1111/joor.12312

Jeong, D. M., Shin, Y. J., Lee, N. R., Lim, H. K., Choung, H. W., Pang, K. M., ... & Lee, J. H. (2017). Maximal strength and endurance scores of the tongue, lip, and cheek in healthy, normal Koreans. *Journal of the Korean Association of Oral and Maxillofacial Surgeons*, *43*(4), 221-228. doi.org/10.5125/jkaoms.2017.43.4.221

Juan, J., Hind, J., Jones, C., McCulloch, T., Gangnon, R., & Robbins, J. (2013). Case study: application of isometric progressive resistance oropharyngeal therapy using the Madison Oral Strengthening Therapeutic device. *Topics in stroke rehabilitation*, *20*(5), 450-470. doi.org/10.1310/tsr2005-450

Kaede, K., Kato, T., Yamaguchi, M., Nakamura, N., Yamada, K., & Masuda, Y. (2016). Effects of lip-closing training on maximum voluntary lip-closing force during lip pursing in healthy young adults. *Journal of Oral Rehabilitation*, *43*(3), 169-175. doi.org/10.1111/joor.12358

Kahrilas, P. J., Lin, S., Logemann, J. A., Ergun, G. A., & Facchini, F. (1993). Deglutitive tongue action: volume accommodation and bolus propulsion. *Gastroenterology*, *104*(1), 152-162. doi.org/10.1016/0016-5085(93)90847-6

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*. doi.org/10.1044/1092-4388(2009/09-0048)

Kent, R. D. (2004). The uniqueness of speech among motor systems. *Clinical linguistics & phonetics*, *18*(6-8), 495-505. doi.org/10.1080/02699200410001703600

Kim, H. D., Choi, J. B., Yoo, S. J., Chang, M. Y., Lee, S. W., & Park, J. S. (2017). Tongue-to-palate resistance training improves tongue strength and oropharyngeal swallowing function in subacute stroke survivors with dysphagia. *Journal of Oral Rehabilitation*, *44*(1), 59-64. doi.org/10.1111/joor.12461

Kleim, J. A., & Jones, T. A. (2008). Principles of experience-dependent neural plasticity: implications for rehabilitation after brain damage. *Journal of speech, language, and hearing research*. doi.org/10.1044/1092-4388(2008/018)

Krishnan, G., & Goswami, S. P. (2018). Dysphagia research in India: A status report. *Journal of Indian Speech Language & Hearing Association*, *32*(2), 39. doi. org/10.4103/jisha.JISHA_44_17

Langmore, S. E., & Pisegna, J. M. (2015). Efficacy of exercises to rehabilitate dysphagia: a critique of the literature. *International Journal of Speech-Language Pathology, 17*(3), 222-229. doi.org/10.3109/17549507.2015.1024171

Lazarus, C., Logemann, J. A., Huang, C. F., & Rademaker, A. W. (2003). Effects of two types of tongue strengthening exercises in young normals. *Folia Phoniatrica et Logopaedica*, *55*(4), 199-205. doi.org/10.1159/000071019

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. doi.org/10.1159/000063192

Lever, T. E., Cox, K. T., Holbert, D., Shahrier, M., Hough, M., & Kelley-Salamon, K. (2007). The effect of an effortful swallow on the normal adult esophagus. *Dysphagia*, *22*(4), 312-325. doi.org/10.1007/s00455-007-9107-2

Logemann, J. (1984). Evaluation and treatment of swallowing disorders. *NSSLHA Journal*, (12), 38-50. doi.org/10.1044/nsshla_12_38

Logemann, J. A. (1998). The evaluation and treatment of swallowing disorders. *Current Opinion in Otolaryngology & Head and Neck Surgery*, *6*(6), 395-400. doi.org/10.1097/00020840-199812000-00008

Luschei, D. E. (2001). *About Us.* Retrieved from The IOPI Medical LLC: https://iopimedical.com/about-us/

Malandraki, G. A., Kaufman, A., Hind, J., Ennis, S., Gangnon, R., Waclawik, A., & Robbins, J. (2012). The effects of lingual intervention in a patient with inclusion body myositis and Sjögren's syndrome: A longitudinal case study. *Archives of*

Physical Medicine and Rehabilitation, *93*(8), 1469-1475. doi.org/10.1016/j.apmr.2012.02.010

Manikantan, K., Khode, S., Sayed, S. I., Roe, J., Nutting, C. M., Rhys-Evans, P., ... & Kazi, R. (2009). Dysphagia in head and neck cancer. *Cancer treatment reviews*, *35*(8), 724-732. doi.org/10.1016/j.ctrv.2009.08.008

Matsuo, K., & Palmer, J. B. (2008). Anatomy and physiology of feeding and swallowing: normal and abnormal. *Physical medicine and rehabilitation clinics of North America*, *19*(4), 691-707. doi.org/10.1016/j.pmr.2008.06.001

Matsuo, K., & Palmer, J. B. (2009). Coordination of mastication, swallowing and breathing. *Japanese Dental Science Review*, *45*(1), 31-40. doi.org/10.1016/j.jdsr.2009.03.004

McKenna, V. S., Zhang, B., Haines, M. B., & Kelchner, L. N. (2017). A systematic review of isometric lingual strength-training programs in adults with and without dysphagia. *American journal of speech-language pathology*, *26*(2), 524-539. doi.org/10.1044/2016_ajslp-15-0051

Molfenter, S. M., Hsu, C. Y., Lu, Y., & Lazarus, C. L. (2018). Alterations to swallowing physiology as the result of effortful swallowing in healthy seniors. *Dysphagia*, *33*(3), 380-388. doi.org/10.1007/s00455-017-9863-6

Molfenter, S. M., Brates, D., Herzberg, E., Noorani, M., & Lazarus, C. (2018). The swallowing profile of healthy aging adults: comparing noninvasive swallow tests to videofluoroscopic measures of safety and efficiency. *Journal of Speech, Language, and Hearing Research*, *61*(7), 1603-1612. doi.org/10.1044/2018_jslhr-s-17-0471

Nekl, C. G., Lintzenich, C. R., Leng, X., Lever, T., & Butler, S. G. (2012). Effects of effortful swallow on esophageal function in healthy adults. *Neurogastroenterology & Motility*, *24*(3), 252-e108. doi.org/10.1111/j.1365-2982.2011.01864.x

Oh, J. C. (2015). Effects of tongue strength training and detraining on tongue pressures in healthy adults. *Dysphagia*, *30*(3), 315-320. doi.org/10.1007/s00455-015-9601-x

Palmer, J. B., Rudin, N. J., Lara, G., & Crompton, A. W. (1992). Coordination of mastication and swallowing. *Dysphagia*, *7*(4), 187-200. doi.org/10.1007/bf02493469

Palmer, J. B., & Hiiemae, K. M. (1997). Integration of oral and pharyngeal bolus propulsion: a new model for the physiology of swallowing. *The Japanese Journal of Dysphagia Rehabilitation*, *1*(1), 15-30. doi.org/10.32136/jsdr.1.1_15

Park, H. S., Oh, D. H., Yoon, T., & Park, J. S. (2019). Effect of effortful swallowing training on tongue strength and oropharyngeal swallowing function in stroke patients with dysphagia: a double-blind, randomized controlled trial. *International journal of language & communication disorders*, *54*(3), 479-484. doi.org/10.1111/1460-6984.12453

Park, J. S., Kim, H. J., & Oh, D. H. (2015). Effect of tongue strength training using the Iowa Oral Performance Instrument in stroke patients with dysphagia. *Journal of physical therapy science*, *27*(12), 3631-3634. doi.org/10.1589/jpts.27.3631

Park, J. W., Kim, Y., Oh, J. C., & Lee, H. J. (2012). Effortful swallowing training combined with electrical stimulation in post-stroke dysphagia: a randomized controlled study. *Dysphagia*, *27*(4), 521-527. doi.org/10.1007/s00455-012-9403-3

Park, T., & Kim, Y. (2016). Effects of tongue pressing effortful swallow in older healthy individuals. *Archives of Gerontology and Geriatrics*, *66*, 127-133. doi.org/10.1016/j.archger.2016.05.009

Parkinson, J. (2002). An Essay on the Shaking Palsy. *The Journal of Neuropsychiatry and Clinical Neurosciences*, *14*(2), 223–236. doi:10.1176/jnp.14.2.223

Perry, B. J., Richburg, B. D., Pomahac, B., Bueno, E. M., & Green, J. R. (2017). The effects of lip-closure exercise on lip strength and function following full facial transplantation: a case report. *American Journal of Speech-Language Pathology*, *26*(2S), 682-686. doi.org/10.1044/2017_ajslp-16-0101

Pitts, L. L., Stierwalt, J. A., Hageman, C. F., & LaPointe, L. L. (2017). The influence of oropalatal dimensions on the measurement of tongue strength. *Dysphagia*, *32*(6), 759-766. doi.org/10.1007/s00455-017-9820-4

Pouderoux, P., & Kahrilas, P. J. (1995). Deglutitive tongue force modulation by volition, volume, and viscosity in humans. *Gastroenterology*, *108*(5), 1418-1426. doi.org/10.1016/0016-5085(95)90690-8

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. *Journal of the American Geriatrics Society, 53*(9), 1483-1489. doi.org/10.1111/j.1532-5415.2005.53467.x

Robbins, J., Kays, S. A., Gangnon, R. E., Hind, J. A., Hewitt, A. L., Gentry, L. R., & Taylor, A. J. (2007). The effects of lingual exercise in stroke patients with dysphagia. *Archives of physical medicine and rehabilitation*, *88*(2), 150-158. doi.org/10.1016/j.apmr.2006.11.002

Roden, D. F., & Altman, K. W. (2013). Causes of dysphagia among different age groups: a systematic review of the literature. *Otolaryngologic Clinics of North America*, *46*(6), 965-987. doi.org/10.1016/j.otc.2013.08.008

Rogus-Pulia, N., & Connor, N. P. (2016). Muscle Strengthening Approaches to Dysphagia Rehabilitation. *Current Physical Medicine and Rehabilitation Reports*, *4*(4), 277-286. doi.org/10.1007/s40141-016-0136-3

Rosen, S. P., Abdelhalim, S. M., Jones, C. A., & McCulloch, T. M. (2018). Effect of body position on pharyngeal swallowing pressures using high-resolution manometry. *Dysphagia*, *33*(3), 389-398. doi.org/10.1007/s00455-017-9866-3

Shaker, R., Belafsky, P. C., Postma, G. N., & Easterling, C. (Eds.). (2012). *Principles of deglutition: a multidisciplinary text for swallowing and its disorders*. Springer Science & Business Media.

Shaker, R., Kern, M., Bardan, E. Y. T. A. N., Taylor, A. N. D. R. E. W., Stewart, E. T., Hoffmann, R. G., ... & Bonnevier, J. (1997). Augmentation of deglutitive upper esophageal sphincter opening in the elderly by exercise. *American Journal of Physiology-Gastrointestinal and Liver Physiology*, *272*(6), G1518-G1522. doi.org/10.1152/ajpgi.1997.272.6.g1518

Smaoui, S., Langridge, A., & Steele, C. M. (2019). The effect of lingual resistance training interventions on adult swallow function: a systematic review. *Dysphagia,* 1-17. doi.org/10.1007/s00455-019-10066-1

Solomon, N. P., Clark, H. M., Makashay, M. J., & Newman, L. A. (2008). Assessment of orofacial strength in patients with dysarthria. *Journal of medical speech-language pathology*, *16*(4), 251.

Steele, C. M., & Huckabee, M. L. (2007). The influence of orolingual pressure on the timing of pharyngeal pressure events. *Dysphagia*, *22*(1), 30-36. doi.org/10.1007/s00455-006-9037-4

Steele, C. M., Bailey, G. L., Polacco, R. E. C., Hori, S. F., Molfenter, S. M., Oshalla, M., & Yeates, E. M. (2013). Outcomes of tongue-pressure strength and accuracy training for dysphagia following acquired brain injury. *International journal of speech-language pathology*, *15*(5), 492-502. doi.org/10.3109%2F17549507.2012.752864

Stierwalt, J. A., & Youmans, S. R. (2007). Tongue measures in individuals with normal and impaired swallowing. *American journal of speech-language pathology , 16*, 148-156. doi.org/10.1044/1058-0360(2007/019)

Takamoto, K., Saitoh, T., Taguchi, T., Nishimaru, H., Urakawa, S., Sakai, S., ... & Nishijo, H. (2018). Lip closure training improves eating behaviors and prefrontal cortical hemodynamic activity and decreases daytime sleep in elderly persons. *Journal of bodywork and movement therapies*, *22*(3), 810-816. doi.org/10.1016/j.jbmt.2017.09.002

Takasaki, K., Umeki, H., Hara, M., Kumagami, H., & Takahashi, H. (2011). Influence of effortful swallow on pharyngeal pressure: evaluation using a high-resolution manometry. *Otolaryngology--Head and Neck Surgery*, *144*(1), 16-20. doi.org/10.1177/0194599810390885

Thüer, U., & Ingervall, B. (1990). Effect of muscle exercise with an oral screen on lip function. *The European Journal of Orthodontics*, *12*(2), 198-208. doi.org/10.1093/ejo/12.2.198

Todd, J. T., Lintzenich, C. R., & Butler, S. G. (2013). Isometric and swallowing tongue strength in healthy adults. *The Laryngoscope*, *123*(10), 2469-2473. doi.org/10.1002/lary.23852

Vanderwegen, J., Guns, C., Van Nuffelen, G., Elen, R., & De Bodt, M. (2013). The influence of age, sex, bulb position, visual feedback, and the order of testing on maximum anterior and posterior tongue strength and endurance in healthy Belgian adults. *Dysphagia*, *28*(2), 159-166. doi.org/10.1007/s00455-012-9425-x

Vose, A. K., Kesneck, S., Sunday, K., Plowman, E., & Humbert, I. (2018). A survey of clinician decision making when identifying swallowing impairments and determining treatment. *Journal of Speech, Language, and Hearing Research*, *61*(11), 2735-2756. doi.org/10.1044/2018_jslhr-s-17-0212

Warren, S. F., Fey, M. E., & Yoder, P. J. (2007). Differential treatment intensity research: A missing link to creating optimally effective communication interventions. *Mental retardation and developmental disabilities research reviews*, *13*(1), 70-77. doi.org/10.1002/mrdd.20139

Witte, U., Huckabee, M. L., Doeltgen, S. H., Gumbley, F., & Robb, M. (2008). The effect of effortful swallow on pharyngeal manometric measurements during saliva and water swallowing in healthy participants. *Archives of Physical Medicine and Rehabilitation*, *89*(5), 822-828. doi.org/10.1016/j.apmr.2007.08.167

Wong, V., Abe, T., Spitz, R. W., Bell, Z. W., Yamada, Y., Chatakondi, R. N., & Loenneke, J. P. (2020). Effects of Age, Sex, Disease, and Exercise Training on Lip Muscle Strength. *Cosmetics*, *7*(1), 18. doi.org/10.3390/cosmetics7010018

Yano, J., Yamamoto-Shimizu, S., Yokoyama, T., Kumakura, I., Hanayama, K., & Tsubahara, A. (2019). Effects of anterior tongue strengthening exercises on posterior tongue strength in healthy young adults. *Archives of Oral Biology*, *98*, 238-242. doi.org/10.1016/j.archoralbio.2018.11.028

Yoshizawa, S., Ohtsuka, M., Kaneko, T., & Iida, J. (2016). Study of training for improving lip incompetence. *Orthodontic waves*, *75*(3), 47-53. doi.org/10.1016/j.odw.2016.07.001

Zald, D. H., & Pardo, J. V. (1999). The functional neuroanatomy of voluntary swallowing. *Annals of Neurology: Official Journal of the American Neurological Association and the Child Neurology Society*, *46*(3), 281-286. doi.org/10.1002/1531-8249(199909)46:3%3C281::aid-ana2%3E3.0.co;2-l

APPENDIX

Table A.1

p-value of the independent variables of the present study

	Pre-test	Post 2 weeks	Pos 4 weeks	Post-test	p value
LS	32.20±6.529	33.10±7.767	36.20±6.339	39.80±5.073	0.000
LE	43.60±26.433	67.60±37.872	78.30±37.479	91.10±41.151	0.000
ATS	41.30±11.490	44.70±12.184	48.50±10.233	52.70±9.393	0.000
ATE	13.40±4.551	19.10±11.100	24.60±16.126	29.70±16.310	0.002
PTS	39.20±10.881	41.30±8.667	45.80±8.470	50.80±8.867	0.000
PTE	8.90±2.644	11.80±5.160	14.70±6.634	18.10±6.523	0.000
SC	22.4310±5.70631	25.8290±7.46073	25.1650±7.13542	32.1660±11.81355	0.039

The table summarizes the mean and standard deviation of all the dependent variables of the study over the four time points along with their *p* value.

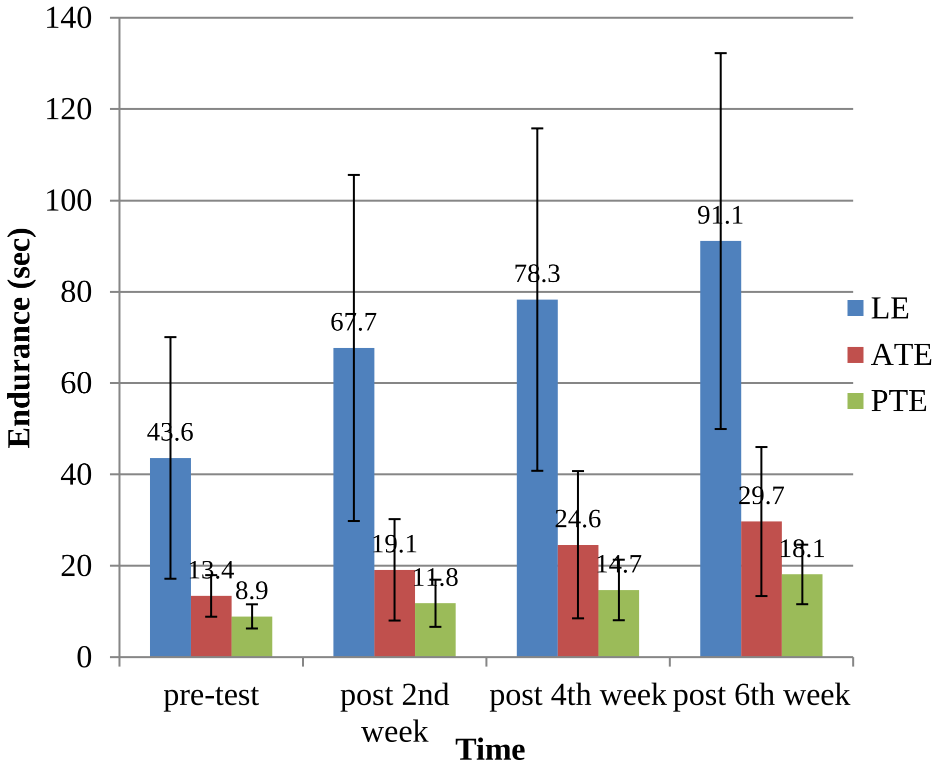

Figure A.1 Means of LE, ATE and PTE at each time point showing increase according to the flow of time over the 6-week regime effortful swallowing regime. Note that the 95 percent confidence intervals are shown by the error bars.

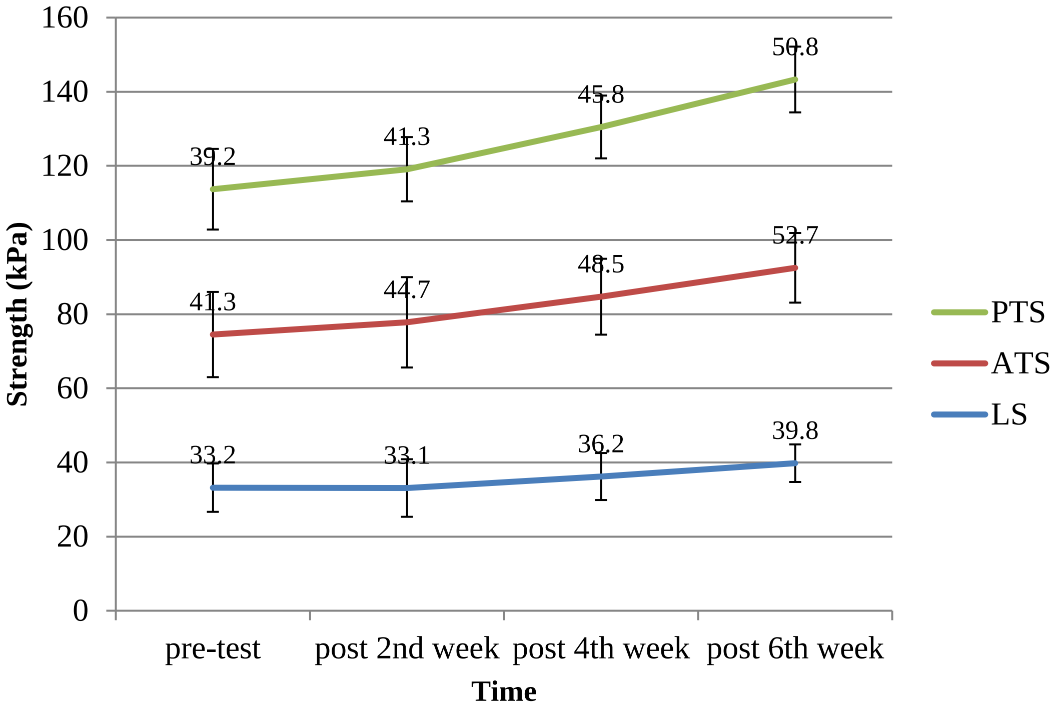

Figure A.2 Means of LS, ATS, and PTS at each time point showing increase according to the flow of time over the 6-week regime effortful swallowing regime. The 95 percent confidence intervals are shown by the error bars.

Demographic Data Sheet for data collection

Subject Id ________________ ________________ Date
____

Name of the participant: ________________________ Date of
birth__________________

Age/sex____________________________________ Contact No
____

Height (in cms)______________________________
Occupation___________________

Weight (in Kgs)______________________________

BMI _______________________________________

Significant medical history (if any) ____

Significant neurological history (if any) ____

H/o smoking /alcohol consumption ________________

Language evaluation:

- ✓ Is the client able to follow instructions? ____
- ✓ Is the client verbal? ____

WHO-DAS disability score *(refer next page)* ____

IOPI measurement and swallowing capacity

Period	**Date of testing**	**Tongue**			**Lips**		**Swallowing capacity**[1] (ml/sec)
			Strength (kPa)	**Endurance** (sec)	**Strength** (kPa)	**Endurance** (sec)	
Pre-test		Anterior					
		Posterior					
2nd week		Anterior					
		Posterior					
4th week		Anterior					
		Posterior					
Post-test (6th week)		Anterior					
		Posterior					

Remarks, if any:

---

[1] Refer next page for calculation

WHO-DAS 12-point disability checklist

NOTE: When scoring, the following numbers are assigned to responses:	
0	**No Difficulty**
1	**Mild Difficulty**
2	**Moderate Difficulty**
3	**Severe Difficulty**
4	**Extreme Difficulty or Cannot Do**

S. No		**SCORE**
S1	Standing for long periods such as 30 minutes?	
S2	Taking care of your household responsibilities?	
S3	Learning a new task, for example, learning how to get to a new place?	
S4	How much of a problem did you have in joining in community activities (for example, festivities, religious or other activities) in the same way as anyone else can?	
S5	How much have you been emotionally affected by your health problems?	
S6	Concentrating on doing something for ten minutes?	
S7	Walking a long distance such as a kilometre [or equivalent]?	
S8	Washing your whole body?	
S9	Getting dressed?	
S10	Dealing with people you do not know?	
S11	Maintaining a friendship?	
S12	Your day-to-day work/school?	
	Overall Score	
H1	Overall, in the past 30 days, how many days were these difficulties present?	
H2	In the past 30 days, for how many days were you totally unable to carry out your usual activities or work because of any health condition?	
H3	In the past 30 days, not counting the days that you were totally unable, for how many days did you cut back or reduce your usual activities or work because of any health condition?	

Calculation of the swallow capacity

- Volume per swallow, time per swallow, and swallow capacity will be calculated on an offline basis.
- Volume per swallow = 100 ml/total number of hyolaryngeal movements (____ ml/swallow)
- Time per swallow = Total time taken to swallow 100 ml/total number of hyolaryngeal movements

Swallow capacity = 100 ml/total time taken to swallow 100 ml

EXERCISE LOG SHEET FOR THE TRAINEES

Pre-test measures	**Date**		**Lip**	**Anterior tongue**	**Posterior tongue**	**Swallowing capacity (ml/sec)**	
		Strength (kPa)					
		Endurance (s)					

6-WEEK EFFORTFUL SWALLOWING REGIME									
WEEK	**DAY**		**DATE**	**EXERCISE (✓)**	**PERIODIC ASSESSMENTS**				**REMARKS[i]**
WEEK 1	1				**Post 2nd week measurements**				
	2				**LIP**	Strength			
	3								
	4					Endurance			
	5								
	6				**TONGUE**		Anterior	Posterior	
	7					Strength			
WEEK 2	1								
	2								
	3					Endurance			
	4								
	5								
	6				**Swallowing capacity**				
	7								
WEEK 3	1				**Post 4th week measurements**				
	2				**LIP**	Strength			
	3								
	4					Endurance			
	5								
	6				**TONGUE**		Anterior	Posterior	
	7					Strength			
WEEK 4	1								
	2								
	3					Endurance			
	4								
	5								
	6				**Swallowing capacity**				
	7								
WEEK 5	1				**Post test measurements**				
	2				**LIP**				
	3								
	4								
	5								
	6				**TONGUE**		Anterior	Posterior	
	7					Strength			
WEEK 6	1								
	2								
	3					Endurance			
	4								
	5								
	6				**Swallowing capacity**				
	7								