Effects of Oropharyngeal Strengthening Exercise (OSE) on Tongue Strength, Submental Muscle Activity, and Quality of Life in a Healthy Elderly Population

A dissertation presented to
the faculty of
the College of Health Sciences and Professions of Ohio University

In partial fulfillment
of the requirements for the degree
Doctor of Philosophy

Taeok Park
May 2015

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This dissertation titled

Effects of Oropharyngeal Strengthening Exercise (OSE) on Tongue Strength, Submental Muscle Activity, and Quality of Life in a Healthy Elderly Population

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Abstract

PARK, TAEOK, Ph.D., May 2015, Speech-Language Science

Effects of Oropharyngeal Strengthening Exercise (OSE) on Tongue Strength, Submental Muscle Activity, and Quality of Life in a Healthy Elderly Population

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Current swallowing interventions focus on rehabilitation in patients with dysphagia using compensatory and rehabilitation strategies. Studies evaluative the effectiveness of a preventative approach for those with a high risk for swallowing disorders are lacking. The risk of swallowing disorders is increased for older individuals. Many older individuals show weak tongue strength and reduced swallowing ability. Is it possible to improve their tongue strength and quality of life using a preventative swallowing intervention? This investigation begins with this question and hypothesizes that a preventative swallowing intervention will have a positive effect, because a strengthening exercise for swallowing muscles would increase muscular and swallowing reserve in older individuals. This investigation evaluates the value of a preventative approach by developing oropharyngeal strengthening exercise (OSE) applied using home-based and self-administered procedures. The OSE combined two swallowing exercises: tongue strengthening exercise and effortful swallow. The conceptual framework of the OSE is based on neuroadaptation, which implies the adaptive modification of the neurological system through training. The OSE may lead to neuromuscular adaptive modifications of swallowing physiology in older individuals. Specifically, changes through the OSE may include increases in the firing rate of motor
units with increasing strength related to oropharyngeal swallowing muscles such as the tongue.

The purpose of this study was to examine the effects of the OSE on (a) maximum tongue pressure as measured by the Iowa Oral Performance Instrument (IOPI), (b) peak amplitude of submental surface electromyography (sEMG), and (c) swallowing quality of life as measured by the SWAL-QOL in 27 healthy older individuals who had a mean age of 73 years old (range 58-85 years old) after 4 weeks of the OSE.

The results of this study showed that the OSE had statistically significant and positive effects on increasing maximum tongue pressure and swallowing quality of life, but there was no difference in peak amplitude of submental sEMG after a 4-week OSE. Maximum tongue pressure increased from 41 kPa to 47 kPa after a 4-week OSE. On the swallowing quality of life questionnaires, participants perceived that physical symptoms related to swallowing were statistically significantly improved after a 4-week OSE. Particularly, frequency of choking during eating was statistically significantly reduced after a 4-week OSE.

This investigation highlighted a new intervention to prevent swallowing disorders in older individuals. There were positive impacts of the OSE on objective and subjective measures. This investigation introduced a new swallowing intervention by combining two swallowing treatment exercises: tongue strengthening exercises and the effortful swallow. Combining these exercises was possible because the two exercises have a common physiological event, namely, pressing the tongue hard into the palate at the initiation of oral swallowing. The OSE was devised to be a more robust approach than the
tongue strengthening exercise alone. In addition, OSE home-based and self-administered approach was both efficient and cost effective. Older individuals were able to perform the swallowing exercise at home independently, with only modest assistance such as a weekly call and email. Future research needs to refine the OSE and apply it to patients with dysphagia.
Acknowledgments

Since I have been in Athens, a lot of people in Communication Sciences and Disorders at Ohio University as well as church helped me to complete my doctoral program. Firstly, I would like to thank my committee members who were so generous of their time and expertise. A special thanks to Dr. Youngsun Kim, my committee chair, for his support. Most of all, I would like to thank him for his patience throughout the entire process of my doctoral program. I would like to gratefully acknowledge my wonderful committee, Dr. Jennifer Horner, Dr. John McCarthy, and Dr. Susan Williams whose support and inspiration enabled me to achieve the dissertation.

I would like to thank students in the Swallowing Research Laboratory at OU for their help during data collection, friends, the doctoral students, and clinic supervisors in CSD for their support. A special thank you goes to Ruth Lee who read and corrected my English in the dissertation as well as encouraged me. In addition, thank you my participants for their time and effort. I really hope my older participants remain healthy. Financial support was provided by the College of Health Sciences and Professions (CHSP) student research grant and the Original Work Grant from Graduate Student Senate (GSS) at Ohio University.

Last but not least, I will always be grateful to my family and Dr. Kim’s family for their love and support.
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Chapter 1: Introduction

The safe swallow involves the transport of saliva, food, or liquid from the mouth to the stomach without airway invasion and includes three stages: the oral, pharyngeal, and esophageal (Logemann, 1998). In the oral stage of swallowing, the tongue plays a critical role in transferring the bolus to the pharynx. The tongue tip contacts the maxillary alveolar ridge, and then the tongue elevates and propels the bolus posteriorly (Cook et al., 1989). This movement of the tongue not only generates tongue pressure against the palate in order to facilitate bolus transfer toward the pharynx but also helps trigger the pharyngeal stage of swallowing. The pharyngeal stage refers to when the bolus is transferred through the pharynx by pharyngeal constriction. During this stage, physiological events such as airway closure and hyolaryngeal excursion occur to protect the airway during the swallow. Hyolaryngeal excursion occurs by contraction of the suprahyoid muscles (Crary, Carnaby, Mann, & Groher, 2006; Dodds, Stewart, & Logemann, 1990; Perlman, Palmer, McCullouch, & Vandaele, 1999) and contributes to airway closure as well as helps the bolus pass safely through the upper esophageal sphincter (UES).

Swallowing involves complex physiological processes and neuromuscular apparatus execution (Dodds, 1989). Swallowing difficulty can occur because of dysfunctional physiological processes and/or changes in neuromotor and sensory systems. Dysfunction in any stage of swallowing can result in presbyphagia (changes that are normal during aging) and potentially increase the risk of a swallowing disorder. Oropharyngeal structures and muscles corresponding to swallowing in the older
population are vulnerable to presbyphagia because of decreased strength, tension, and endurance over time (Crow & Ship, 1996; Nicosia et al., 2000; Price & Darvell, 1981; Robbins, Levine, Wood, Roecker, & Luschei, 1995; Wohllert, 1996). In addition, each stage of swallowing has different anatomical, physiological, and functional changes with aging. One of the most noticeable physiological changes in the oral stage is reduced tongue strength. Reduced tongue strength causes slower tongue movement and slower transport of the bolus in the oropharyngeal stage of swallowing. In the pharyngeal stage of swallowing, the older population shows slower transition of the bolus than the younger population (Im, Kim, Oommen, Kim, & Ko, 2011). The slower pharyngeal swallow results from reduced pharyngeal constriction and pharyngeal peristaltic motion as well as weakened suprahyoid muscles associated with advancing age and/or disease (Robbins, Hamilton, Lof, & Kempster, 1992; Tracy et al., 1989).

Reduced reserve and flexibility can explain the physiological and functional changes in the older population. The younger population tends to have more muscular reserve to execute the whole process of swallowing in normal circumstances than the older population. This muscular reserve also plays an important role in the context of disease and illness (Buchner & Wagner, 1992; Johnson, 1993; Kenney, 1985; Troncale, 1996). With adequate reserve, individuals may be able to swallow safely because of well-preserved muscular strength and flexibility after incidence of disease or accident. Lingual pressure reserve was investigated by Nicosia and colleagues in 2000. This study pointed out that lingual isometric and swallowing pressure were less in older participants as compared to younger participants. This result can explain reduced lingual pressure
reserve for swallowing in the older population as compared to the younger population. Although the older population has age-related muscle changes and reduced reserve for swallowing, they can compensate and adjust their swallowing performances based on their necessities. Additionally, changes in swallowing function may influence their quality of life. Changes in swallowing make the older population hesitant to socialize during mealtime given the safety, health and social issues that arise with swallowing dysfunction. It is important for clinicians to understand monitor swallowing performance and functions of swallowing in the older population.

The purpose of behavioral rehabilitation for dysphagia is not only to restore neuromuscular swallowing efficiency but also to improve the quality of life for patients with swallowing difficulties. Among the behavioral rehabilitation strategies, both tongue strengthening exercise and repeated effortful swallows have frequently been used for patients with oropharyngeal swallowing disorders. First, tongue strengthening exercises for patients with tongue weakness are performed by pushing the tongue against the hard palate. The tongue strengthening exercise helps patients who have difficulties transferring the bolus due to tongue weakness. The tongue strengthening exercise has an effect on competent transportation of the entire bolus without oropharyngeal residue as well as airway protection (Robbins et al., 2005, 2007). Robbins et al. (2005) conducted tongue strengthening exercise in older participants for 8 weeks. They report that the tongue strengthening exercise on gradually increased maximum tongue pressure after every two weeks (from 44 kPa to 49 kPa). These results suggest that tongue strengthening exercise may have a positive influence on swallowing function. Second, repeated effortful
swallows were developed to increase strength of pharyngeal muscles. Repeated effortful swallows emphasize strong contraction of participant’s neck muscles during the swallow. In addition, participants were initially encouraged to push his/her tongue hard against the hard palate and then to swallow hard. Huckabee, Butler, Barclay, and Jit (2005) reported that repeated effortful dry swallows showed higher levels of sEMG of submental muscles and higher average pressure within the pharynx as compared to noneffortful dry swallows. The increased contraction of the pharynx resulted in increased pharyngeal swallowing pressure which can reduce residue in the oropharynx. Repeated effortful swallows have been applied to facilitate the pharyngeal stage of swallowing and bolus transfer through the pharynx in patients with dysphagia. Bulow et al. (2001) reported changes in pharyngeal stage of swallowing during effortful swallows in 8 patients with dysphagia. The result was that effortful swallows helped reduce the depth of contrast penetration and aspiration in patients with dysphagia. Both treatment exercises have positive effects on swallowing physiology and function for patients with oropharyngeal residue and reduced laryngeal vestibule closure (Hind, Nicosia, Roecker, Carnes, & Robbins, 2001; Robbins et al., 2007). In summary, tongue strengthening exercises and repeated effortful swallows not only have been reported to have positive effects in the older population and/or patients with dysphagia (Bulow, Olsson, & Ekberg, 1999; Bulow et al., 2001; Hind et al., 2001; Robbins et al., 2005, 2007). Clinically, both treatments have been used frequently for patients with dysphagia.

The older population is likely to have higher risk of stroke, degenerative disease, and head and neck cancer, all of which are related to swallowing disorders. Previous
investigations of swallowing exercises focus on rehabilitation and/or compensation of swallowing function. It is important and beneficial to develop appropriate and effective exercise strategies to improve muscular reserve in the older population. It is necessary to develop age-appropriate intervention strategies and, if possible, a preventive exercise program for the older population. In addition, previous investigations focus on effectiveness of one target treatment maneuver in each group of subjects. Several exercises in swallowing rehabilitation can be applied sequentially and/or concurrently to dysphagic patients. More research is needed to identify the effectiveness of an intervention program in which participants have several maneuvers during a certain period of time.

This investigation examined the effectiveness of a preventative approach by combining two highly used swallowing exercises for the older population: a tongue strengthening exercise and repeated effortful swallows. The combined exercises may be referred to as the Oropharyngeal Strengthening Exercise (OSE). The OSE was developed based on the studies of Bulow et al. (2001) and Yeates, Steele, and Pelletier (2010). According to Bulow et al. (2001), patients with dysphagia poorly performed effortful swallow due to weak tongue strength. Bulow et al. (2001) suggested, “It probably would be essential to give these patients oral motor exercises (tongue training) in combination with a before starting with effortful swallow (p. 194).” For tongue strengthening exercise, each participant pushes the tongue against the alveolar ridge for 3-5 seconds. For effortful swallow, each participant pushes the tongue against the alveolar ridge for 1-2 seconds and then swallows while squeezing hard with the neck muscles. What both the tongue
strengthening exercise and the effortful swallow have in common is pushing the tongue against the alveolar ridge for an extended period of time. The investigator has developed the OSE by placing the tongue-to-palate maneuver in deliberate proximity with the effortful swallow. The OSE requires pressing the tongue hard in the initial portion of the effortful swallow. The independent effectiveness of both exercises has been shown to increase oropharyngeal muscular and swallowing pressure and improve the oropharyngeal swallow which includes airway protection (Robbins et al., 2007; Hind et al., 2001). It is our intention to assess whether a combined exercise can help increase muscle reserve and activity, and improve the quality of life for the older population and patients with dysphagia.

The OSE will be executed in a home-based and self-administered program for the older population. Home-based and self-administered OSE program will provide great promise to make up for on-site intervention like widely used traditional intervention in terms of time management, transportation, and cost (Leff, et al., 2005; Wulf, Shea, & Lewthwaite, 2010). In addition, to perform the self-administered OSE program, the investigator will provide clear instruction for OSE program and confirm mastery of OSE in each participant before independently performing the program. Self-administered training has shown effective motor learning than on-site controlled training (Wulf et al., 2010) However, monitoring their performance is essential for self-administered program. Undergraduate assistant students and the investigator will call and email to participants every week to track their performance. This investigation will support the feasibility and acceptability of home-based and self-administered swallowing exercise program. This
study will serve as the first step in determining whether a combined exercise measurably affects tongue strength, peak amplitude of submental muscles activity, and/or the swallowing quality of life after a 4-week exercise program.
Chapter 2: Review of Literature

Normal Swallowing and its Physiology

Swallowing is the safe transport of food or liquid from the mouth to the stomach. An effective swallow encompasses complex physiological processes which are dependent on one another. These physiological processes occur when the complex neuromuscular apparatus executes the swallowing sequence (Dodds, 1989). Swallowing is divided into three physiologic stages: the oral, pharyngeal, and esophageal stages (Logemann, 1998).

The oral stage includes bolus formation and posterior propulsion of the bolus by peristaltic motion of the tongue. While the bolus is being prepared for swallowing, the tongue tip is poised against the superior incisors or maxillary alveolar ridge (Cook et al., 1989). A semisolid or liquid bolus is cupped within a depression of the anterior one to two-thirds of the tongue (Dodds, 1989; Logemann, 1986). In the case of a large bolus, the posterior oral cavity is sealed off by the elevation of the tongue base against the soft palate (Dua, Shaker, Ren, Arndorfer, & Hofmann, 1995). Once the oral stage of swallowing begins, the tongue elevates and rolls posteriorly in a peristaltic motion, making sequential contact with the hard and soft palate. This process generates intraoral pressure for propelling the bolus into the pharynx. Meanwhile, the anterior portion of the tongue is anchored against the hard palate, followed by sequential elevation of the mid, dorsal, and posterior portions to transfer the bolus posteriorly. The propelling movement of the tongue lets the bolus move from the anterior to mid and dorsal portions (Chi-Fishman, Stone, & McCall, 1998). Once the anterior to mid portion of the tongue has transferred the bolus to the posterior tongue and into the pharynx, the posterior tongue
contacts the posterior wall of the pharynx which contributes to the positive pressure imparted to the bolus to propel the bolus downward (McConnel, 1988). Tongue pressure generation may be involved in bolus clearance and may even play an important role in protection from airway penetration or aspiration (Robbins et al., 1995). Propulsion of the bolus from the oral to pharyngeal swallow is adapted by bolus volumes and viscosity of the texture. Increased bolus volumes and viscosity result in increased propulsion in the oral cavity (Dantas et al., 1990; Kahrilas & Logemann, 1993). At the end of the oral stage, the posterior tongue is lowered to allow the bolus to transfer into the pharynx. The oral stage of swallowing is critical for normal initiation and execution of pharyngeal bolus transport (Robbins, 1996).

Dodds (1989) indicated that tongue movement during the oral stage of swallowing is a major component of the pharyngeal stage of swallowing because tongue movements stimulate faucial and oropharyngeal sensory receptors that trigger the pharyngeal swallow. This suggests that tongue exercises involving sensory or motor stimulation may help facilitate swallowing function in populations with swallowing disorders.

The pharyngeal stage of swallowing begins when a bolus is propelled from the oral cavity into the pharyngeal cavity, i.e. when the bolus passes the anterior faucial pillars. There are a series of physiological events that constitute the pharyngeal stage of swallowing in order to protect the airway and transfer the bolus safely to the esophagus (Logemann, 1998; Robbins, 1988). First, the soft palate elevates to approximate against the posterior pharyngeal wall in order to prevent nasopharyngeal regurgitation (Groher,
In addition, the hyoid and larynx move upward and forward by contraction of the suprahyoid muscles which include submental muscles such as the anterior belly of the digastric, mylohyoid, and geniohyoid muscles (Crary et al., 2006; Dodds et al., 1990; Doty & Bosma, 1956; Perlman et al., 1999). The displacement of the hyoid and larynx is referred to as hyolaryngeal excursion. Hyolaryngeal excursion occurs vertically and anteriorly. The vertical hyolaryngeal movement contributes to airway protection, and the anterior hyolaryngeal movement is essential for opening the UES (Cook et al., 1989; Jacob, Kahrilas, Logemann, Shah, & Ha, 1989). Laryngeal closure is important for protecting the airway during the swallow (Logemann et al., 1992). Laryngeal closure occurs by the contraction of the intrinsic laryngeal muscles that results in the approximation of the arytenoids and epiglottis, false vocal cords, and true vocal cords to prevent entry of materials into the larynx (Logemann, 1983). The opening of the UES is associated with anterior hyoid excursion, bolus pressure. The anterior hyoid excursion pulls the UES to transfer bolus toward the esophagus (Cook, 1993; Huckabee et al., 2005). In addition, bolus pressure facilitates the maximal extent of UES opening during passing the bolus from pharynx and opened UES.

Pharyngeal constriction is a peristaltic wave in the pharynx (Robbins & Levine, 1988) which transports the bolus through the pharynx (Dodds et al., 1990). During the final portion of the pharyngeal stage of swallowing, the bolus is forced from top to bottom and passes through the opening of the UES by contraction of pharyngeal sphincters.
The esophageal stage of swallowing is when the bolus passes through the lower esophageal sphincter (LES) into the stomach. The bolus is pushed by the peristaltic wave of the esophageal sphincter. The esophageal sphincter is closed after the entire bolus is passed.

**Aging and Swallowing**

The older population is sociable and desires to have opportunities to share mealtimes during social occasions (Humbert & Robbins, 2008). Difficulties with swallowing can curtail social interactions with family and friends, thereby decreasing the quality of life in this population.

Changes in swallowing occur in all adults over time. Physical changes in the older population are associated with increased risk for disordered swallowing. It is estimated that 40% of adults aged 60 and older currently suffer from swallowing difficulties (Doggett, Turkelso, & Coates, 2002; Feinberg, Knebl, Tully, & Segall, 1990). This high percentage is associated with aging and age-related diseases. Motor and sensory functions associated with swallowing change with age. Healthy older adults do not present swallowing disorders, but neurologic and neuromuscular age-related changes may increase the risk for swallowing disorder. This phenomenon is referred to as presbyphagia (Robbins et al., 1992). Presbyphagia involves neuromuscular degeneration of anatomy, physiology, sensory feedback, motor control, and central processing of swallowing (Kahane, 1981; Lowit, Brendel, Dobinson, & Howell, 2006; Torre & Barlow, 2009; Liss, Weismer, & Rosenbek, 1990). It is important to sort out which characteristics are related to aging in order to develop appropriate diagnostic and treatment strategies for
these populations. In addition, the changes in swallowing function may provide insights in understanding onset and progression of disease in these populations.

Each stage of swallowing has different anatomical and physiological changes with aging. The oral stage involves the lips, tongue, and oropharynx. These muscles present with decreased strength, tension, mobility, and endurance with aging (Crow & Ship, 1996; Nicosia et al., 2000; Price & Darvell, 1981; Robbins et al., 1995). Changes in tongue strength are especially important to the oral stage of swallowing. For older individuals, tongue movement is slower and tongue strength is reduced. Reduced tongue strength and function may contribute to a slower swallow and longer duration of oral transit time (Robbins et al., 1992). In tongue strength measures, Robbins and colleagues (1995) reported that lower maximum isometric pressures in the tongue are generated in older adults than in younger adults (Robbins et al., 1995). These muscular changes have effects on slower oral manipulation and transition, extra tongue effort and motion, and reduced biting force during the swallow.

The older population shows different placement of the bolus in the oral stage (Tracy et al., 1989). The bolus in the older population is held more posteriorly. By the posterior bolus placement, the older population tries to compensate for reduced function of tongue strength and coordination. In addition, reduced maximum isometric tongue pressure may indicate not only that tongue musculature undergoes change with age, but also that other muscles of the floor of the mouth and the pharynx may change with aging (McComas, 1998).
As for age-related changes in the sensory processing of swallowing, the older population may lose neurons in the sensory components of the cranial nerves, subcortical relay nuclei, and cortical somatosensory areas. Previous investigations have found that decreased lingual sensation reduces taste and perception of viscosity or pressure on the tongue with age (Pelletier & Dhanaraj, 2006; Schiffman, 1997; Smith, Logemann, Burghardt, Zecker, & Rademaker, 2006). Taste detection and recognition thresholds in the older population increase due to the decreased number of taste buds. These changes contribute to taste perception changes. Moreover, the changes in the lips and tongue reduce perception of spatial tactile recognition. Meanwhile, the tongue muscles increase in fatty and connective tissues and show atrophy with aging (Robbins, 2003; Urago, 1991). Furthermore, dentures often are poorly fitted in the older population (Jaradeh, 1994). Masticatory ability is diminished with age (Nagao, 1992).

The age-related changes in the pharyngeal stage involve pharyngeal constriction, hyolaryngeal excursion, and UES opening in the older population. Overall, pharyngeal swallowing in the older population is slower than in younger population. The pharyngeal peristaltic motion helps bolus transit toward the esophagus. For the older population, the pharyngeal peristaltic motions are significantly slowed (Tracy et al., 1989), and pharyngeal contraction is reduced (Robbins et al., 1992). The decreased pharyngeal peristaltic motions and contraction contribute to slower bolus velocity during transport in the pharyngeal stage of swallowing. Lower swallowing pressure in the pharynx may be associated with difficulties of pharyngeal clearance (Humber et al., 2009). In addition, the initiation of hyolaryngeal excursion, which triggers the pharyngeal stage, is more delayed
in the older adults (0.6 sec) than in younger adults (0.1-2 sec) (Robbins et al., 2009). This indicates that the swallowing threshold is increased and neural processing time is slower for the older adults (Aviv, Martin, Kee, Devell, & Blitzer, 1993). Meanwhile, the duration of UES opening is slightly prolonged (Robbins et al., 1992).

The changes that occur in the esophageal stage are related to peristaltic waves and muscle tone in the esophagus. In the older population, decreased muscle tone of the esophagus is associated with reduced esophageal peristalsis. The peristaltic wave is less efficient with age. In addition, UES relaxation is delayed and UES pressure is reduced (Fulp, Dalton, Castell, & Castell, 1990; Shaker et al., 1993). These changes in esophageal peristalsis have an effect on esophageal transit.

**Swallowing Reserve in Older Individuals**

Aging constantly involves changes in the entire structures and functions of oropharynx for swallowing. However, swallowing dysfunction due to age-related changes does not occur for most of the older population, because the older population compensates and adjusts their swallowing performances based on task demands. It is important for a clinician to understand and evaluate altered performance and function in the older population. In addition, it is necessary to differentiate whether swallowing changes are associated with advancing age alone or from medical issues such as neurological disease, cancer, and traumatic injury.

Oropharyngeal and neurological structures and functions of swallowing in the older population are subject to reduced reserve and flexibility (Logemann, Paulski, & Rademaker, 2002). “Muscular reserve is the difference between extent of movement
needed to accomplish a desired functional result . . . and the actual extent of movement used” (Kenney, 1985, cited by Logemann et al., 2002, p. 440). In swallowing, it is my understanding that the swallowing reserve is the difference between what a person has and what a person needs to have for safe swallow. Individuals who have more swallowing reserve than what they need to have are able to perform safe swallow as always. However, if they have less swallowing reserve than what they need to have, they may be vulnerable to swallowing disorders when disease and illness occur (Buchner & Wagner, 1992; Johnson, 1993; Kenney, 1985; Troncale, 1996). The concept of reserve applies to various physiological processes such as respiratory and swallowing system.

Swallowing reserve is measured by comparing differences between regular swallow and effortful swallow in tongue pressure, amplitude of swallowing muscles, and temporal characteristics of swallowing. Older individuals have less swallowing reserve than younger individuals (Logemann et al., 2002). For example, reserve with aging can be explained by investigating the difference of tongue pressure and strength in older and younger population. Nicosia et al. (2000) explained lingual “pressure reserve” through the investigation of the difference of maximum isometric lingual pressure and maximum pressure during saliva swallows in 10 older and 10 younger participants. The finding was that maximum isometric pressure was reduced in older participants when compared to younger participants. However, maximum lingual pressure during saliva swallows was not significantly different between older and younger participants. The reduced maximum isometric pressure in older participants indicated reduced lingual pressure reserve for swallowing.
For reserve related to submental muscle, significant age-related reduction in amplitude of submental sEMG was reported during effortful saliva swallows and water swallows (Vaiman, Eviatar, & Segal, 2004). It may be true that muscular reserve is critical whenever the older populations have higher demands of muscular strength during the swallow. In reserve as measured by temporal characteristics of swallowing, younger individuals have faster initiation and longer duration of hyolaryngeal excursion than older individuals in the absence of any signs of swallowing disorders (Kim, McCullough, & Asp, 2005, 2007). Most research indicates that the older population has reduced temporal and pressure reserve for increased swallowing demands (Ginocchio, Borhie, & Schindler, 2009; Robbins et al., 1992; Tracy et al., 1989). The younger population has more muscular reserve to perform swallowing safely than the older population.

The benefit of more reserve may play an important role in case of disease and accident. With adequate reserve, each subject is able to swallow safely with existing muscular strength and flexibility after an incidence of disease or accident. The older population is more likely to be at risk for developing dysphagia due to the vulnerability of diseases and related complications (Carnes & Wood, 1995). It is necessary to investigate who those the reduced reserve in the older population has an effect on swallowing function and quality of life (Ney, Weiss, Kind, & Robbins, 2009). As proposed by Yeates et al. (2010), the concept of swallowing reserve has stimulated further understanding of age-related swallowing changes.

In summary, changes in the swallowing mechanism occur as a normal part of aging. Older individuals who experience temporary or chronic illnesses may be at a
higher risk than younger individuals to swallowing difficulties. The older population has a higher incidence of neuromuscular, cardiorespiratory and cardiovascular disease. It is necessary to develop age-appropriate intervention strategies and possibly a preventive exercise program, particularly for “at-risk” or “vulnerable” individuals within the older population to increase their swallowing reserve.

**Tongue Strengthening Exercise and Repeated Effortful Swallows**

Patients with dysphagia show muscle weakness and difficulty in coordinating swallowing. The purpose of behavioral rehabilitation for dysphagia is to restore the neuromuscular swallowing efficiency and ultimately to improve the quality of life for patients with dysphagia (Huckabee et al., 2005). Most behavioral rehabilitation is associated with strengthening exercises of the neuromuscular substrates of swallowing. This may help improve functional physiology of swallowing and swallowing safety (Kahrilas, Logemann, Lin, Ergun, & Facchini, 1993).

**Tongue strengthening exercise.** The tongue plays a critical role in the oropharyngeal stage of swallowing. The tongue forms and holds a bolus (Youmans & Stierwalt, 2006). Also, the tongue helps the bolus move posteriorly by stripping actions during the oral stage of swallowing. The tip of the tongue elevates and the middle of the tongue contacts the hard palate during the squeezing of the bolus (Kahrilas et al., 1993; Lowe, 1981; Shawker, Sonies, & Stone, 1984). The tongue action contributes to propulsive force in transporting the bolus through the oropharynx (Robbins et al., 2005). When the tongue is weak or damaged, it may be difficult to coordinate swallowing. In addition, tongue damage leads to difficulty in the transfer of the bolus toward the pharynx.
This indicates that tongue weakness may result in increased oral transit time during swallowing (Clark, Henson, Barber, Stierwalt, & Sherrill, 2003; Lazarus et al., 1996, 2000). In addition, weakness of the tongue may prevent the transportation of the entire bolus, leaving oral residue in the oral cavity. These difficulties are shown in stroke patients, head and neck cancer patients, and in healthy older population.

Tongue strengthening exercise may be useful to patients with tongue weakness to improve tongue strength. Tongue strengthening exercise can be facilitated by using a tongue depressor and/or the Iowa Oral Performance Instrument (IOPI). The IOPI also can be used as biofeedback to give quantitative information on how much force a patient is using when pushing the tongue (Youmans & Stierwalt, 2006).

One of the most frequently mentioned tongue strengthening exercises is lingual resistance exercise. Lingual resistance exercise has been shown to increase tongue pressure (Robbins et al., 2005). Robbins and colleagues (2005) conducted a study using lingual resistance exercise with the healthy older adults for 8 weeks. This study reported that peak isometric pressure and peak swallowing pressure were significantly increased after lingual resistance exercise. The tongue resistance exercise had the effect of gradually increasing peak isometric pressures from 41 kPa at the baseline to 44, 47, and 49 kPa after every two weeks. Peak swallowing pressure was measured when swallowing four different boluses: 3 ml and 10 ml thin liquid, and 3 ml semisolid with regular swallow and 3 ml thin liquids with effortful swallow. The peak swallowing pressures were increased for all bolus conditions with the exception of the 3 ml thin liquid. These results indicated that increased isometric strength by lingual resistance exercise carries
over to swallowing function. In addition, lingual volume was increased as measured by Magnetic Resonance Imaging (MRI).

Robbins et al. (2007) reported that maximum isometric pressure was an average of 35.6 kPa at the baseline; maximum isometric pressure increased to an average of 45.3 kPa after 4 weeks of tongue exercise and then to 51.8 kPa after 8 weeks of tongue exercise in patients with dysphagia. In addition, tongue strengthening exercise contributed to the pharyngeal stage of swallowing by reducing airway invasion (Robbins et al., 2007), as measured by the penetration and aspiration scale (PA scale). The PA scale scores in stroke patients changed from about 6 points (aspiration: bolus passes below the vocal folds, and is ejected into the larynx) to 3 (penetration: bolus enters the airway, remains above the vocal folds, and is ejection from the airway) after 4 weeks of tongue exercise, and to about an average of 2 points (bolus enters the airway, remains above the vocal folds, and is ejected from the airway) after 8 weeks of tongue exercise (Robbins et al., 2007). Lingual resistance exercise also reduced oropharyngeal residue. Tongue exercise even had effects on the quality of life related to swallow as patients’ perspective. For subcategories of swallowing quality of life questionnaire, fatigue, communication, and mental were improved after tongue exercise (Robbins et al., 2007). Overall, increased tongue strength through tongue strengthening exercise has positive effects on tongue muscles and swallowing function in patients with swallowing disorders (Connor et al., 2009).

**Repeated effortful swallows.** The pharyngeal stage begins when the bolus first enters the pharyngeal cavity and ends when the bolus tail passes the UES. Transfer of the
bolus in the pharyngeal stage is facilitated by pharyngeal constriction to transfer the bolus through the pharynx to the UES (Curtis, Cruess, Dachman, & Maso, 1984). In addition, pharyngeal constriction contributes to clearing the pharynx. Impaired pharyngeal constriction may leave residue in the pharynx. Pharyngeal dysphagic patients often show dysfunction of pharyngeal constriction, pharyngeal residue, and airway protection problems in the pharynx. Among several techniques, repeated effortful swallows can be applied to facilitate the pharyngeal stage of swallowing in patients with pharyngeal dysphagia. There are two different approaches to instructing to patients to conduct the repeated effortful swallows. One approach involves instructing patients to swallow by squeezing hard with all of the patient’s throat and neck muscles (Logemann, 1999). The other approach highlights lingual to palate contact during the effortful swallow (Bulow et al., 1999, 2002; Huckabee & Steele, 2006). A clinician may say, “Swallow hard; to do this, start the swallow by pushing your tongue hard against the roof your mouth” (Yeates et al., 2010) or “swallow very hard while squeezing the tongue in an upward-backward motion toward the soft palate” (Bulow et al., 1999). Huckabee and Steele (2006) compared changes of two different approaches to conduct the effortful swallow in peak amplitude of submental surface electromyography and orolingual and pharyngeal pressure in 20 healthy participants. The approach with tongue-to-palate emphasis resulted in greater changes in amplitude of surface electromyography, middle and posterior tongue pressure, and upper and lower pharyngeal pressure. Specifically, for amplitude of surface electromyography, the approach without tongue emphasis was 85.87 µV and the approach with tongue emphasis was 184.95 µV. In addition, the effortful swallow is
repeated with and/or without a bolus or saliva as a focused neuromuscular exercise (Bryant, 1991; Huckabee et al., 2005; Huckabee & Cannito, 1999).

The repeated effortful swallows show higher levels of muscle activity as compared to regular swallows. These muscles are involved in the opening of the UES and contraction of the pharynx (Huckabee et al., 2005). Muscle activity during the repeated effortful swallows can be visualized by surface electromyography (sEMG). The amplitude in sEMG corresponds to muscle activation, serving as biofeedback for a patient (Crary, 1995). The sEMG amplitude of submental muscle activation increases during the repeated effortful swallow in healthy adult participants (Lazarus, Logemann, Song, Rademaker, & Kahrilas, 2002; Huckabee et al., 2005).

The repeated effortful swallow has positive effects on the oral and pharyngeal stages of swallowing. The repeated effortful swallow results in increasing oral pressure which in turn decreases oral residue (Hind et al., 2001). For the pharyngeal stage of swallowing, the repeated effortful swallow has effects on displacements and durations associated with hyoid movements during swallowing (Bulow et al., 1999; Ding et al., 2002; Hind et al., 2001). The repeated effortful swallow increases the duration of laryngeal vestibule closure, protecting the airway for a longer time and decreasing the risk of aspiration (Hind et al., 2001). In addition, the repeated effortful swallow contributes to muscle activation in healthy adult participants (Bulow et al., 1999; Hind et al., 2001; Huckabee et al., 2005). The activation of submental muscles is increased by the effortful swallow as compared to the normal swallow. Huckabee et al., (2005) evaluated the relation between measurements of suprathyroid muscle contraction and pharyngeal
pressure generation. The activation of the effortful swallow was approximately 92µV and the activation of the normal swallow was approximately 39 µV in submental sEMG. The repeated effortful swallow showed highest amplitudes in sEMG among swallow maneuvers including the supersupraglottic swallow, Mendelsohn maneuver, and tongue-hold (Lazarus et al., 2002).

The repeated effortful swallow generates increased orolingual and pharyngeal pressures (Bulow et al., 1999, 2001, 2002; Hind et al., 2001; Huckabee & Steele, 2006, Steele & Huckabee, 2007). This contributes to reduced pharyngeal residue (Coulas, Smith, Qadri, & Martin, 2009; Logemann, 1998; Veis, Logemann, & Colangelo, 2000). For patients with head and neck cancer, mean tongue based-pharyngeal wall contact durations were longer for the repeated effortful swallow than the normal swallow. In addition, patients with the repeated effortful swallows not only increased oral pressure but also increased duration of maximal anterior hyoid excursion, laryngeal vestibule closure, and extent of superior hyoid movement, with a trend toward oral bolus clearance (Hind et al., 2001).

The repeated effortful swallow has shown mixed effects on the pharyngeal swallow. Huckabee et al. (2005) reported greater pharyngeal pressure generated by the repeated effortful swallow than by normal swallows at the manometric sensors. In addition, the repeated effortful swallow generated significantly lower pressure than the normal swallowing condition in the UES. These results indicated that the repeated effortful swallow contributes to increased muscle contraction of the collective floor of mouth muscles, increased pressure in the pharynx, and decreased pressure in the UES
(Huckabee et al., 2005). However, Huckabee et al. (2005) reported no significant change was reported in swallowing function, airway protection or submental muscle activity when using the repeated effortful swallows. Bulow et al. (1999) also reported that the repeated effortful swallow had no effect on swallowing function. There were no significant improvements in hyoid movement in both healthy older adults and patients with dysphagia. In addition, there were no changes in laryngeal penetration and aspiration. Ding et al. (2003) reported that there was no significant difference in amplitude of submental sEMG when comparing younger and older participants after the repeated effortful swallow exercise. The study by Bulow et al. (2001) further reported distance of maximal hyoid and laryngeal movement in regular swallow and effortful swallow in healthy adults. Distance of hyoid movement of effortful swallow (12.6 mm) was less than its regular swallow (16.3 mm) as well as distance of laryngeal elevation of effortful swallow (19.2 mm) was less than its regular swallow (25.6 mm). Thus the repeated effortful swallows have not demonstrated improvements consistently and may rather have negative implications for hyolaryngeal excursion.

Each maneuver of swallowing exercises targets specific aspects of the oropharyngeal physiology of swallowing (Clark, 2003; Logemann, 1999). Some research focuses on the effectiveness of each individual treatment maneuver. Other research focuses on the effectiveness of one treatment by measuring several parameters. For example, the effectiveness of the tongue strength exercise is investigated by measuring the maximum isometric pressure, swallowing pressure, and muscle activity in normal participants (Robbins et al., 2005). However, clinically, several exercises in swallowing
rehabilitation can be applied sequentially and/or concurrently by dysphagic patients. Most patients with dysphagia have dysfunction resulting from a number of specific physiological problems. Thus, for a swallowing intervention, it is necessary to explore several swallowing exercises to improve swallowing function based on physiological impairments. Bulow et al. (2001) suggested developing a combined swallowing exercise. Specifically, the combination of tongue strength exercises and effortful swallow is for patients with a weak tongue. This combination may help patients perform the effortful swallow well.

Further research is needed to identify the effectiveness of an intervention program in which a patient is treated concurrently using several maneuvers over a certain period. Only a limited body of research has reported the effectiveness of three or more interventions which include the Mendelsohn Maneuver, effortful swallow, supraglottic swallow, and chin tuck (Bulow et al., 2002; Karen, Rosenbek, & Sapienza, 2008; Lazarus et al., 2002).

**Neuroadaptation**

Neuroadaptation is the underlying conceptual framework of the oropharyngeal strengthening exercise (OSE) in this investigation. Neuroadaptation, defined as adaptive modifications of the neurological system, is promising (Drubach, Makely, & Dodd, 2004). Modifications of the neurological system occur during normal development, after neurological damage, with external intervention, and over the life span (Martin, 2009; Robbins et al., 2008). There is evidence that the damaged brain relearns and recovers lost function in response to external intervention (Malandraki, Johnson, & Robbins, 2011).
Specifically, external intervention such as sensory stimulation and motor skill acquisition can lead to behavioral changes corresponding to neuroadaptation. Behavioral changes in response to motor training and/or muscle strengthening exercise have an effect on neuroadaptation and drive cortical excitability (Pascual-Leone, Amedi, Fregni, & Merabet, 2005). For example, previous studies reported the effect of tongue task training on the tongue motor cortex: neuromodulatory changes, such as expansion of the cortical activity within the tongue motor cortex, occurred after the training (Hamdy, Rothwell, Aziz, Singh, & Thompson, 1998; Sessle et al., 2005).

The theory of neuroadaptation helps explain how exercise results in changes in function. Robbins and colleagues (2007) investigated the effects of tongue strengthening exercise on tongue strength and muscle fibers in poststroke patients. Their findings revealed that tongue strengthening exercises increased maximum tongue isometric pressure and pharyngeal swallowing pressure. There was also improved swallowing kinematics and reduced residue. In addition, this study showed increased volume of tongue muscles using MRI. These findings indicate that tongue strengthening exercise is able to improve muscle strength and subsequently improve swallowing performance. It is our expectation that the proposed intervention of this investigation may help improve neural activation of muscular and neuromuscular changes in older individuals. Table 1 presents the principles and definitions of neuroadaptation.
Table 1

*Principles and Definition of Neuroadaptation*

<table>
<thead>
<tr>
<th>Principle</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>Use it or lose it</td>
<td>• Cortical representation could be altered or enhanced through increasing environmental input (Nudo, Jenkins, &amp; Merzenich, 1990)</td>
</tr>
<tr>
<td>Use it and improve it</td>
<td>• Training or target practice can result in an enhancement of function and the underlying neural mechanisms associated with that behavior (Cohen et al., 1998; Nudo, 2003; Rioult-Pedotti, Friedman, &amp; Donoghue, 2000; Rioult-Pedotti, Friedman, Hess, &amp; Donoghue, 1998)</td>
</tr>
<tr>
<td>Plasticity is experience specific</td>
<td>• Certain changes in the neural substrates may be related to only particular behavior and training (Kleim et al., 2002)</td>
</tr>
<tr>
<td>Repetition matters</td>
<td>• Extensive and prolonged practice may modify neural substrates (Robbins et al., 2008)</td>
</tr>
<tr>
<td>Intensity matters</td>
<td>• Neural changes are led by stimulating a threshold of intensity (Luke, Allred, &amp; Jones, 2004; Lisman &amp; Spruston, 2005; Peinemann et al., 2004)</td>
</tr>
<tr>
<td>Time matters</td>
<td>• Time of intervention to maximize impact of neural change and promote cost effectiveness</td>
</tr>
<tr>
<td>Salience matters</td>
<td>• Strength training likely does not enhance skilled movement and induce changes in neural function (Ludlow et al., 2007)</td>
</tr>
<tr>
<td>Age matters</td>
<td>• Neural plasticity occurs over the life span (Kramer, Bherer, Colcombe, Dong, &amp; Greenough, 2004; Sawaki, Yaseen, Kopylev, &amp; Cohen, 2003)</td>
</tr>
<tr>
<td>Transference</td>
<td>• “The ability of plasticity within one set of neural circuits to promote concurrent or subsequent plasticity” (Kleim &amp; Jones, 2008)</td>
</tr>
<tr>
<td>Interference</td>
<td>• “The ability of plasticity within a given neural circuitry to the induction of new, expression of existing, plasticity within that same circuitry” (Kleim &amp; Jones, 2008)</td>
</tr>
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</table>
Introduction to Oropharyngeal Strengthening Exercise (OSE)

Current treatment of dysphagia focuses on rehabilitation of patients with dysphagia using compensatory and rehabilitation strategies. This investigation, in contrast, is interested in appraising the value of a preventive approach by creating a combination of two widely used swallowing exercises: tongue strengthening exercise and repeated effortful swallows. This investigation will examine the effect of the intervention on tongue strength, muscle activity, and swallowing quality of life. If this study yields positive findings, it will be significant because it will provide scientific evidence of improvement of muscular reserve in the older population after the training. In addition, the data from this investigation will provide important information regarding whether it is possible for the older individuals to perform a home-based, self-administered program.

The OSE, the combined exercise program in this investigation, is a combination of tongue strengthening exercise and repeated effortful swallows. These two exercises are easily combined by older individuals. During the oral stage of swallowing, the tongue presses against the hard palate in order to transfer the bolus into the pharynx. In the tongue strengthening exercise, each participant is instructed to press the tongue against the hard palate for 3 seconds. During the initiation of the effortful swallow, each participant presses the tongue hard against the hard palate and swallows hard (Huckabee & Steele, 2006; Yeates et al., 2010). The instruction in this study is “Put your tongue behind your upper teeth, and feel that ridge there? That is where your tongue normally goes when you take a swallow. The tongue pushes the food or liquid back into your throat. Put your tongue behind your upper teeth or top of your mouth and push hard for 3
seconds, and then swallow. As you swallow, I want you to squeeze all your mouth and throat muscles as hard as possible as if you are trying to swallow a ping pong ball.” The principle of the proposed exercise program reflects the integration of the tongue strengthening principle and the effortful swallow by incorporating tongue strengthening into the initial portion of the effortful swallow (Yeates et al., 2010).

OSE incorporates suggestions by Bulow et al. (2001). Bulow et al. (2001) investigated the effects of effortful swallow in 8 patients with pharyngeal dysfunction. Half of the patients had difficulty executing the effortful swallow probably due to weak tongue muscles. Specifically, when they performed the effortful swallow, their tongue tips were poorly elevated during the initial portion of effortful swallowing. Bulow (2001) suggested that before starting an effortful swallow, patients should perform the tongue strengthening exercise, because the latter requires patients to elevate the tongue against the palate and sustain it before initiating the swallow.

To examine the effectiveness of the prevention program of swallowing in older individuals, it is important to measure tongue pressure, submental muscle activity before and after the swallowing exercises; postexercise measurements will help determine whether there is improved muscular reserve. Perhaps if proven to be effective, the OSE tongue strength exercise combined with repeated effortful swallows may be useful to older individuals who are more at risk for developing dysphagia if they become frail or ill. In addition, this study may contribute evidence showing that prevention programs are worthwhile.
Research Aims of Current Study

The proposed investigation is designed to explore whether a home-based, self-administered OSE program for healthy older individuals has a measurable effect on maximum tongue pressure, peak amplitude of submental muscle activity, and swallowing quality of life. In detail, the research objectives of the proposed investigation are (a) to determine whether the oropharyngeal strengthening exercise increases participants’ maximum tongue pressure, (b) to determine whether the oropharyngeal strengthening exercise increases peak amplitude of submental muscle activity, and (c) to determine whether the oropharyngeal strengthening exercise increase “swallowing quality of life” in healthy older individuals.

Research aim I. To examine maximum tongue pressure using the Iowa Oral Performance Instrument (IOPI) after a 4-week OSE program using a home-based, self-administered procedure in healthy older individuals. The maximum tongue pressure has been used to measure the effectiveness of the tongue strengthening exercise and/or effortful swallow in healthy adults (Hind et al., 2001; Robbins et al., 2005). However, there is no research measuring tongue pressure to examine the combined tongue strengthening exercise and effortful swallow, so called oropharyngeal strengthening exercise (OSE).

H₀₁: There will be no difference in maximum tongue pressure pre and post OSE in healthy older individuals.

Hₐ₁: Maximum tongue pressure will be significantly higher (at $p < .05$) in healthy older individuals after 4 weeks of the OSE.
Research aim II. To examine peak amplitude of submental muscle activity using surface electromyography (sEMG) after a 4-week OSE program using home-based, self-administered procedure in healthy older individuals. The peak amplitude of submental sEMG has been used to measure the effectiveness of the tongue strengthening exercise and/or effortful swallow in normal population and patients with dysphagia (Crary, 1995). However, there is no research studying peak amplitude of submental sEMG to examine the combined tongue strengthening exercise and effortful swallow.

H₀₂: There will be no difference in peak amplitude of submental surface electromyography pre and post OSE in healthy older individuals.

Hₐ₂: Peak amplitude of submental surface electromyography will be significantly higher (at \( p < .05 \)) in healthy older individuals after 4 weeks of the OSE.

Research aim III. To identify swallowing quality of life using the Swallowing Quality of Life questionnaire (SWAL-QOL) (McHorney et al., 2000) after a 4-week OSE program using a home-based, self-administered procedure in healthy older individuals. The SWAL-QOL will allow the investigator to understand functional status of activity related to swallowing in healthy older individuals.

H₀₃: There will be no difference in the SWAL-QOL scores pre and post OSE in healthy older individuals.

Hₐ₃: SWAL-QOL total scores will be significantly higher (at \( p < .05 \)) in healthy older individuals after 4 weeks of the OSE.
Chapter 3: Method

Research Design

The investigation has adapted one-group pretest and posttest design to examine the effects of oropharyngeal strengthening exercise (OSE) in healthy older individuals.

Participants

Thirty-one older individuals from the local community expressed interest in participating in the study, of whom 27 were included as participants. Two participants who did not satisfy the inclusionary criteria were excluded from the study. One participant did not complete the 4-week OSE program due to surgery during the exercise program. One participant did not participate in the last session for a posttest. The participants consisted of 23 females and 4 males. Mean age of participants was 73 years old and ranges were from 58 to 85 years.

Participants met from the following inclusionary criteria: (a) above 55 years old, (b) normal oral structure and function, (c) no history of swallowing impairment (dysphagia), (d) no history of neurologic or head and neck impairments, and (e) nonsmokers or discontinued smoking for at least 5 years. Participants were excluded if they reported: (a) oral sensory deficits and (b) undergoing treatments or taking medication that affects their swallowing function. Informed consent was given by all participants prior to study initiation.

Oropharyngeal Strengthening Exercise (OSE)

The oropharyngeal strengthening exercise (OSE) program in this investigation consists of combined tongue strengthening exercise and repeated effortful swallows. The
OSE program sequentially executed tongue strengthening exercise and then effortful swallow. Initially, the OSE emphasized using the tongue to push hard against the palate for approximately 3 seconds so that the tongue muscles were engaged in strengthening. Location of the tongue tip was the alveolar ridge when pushing the hard palate. The target location of the tongue was based on tongue movements in normal oral stage of swallowing, in the oral stage and consistent with previous studies (Huckabee & Steele, 2006; Martin, 1991; Steele & Van Lieshout, 2004, 2009). The effortful swallow may elicit greater submental muscle activity and intraoral pressure (Yeates et al., 2010). The following instruction was developed and given to participants: “Put your tongue behind your upper teeth, and feel that ridge there? That is where your tongue normally goes when you take a swallow. The tongue pushes the food or liquid back into your throat. Put your tongue behind your upper teeth or top of your mouth and push hard for 3 seconds, and then swallow. As you swallow, I want you to squeeze all your mouth and throat muscles as hard as possible as if you are trying to swallow a ping pong ball.” This instruction was adapted and manipulated for this investigation from Yeates et al. (2010). Each participant received feedback from the investigators to ensure mastery of the OSE program.

**Instrumentation and Questionnaire**

There were two instruments and one questionnaire in this investigation: (a) Iowa Oral Performance Instrument (IOPI), (b) portable surface electromyography (sEMG), and (c) the Swallowing Quality of Life (SWAL-QOL) questionnaire.
Iowa Oral Performance Instrument (IOPI). The IOPI has been used to examine tongue strength and endurance for speech motor control as a clinical tool (Robin, Goel, Somodi, & Luschei, 1991, 1992). The IOPI, a small portable instrument, measures tongue pressure exerted against an air-filled bulb when held in the anterior oral cavity (see Figure 1).

Figure 1. Positioning of air filled tongue bulb.

The following procedures were performed. Participants were seated upright and asked to “Press your tongue against the roof of your mouth as hard as possible” (Robbins et al., 2005). The instrument displayed maximum tongue pressure from a numerical display (in kPa).

Surface Electromyography (sEMG). The sEMG was used to examine and record the electrical activity of muscle activity during the swallow. SEMG provides information about the onset and offset of muscle activation during the swallow. SEMG
consists of surface electrodes, an electrode cable, and a master-unit (Crary & Groher, 2000). An electrode cable connects to the electrodes to communicate the electromyographic meter-unit.

The sEMG signal of muscle activity was detected by electrodes applied under the electrode field. The peak amplitude of the sEMG signal was measured by using the portable sEMG (in $\mu$V).

For this investigation, each participant was seated upright and had the electrode field (the skin under the chin) cleansed by an alcohol pad to reduce impedance. Electrodes were coated with a light layer of conduction gel to improve the connection signal between the skin and the electrode. Each participant was adhered to surface electrodes on the surface submental muscles which were located between the midline of the mandibles anteriorly and the hyoid bone posteriorly (Bryant, 1991). The site of submental muscles was identified by placing one finger on the center of the submental area. The placement of electrodes is illustrated in Figure 2.

*Figure 2. Positioning of the submental sEMG electrodes.*
Each electrode patch contained a triad of three electrodes. The active electrodes were located parallel to the fibers of the submental musculature to maximize the amplitude of the signal (Lenius, Carnaby-Mann, & Crary, 2009; Stepp, 2012). The electrodes on the submental muscles detected the sEMG activity (Huckabee & Steele, 2006). The participants were instructed to prevent factors which would affect the outcome, “Do not elevate your shoulders and bite excessively to avoid involvement of other muscles.” Participants waited a minimum of 10 seconds between each trial in order to avoid effects of fatigue. Saliva swallows were used when measuring the sEMG.

**The Swallowing Quality of Life (SWAL-QOL) questionnaire.** SWAL-QOL includes total 44 items and 11 subcategories (fatigue, sleep, burden, eating desire, eating duration, symptoms frequency, communication, fear, mental health, social functioning, and food selection). SWAL-QOL used the Likert method of scaling. Each item is given a score from 1 to 5.

Each participant’s SWAL-QOL (McHorney et al., 2000) scores were collected before and after the exercises. SWAL-QOL subcategories were entered for analysis. The investigator was blinded to participant identity and condition at all times, and examined and analyzed the SWAL-QOL. The SWAL-QOL questionnaire provided information regarding the effectiveness of the exercise and was applied to compare the quality of life from the patient’s perspective with physiologic function.

Each participant was allowed ample time to fill out the SWAL-QOL and pose any questions they might have. The investigator assisted in completing the SWAL-QOL for participants who did not understand questions in the SWAL-QOL.
Exercise sheet. An exercise sheet included a set of swallowing instructions and a picture to help identification of tongue placement during exercises. Participants marked the time and day of exercise on the exercise sheet. The exercise sheet is provided in Appendix A.

Experimental Procedures

All data for this investigation were collected in the local community. Each participant attended two data collection sessions within a 4-week period. The first data collection session was conducted at the orientation session before beginning the exercise program, and the second session was conducted after 4 weeks of home-based, self-administered training. All participants completed measures of maximum tongue pressure by IOPI, peak amplitude of submental muscle activity by sEMG, and the SWAL-QOL questionnaire to compare between pre and post training measurements.

Participant screening. Participants completed an informed consent form for the Institutional Review Board (IRB), a brief demographic and screening questionnaire, and an oral motor examination to ensure that the participants satisfied the inclusion criteria. The questionnaire was designed to confirm general health and swallowing function by the dysphagia laboratory at Ohio University. The screening questionnaire is provided in Appendix B. Participants provided demographic information through the SWAL-QOL questionnaire.

An oral motor and neurological examination (i.e., cranial nerve function) were conducted to document the structure and function of the oropharynx associated with swallowing. The oral and neurological examination is provided in Appendix C.
**Preexercise measurement.** Participants were assessed in maximum tongue pressure, peak amplitude of submental muscles activity, and the SWAL-QOL. All evaluations were performed at the local community.

**Orientation.** The investigator explained the general aims and procedures of the investigation. To understand the exercise program, the OSE program was explained and demonstrated. The investigator demonstrated the exercise and participants practiced the program at least 10 times. During the practice, feedback was given to guide performance and mastery. In addition, the investigator provided participants with written instructions of the steps of exercise to facilitate understanding of the program and an exercise sheet to record exercise dates.

**Home-based, self-administered exercise for 4 weeks.** The home-based, self-administered training program of oropharyngeal strengthening exercise involved the following: 10 times per session, 3 sessions a day, on 3 days of the week as recommended for strength training by the American College of Sports Medicine (1990). After week 4, participants submitted exercise sheets that recorded their practice. Exercise sheets and instruction for exercise were distributed to the participants. The investigator tracked the performance of the participants every week during the OSE program via call or email.

**Follow up by weekly call and email during 4-week OSE.** Two undergraduate students and the investigator followed up participants’ performance using a weekly call and email. The undergraduate students understood the OSE program and observed orientation and preexercise evaluation before follow up.
Postexercise measurement. Participants were reassessed for maximum tongue pressure, peak amplitude of submental sEMG, and the SWAL-QOL.

Data Analysis

Maximum tongue pressure, peak amplitude of submental sEMG, and SWAL-QOL scores were collected and analyzed separately for pre- and postexercise measurements.

Maximum tongue pressure. Maximum tongue pressure was collected three times using the IOPI. The average of three time measurements was submitted for analysis.

Peak amplitude of submental sEMG. Peak amplitude of the submental muscle activity was normalized to reduce variability and improve reliability in interpreting sEMG results (Huckabee & Steele, 2006; Stepp, 2012; Wheeler-Hegland, Rosenbek, & Sapienza, 2010). This normalization provided a reference value for each participant. For this investigation, the following steps were performed to normalize the data. Peak amplitude of submental sEMG data was collected for a regular swallow and effortful swallow. Each participant performed regular swallows and effortful swallows in order to record and calculate sEMG data. The data from the effortful swallows served as reference values to normalize the data.

For example, if a participant has 98.57 µV as highest sEMG measure during the effortful swallow, that value is given a value of 100. Thus, for the same participant, if the maximum sEMG for the regular swallow is 68.06 µV, normalization rescaled this value like 100 x 68.06 / 98.57, with respect to the reference value. The comparison between
pre- and postexercise sEMG data was made with normalized value of the effortful swallow.

**SWAL-QOL.** Total scores and percent of subcategories’ scores in SWAL-QOL were submitted for analysis. Total scores were calculated by sums of scores for each item. Subcategories’ scores were calculated to percent by using the below formula to control equally comparable value, because each subcategory included different number of item.

\[
\frac{\text{Sums of each item in subcategory expressed} - \text{Minimum possible score}}{\text{Maximum possible score} - \text{Minimum possible score}} \times 100
\]

For example, symptoms frequency in subcategory contained 14 questions. Maximum total score of symptoms frequency was 70 (14 questions x 5) and minimum total score was 14 (14 questions x 1). If a participant has 56 scores which is sums of scores for each item expressed, percent of physical symptom is 75 %.

\[
\frac{56 - 14}{70 - 14} \times 100 = 75
\]

**Statistical Analysis**

SPSS v18.0 (SPSS Inc., Chicago, IL) was used for all the statistical analyses. The research design and analyses for each research question in described below:

Aim I: The maximum tongue pressure of IOPI provided continuous data. Pre- and postexercise scores of each continuous variable were compared using the matched pairs \( t \) test.

Aim II: The peak amplitude of submental sEMG provided continuous data. Pre- and postexercise scores of each continuous variable were compared using the matched pairs \( t \) test.
Aim III: The SWAL-QOL questionnaire provided continuous data. Pre and postexercise scores of all SWAL-QOL data were compared using the matched pairs $t$ test.
Chapter 4: Results

Reliability

Interjudge reliability was derived by having a second examiner blindly measure the maximum tongue pressure and peak amplitude of sEMG 6 participants. The second rater was a graduate student who has undergone training on tongue pressure and sEMG measure for a previous investigation. For reliability, intraclass correlation coefficient was used. A significant correlation of maximum tongue pressure was observed ($r = 0.99$, $p < 0.01$). Also, peak amplitude of sEMG was exactly matched between the investigator and the second rater. Intrajudge reliability was derived by having a principal investigator remeasure 6 participants’ maximum tongue pressure and peak amplitude of sEMG. Both maximum tongue pressure and peak amplitude of sEMG were exactly matched between the first and second measures.

Research Aim I: Maximum Tongue Pressure using IOPI

The first aim of this study was to examine maximum tongue pressure using IOPI after a 4-week OSE program using home-based, self-administered procedures in healthy older participants. For the maximum tongue pressure at baseline, the mean was 37.51 kPa and standard deviation was 15.26 kPa. For the maximum tongue pressure after a 4-week OSE, the mean was 45.68 kPa and standard deviation 9.38 kPa. The mean of maximum tongue pressure was positively increased by 8.17 kPa. The range of maximum tongue pressure in all participants at baseline was between 13 and 63 kPa. The range of maximum tongue pressure in all participants after a 4 week OSE was between 25.33 and 59.67 kPa.
Table 2 provides the mean and standard deviation of maximum tongue pressure at baseline and after a 4-week OSE. In addition, Figure 3 presents the mean of maximum tongue pressure at baseline and after 4-week OSE.

Table 2

*Mean and Standard Deviation of Maximum Tongue Pressure (kPa) at Baseline and After a 4-Week OSE*

<table>
<thead>
<tr>
<th>Time</th>
<th>Mean (kPa)</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>37.51</td>
<td>15.26</td>
</tr>
<tr>
<td>Week 4</td>
<td>45.68</td>
<td>9.38</td>
</tr>
</tbody>
</table>

*Figure 3*. Mean of maximum tongue pressure at baseline and after 4-week OSE.
After a 4-week OSE program, the maximum tongue pressure in older participants significantly increased ($t(26) = -3.598, p = 0.001$). In particular, 11 participants showed an increase of more than 10 kPa in maximum tongue pressure after a 4-week OSE. Among those eleven participants, 3 participants showed increases of more than 20 kPa in maximum tongue pressure between baseline and after a 4 week OSE. One participant even showed an increase from 20.61 kPa to 50.33 kPa, the difference being 29.72 kPa. However, 6 participants showed reduced maximum tongue pressure after a 4-week OSE. Those participants showed the range of maximum tongue pressure at baseline between 49.33 kPa and 63 kPa. Figure 4 presents the mean of maximum tongue pressure in each participant at baseline and after the 4-week OSE.

![Figure 4. Mean of maximum tongue pressure in each participant at baseline and after a 4-week OSE.](image)
Research Aim II: Peak Amplitude of Submental sEMG

The second aim of this study was to examine peak amplitude of submental surface electromyography (sEMG) after a 4-week OSE program using home-based, self-administered procedures in healthy older participants. For the normalized peak amplitude of submental sEMG at the baseline, the mean was 56.60 µV and standard deviation was 26.30 µV. For the normalized peak amplitude of submental sEMG after a 4-week OSE, the mean was 61.11 µV and standard deviation was 19.20 µV. The range of normalized peak amplitude of submental sEMG at baseline was between 10.82 µV and 91.23 µV, and the range of normalized peak amplitude of submental sEMG after a 4-week OSE was between 20.09 µV and 97.60 µV. Table 3 provides the mean and standard deviation of the normalized peak amplitude of submental sEMG at baseline and after a 4-week OSE.

Table 3

<table>
<thead>
<tr>
<th>Time</th>
<th>Mean (µV)</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>56.60</td>
<td>26.30</td>
</tr>
<tr>
<td>Week 4</td>
<td>61.11</td>
<td>19.20</td>
</tr>
</tbody>
</table>

Figure 5 presents the mean of normalized peak amplitude of submental sEMG at baseline and after a 4-week OSE.
Figure 5. Mean of normalized peak amplitude of submental sEMG at baseline and after a 4-week OSE.

The normalized peak amplitude of submental sEMG was not significantly different between baseline and after a 4-week OSE ($t(26) = -0.726, p = 0.474$). Among participants, 13 participants showed larger normalized peak amplitudes of submental sEMG after a 4-week OSE than at baseline. The two largest positive changes after a 4-week OSE were by 63.75 µV and 60.60 µV. The normalized peak amplitude of submental sEMG in one participant was changed from 11.37 µV to 75.11 µV. For the other participant, the normalized peak amplitude of submental sEMG was changed from 14.01 µV to 74.61 µV.

**Research Aim III: Swallowing Quality of Life**

The third aim of this study was to examine swallowing quality of life (SWAL-QOL) after a 4-week oropharyngeal strengthening exercise (OSE) using home-based and self-administered procedures in healthy older participants. The mean of total scores at
baseline was 199.04 and standard deviation was 16.08. The mean of total scores after a 4-week OSE was 200.81 and standard deviation was 15.41. Table 4 presents total score of Swallowing Quality of Life questionnaire of each participant at baseline and after a 4-week OSE. Appendix D presents all data of SWAL-QOL questionnaire at baseline and after a 4-week OSE.

Table 4

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Baseline</th>
<th>After OSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>195</td>
<td>193</td>
</tr>
<tr>
<td>2</td>
<td>209</td>
<td>215</td>
</tr>
<tr>
<td>3</td>
<td>210</td>
<td>213</td>
</tr>
<tr>
<td>4</td>
<td>220</td>
<td>220</td>
</tr>
<tr>
<td>5</td>
<td>216</td>
<td>217</td>
</tr>
<tr>
<td>6</td>
<td>198</td>
<td>204</td>
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<td>7</td>
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<td>8</td>
<td>170</td>
<td>173</td>
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<tr>
<td>9</td>
<td>200</td>
<td>202</td>
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<tr>
<td>10</td>
<td>183</td>
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<td>11</td>
<td>177</td>
<td>177</td>
</tr>
<tr>
<td>12</td>
<td>173</td>
<td>174</td>
</tr>
<tr>
<td>13</td>
<td>164</td>
<td>170</td>
</tr>
</tbody>
</table>
The total SWAL-QOL score was significantly different between baseline and after a 4-week OSE ($t(26) = -3.129, p = 0.004$). In subsections of SWAL-QOL, means of percentage of food selection, burden, social functioning, and communication were not different between baseline and after a 4-week OSE. The means of percentage in eating duration, desire, sleep, and fatigue after a 4-week OSE were greater than baseline. Table 5 provides the mean and standard deviation of all percentage scores for each subsection.
Table 5

_The Mean and Standard Deviation of Percentage Scores for Each Subset_

<table>
<thead>
<tr>
<th>SWAL-QOL</th>
<th>Baseline</th>
<th></th>
<th>After OSE</th>
<th></th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>Food selection</td>
<td>88.89</td>
<td>18.45</td>
<td>89.35</td>
<td>18.57</td>
<td>.327</td>
</tr>
<tr>
<td>Burden</td>
<td>85.19</td>
<td>18.68</td>
<td>87.04</td>
<td>17.50</td>
<td>.256</td>
</tr>
<tr>
<td>Mental health</td>
<td>94.41</td>
<td>6.98</td>
<td>97.78</td>
<td>1.32</td>
<td>.327</td>
</tr>
<tr>
<td>Social functioning</td>
<td>98.89</td>
<td>4.24</td>
<td>98.89</td>
<td>4.24</td>
<td>1.00</td>
</tr>
<tr>
<td>Fear</td>
<td>90.05</td>
<td>11.79</td>
<td>90.97</td>
<td>11.67</td>
<td>.256</td>
</tr>
<tr>
<td>Eating duration</td>
<td>83.33</td>
<td>21.65</td>
<td>86.11</td>
<td>18.78</td>
<td>.083</td>
</tr>
<tr>
<td>Eating desire</td>
<td>82.10</td>
<td>22.49</td>
<td>83.33</td>
<td>20.15</td>
<td>.103</td>
</tr>
<tr>
<td>Communication</td>
<td>97.22</td>
<td>6.33</td>
<td>97.22</td>
<td>6.33</td>
<td>1.00</td>
</tr>
<tr>
<td>Sleep</td>
<td>84.26</td>
<td>23.66</td>
<td>85.19</td>
<td>24.03</td>
<td>.161</td>
</tr>
<tr>
<td>Fatigue</td>
<td>77.16</td>
<td>21.63</td>
<td>77.47</td>
<td>20.65</td>
<td>.832</td>
</tr>
<tr>
<td>Physical symptom</td>
<td></td>
<td>76.59</td>
<td>9.51</td>
<td>85.78</td>
<td>10.25</td>
</tr>
</tbody>
</table>

*p < 0.05.
Figure 6 presents percentage of subsets in SWAL-QOL at baseline and after a 4-week OSE.

Figure 6. Percent of subsets of SWAL-QOL at baseline and after a 4-week OSE.

There was no significant difference in any category of SWAL-QOL except in the frequency of physical symptoms associated with swallowing difficulties. The frequency of physical symptoms associated with swallowing difficulties was significantly reduced after a 4-week OSE ($t(26) = -13.414, p < 0.01$).

In the frequency of physical symptoms associated with swallowing difficulties, the number of participants who answered “often choking during eating” was reduced
from 4 to 1 after a 4-week OSE. Also, the number of participants who answered “never choking during eating” was increased from 9 to 11 after a 4-week OSE. Frequency of choking during eating food was significantly reduced ($t(26) = -2.302, p = 0.03$).

Frequency of participants choking during eating is presented by Figure 7.

Figure 7. Frequency of choking during eating food in SWAL-QOL at baseline and after a 4-week OSE.
Chapter 5: Discussion

Overall Impact of OSE

The 4 weeks of the OSE program had positive effects such as increased tongue strength as well as improved swallowing quality of life as participants’ view. Comparing maximum tongue pressure before and after a 4-week OSE, maximum tongue pressure was increased by 8.17 kPa. This indicated that the OSE contributed to increasing overall tongue strength. For effects of the OSE in swallowing quality of life, participants reported reduced frequency of physical symptoms associated with swallowing difficulties. Particularly, frequency of choking during eating was reduced. This indicated that the OSE program may help improve airway protection. However no significant changing muscle activity occurred after the 4-week OSE. This would imply that submental muscle activation, which is related to hyolaryngeal excursion, may not be affected by the OSE.

Improved Tongue Strength

The major finding of the investigation was that older individuals significantly increased their maximum tongue pressure after performing the OSE for 4 weeks. The finding provides that a home-based, self-administered training program of the OSE contributes to improving tongue strength capacities in older individuals. This finding was similar to previous studies (Robbins et al., 2005, 2007; Yeates, Molfenter, & Steele, 2008). According to Robbins and colleagues (2005), tongue strengthening exercise in older individuals has been shown to increase maximum tongue pressure. Maximum tongue pressure at baseline was increased from 41 kPa to 47 kPa after 4 weeks of tongue strengthening exercise (Robbins et al., 2005). However, there are several differences
between the present study and that of Robbins et al. Comparing tongue strengthening exercise only to the OSE, the OSE program for 4 weeks showed 2 kPa more in improvement than only tongue strengthening exercise for 4 weeks (Robbins et al., 2005). Maximum tongue pressure after tongue strengthening exercise for 6 weeks in Robbins and colleagues’ study was improved from 41 kPa to 49 kPa, which was similar in result to a 4-week OSE. On the other hand, Robbins and colleagues in 2005 conducted tongue strengthening exercise for 30 times, three times a day, on 3 days of the week. Potentially, the effects of the OSE program on tongue strength were greater than only tongue strengthening exercise in increasing maximum tongue strength in terms of the frequency of exercise condition. It is possible the effects of the effortful swallow may help to increase maximum tongue and oral pressure (Hind et al., 2001). The results of this investigation are critical to determining the load, number of repetitions, and duration of the OSE to maximize efficient and effective outcomes in older individuals. In summary, our home-based, self-administered OSE showed a greater improvement of maximum tongue pressure than the on-site clinical tongue strength training developed by Robbins et al. (2005).

There were individual differences among participants. Participants who had relatively low maximum tongue pressure at baseline presented greater improvement than participants with high maximum tongue pressure at baseline. Figure 8 presents each participant’s maximum tongue pressure at baseline and after a 4-week OSE, ordering participants from low to high maximum tongue pressure at baseline.
Participants who had less than approximately 44 kPa in maximum tongue pressure at baseline showed positive improvement in maximum tongue pressure. Participants with greater than 44 kPa maximum tongue pressure at baseline presented positive or negative change in maximum tongue pressure. This suggests that participants with low maximum tongue strength will improve more in tongue strength than those with existing normal tongue strength. It is important to develop a screening tool to select candidates for the exercise program. Overall, the results of tongue strength after the OSE provided evidence to support the effect of the OSE as swallowing intervention for older individuals.

Robbins and colleagues (2007) reported increased lingual volume after the tongue strengthening exercise. Older individuals tend to lose muscle mass and fibers. The loss of muscle mass results in atrophy of fast-twitch fiber types associated with strength and
power (Macluso & De Vito, 2004). Improved strength would explain the relation of increased muscle mass and volume. Potentially, participants in this investigation who showed improved tongue strength have increased their tongue muscle mass and volume along with tongue strength. It is necessary to investigate tongue muscle mass and volume changes after the OSE.

**Tongue Strength on Aging and Intervention**

One of interesting findings was decreased tongue strength with aging. In this investigation, maximum tongue pressure was reduced considerably after 75 years old in comparison to those from 58 to 74 years old. This finding may present sarcopenia which is age-related loss of tongue muscle strength in age range from 75 years old (Campbell, McComas, & Petito, 1973; Evans, 1995; Santtilli, Bernetti, Mangone, & Paoloni, 2014).

However, after performing the OSE, older individuals above 75 years old showed greater improvement of maximum tongue pressure between baseline and after a 4-week OSE than those below 75 years old. According to Santilli and colleagues (2014), physical activity helps prevent and manage sarcopenia as a protective factor. This investigation additionally supported the OSE as one of physical activities may help positive effects on sarcopenia related to tongue muscles. Figure 9 presents each participant’s maximum tongue pressure of baseline and after a 4-week OSE program by age.
Impact on Submental Muscles

The results of the investigation showed that a 4-week OSE did not contribute to increasing activity of submental muscles. According to the analysis of peak amplitude of submental surface electromyography (sEMG), peak amplitude of submental sEMG in older individuals was not significantly changed after a 4-week OSE program. This may implies that the OSE program did not alter neuromuscular activity to increase hyolaryngeal excursion. Submental muscles are connected to the mandible and hyoid and are involved in tongue movement as well as hyolaryngeal excursion. Submental muscles are activated for both the tongue strengthening exercise and effortful swallow.

Figure 9. Each participant’s maximum tongue pressure of baseline and after a 4-week OSE by age
Specifically, contraction of submental muscles causes elevation of the hyoid and larynx (hyolaryngeal excursion). This movement is strongly associated with the effortful swallow, but the effects of the effortful swallow vary. Bulow et al. (1999) suggested that the effortful swallow had opposing effects on biomechanical characteristics of hyolaryngeal excursion and pharyngeal contraction. Distance of maximum hyoid movement and maximal laryngeal elevation during effortful swallow were less than during regular swallows. Also, pharyngeal peak contraction of effortful swallow (251 mmHg) was less than regular swallow (255 mmHg). Contrary to the study of Bulow and colleagues (1999), Hind and colleagues (2001) found positive temporal changes of pharyngeal swallowing including increased duration of hyoid excursion, laryngeal closure, and opening of UES during the effortful swallow. However, the results found by Hind and colleagues did not explain effects of the effortful swallow after training for a certain period of time. Further, the OSE program may not affect the opening of the UES, which is caused, in part, by hyolaryngeal excursion through contraction of the submental muscles.

The other potential interpretation of no significant change in sEMG activity is that each participant uses a different strategy to perform the effortful swallow in OSE. Previous studies suggested that each participant might perform the effortful swallow task with different strategies (Huckabee & Steele, 2006). In addition, Yeates et al. (2010) pointed out different instructions of effortful swallow, including a strategy of tongue-to-palate emphasis, a strategy of tongue to palate inhibition, or a strategy of utilizing pharyngeal muscles to increase effort. Huckabee and Steele (2006) utilized sEMG as
biofeedback to assist master of two strategies of effortful swallow including a strategy of tongue-to-palate emphasis and tongue-to-palate inhibition. They observed that amplitude of submental sEMG was greater for participants using the strategy of tongue-to-palate emphasis (120.81 µV) than for tongue-to-palate inhibition (21.73 µV) during session for mastery of effortful swallow (Huckabee & Steele, 2006). A strategy of tongue-to-palate contact may help to generate greater orolingual pressure than a strategy of tongue to palate inhibition. For results in this investigation, participants with higher peak amplitude of submental sEMG may have stronger contract of tongue to palate than participants with lower peak amplitude of submental sEMG while performing the effortful swallow. Further research needs to clarify a specific strategy for effortful swallow to maximize effects of swallowing function.

Even though there was no significant difference in peak amplitude of submental muscle activity before and after a 4-week OSE, an interesting result was found in relation to maximum tongue pressure. Among 21 participants who improved in maximum tongue pressure after the OSE, 11 participants (52%) also showed improvement in peak amplitude of submental sEMG. This may imply that stronger tongue strength by a 4-week OSE may contribute to peak amplitude in submental muscle activity in some individuals. Figure 9 presents the Venn diagram of the number of participants who improved in maximum tongue pressure, peak amplitude of submental sEMG, or both after a 4-week OSE.
Participants trained submental muscles by performing the effortful swallow in the OSE, although participants did not present positive changes in peak amplitude of sEMG. Peak amplitudes of submental sEMG were significantly different between the regular swallow and effortful swallow. However, the lack of significant difference in peak amplitudes of submental sEMG from baseline to after a 4-week OSE may be due to the fact that the three participants did not fully practice an effortful swallow in the OSE: a) participant 9 completed 34/36 sessions, b) participant 21 completed 31/36 sessions, and c) participant 28 completed 27/36 sessions. Several participants reported their mouth felt dry as well as fatigued because of effortful swallowing in the OSE. Also, participants reported that during the OSE, the tongue strengthening exercise portion was relatively easier to conduct than the effortful swallow in the OSE. It is necessary to develop clearer instruction and guidance to perform the effortful swallowing considering the feedback.
from this study. In addition, is a 4-week OSE enough to improve muscular activity? More research is required to determine the necessary duration and frequency of the intervention.

**Improvement Based on Participants’ Perspectives**

Qualitative effects of a 4-week OSE program were identified by using SWAL-QOL questionnaire. According to results of SWAL-QOL responses before and after a 4-week OSE, the 4-week OSE program influenced overall swallowing quality of life, physical symptoms associated with swallowing difficulties, and frequency of cough during eating.

In the results of SWAL-QOL responses, the OSE contributed to improving overall swallowing quality of life and particularly in reduced symptoms of swallowing difficulties in older individuals. Previous researchers who assessed swallowing quality of life using SWAL-QOL questionnaire reported different physical symptoms associated with swallowing difficulties among several subsections. Leow and colleagues reported that older individuals showed more physical symptoms associated with swallowing difficulties than younger individuals (Leow, Huckabee, Anderson, & Beckert, 2010). There was a similarity in the findings of Leow and colleagues and this investigation. Percentage score for symptom frequency in older individuals was 91% while for this investigation was 89%. Questions on symptoms of swallowing difficulty were similar for symptoms such as choking, saliva, chewing difficulty, and food sticking in the oropharynx. The finding may imply that the participants experienced reduced physical symptoms associated with swallowing, such as choking, saliva, chewing difficulty, and food sticking in the oropharynx through a 4-week OSE program.
Among symptoms associated with swallowing difficulties, frequency of coughing during eating was significantly reduced after training with the OSE for 4 weeks. This result suggests that the OSE program has a positive influence on airway protection. Robbins and colleagues in 2007 reported the effect of tongue strengthening exercise for 8 weeks on SWAL-QOL and airway protection using the Penetration-Aspiration Scale (PA scale) in stroke patients. Stroke patients after the 8 week tongue strengthening exercise demonstrated decreased PA scale scores, which indicated reduced airway invasion of liquid as well as reported reduced frequency of coughing on liquid. This result of the investigation suggests that the OSE may improve airway protection of food or liquid in older individuals. In addition, physiological improvement of tongue strength can transfer to the functional improvement of swallowing.

The data of SWAL-QOL may provide insight to presymptomatic signs and impact of signs made by the OSE in terms of overall health and dysphagia associated with swallowing quality of life for older individuals. The results of subsections in SWAL-QOL presented relatively lower percentages of scores in burden, eating duration and desire, sleep, and fatigue. Among these subsections, eating duration and desire are in need of being carefully observed in older individuals. Eating duration and desire vary between normal and degenerative diseases, such as Parkinson’s disease, as well as severity of degeneration. All subsections except sleep were significantly different between healthy older individuals and individuals with Parkinson’s disease; furthermore, eating duration and desire were reduced when comparing early stage Parkinson’s disease and later stage Parkinson’s disease as well as younger and older individuals (Leow et al.,
The present study supports the suggestion by Leow and colleagues in 2010 that SWAL-QOL can provide information on influence of healthy aging and alert health care professionals for future problems by observation of presymptomatic signs.

Participants reported that they realized the need for swallowing exercise for the future. Awareness of swallowing importance was elicited through participating in this investigation. Participants provided feedback that they would like to continue the OSE after the investigation.

The results of SWAL-QOL provided qualitative data on effects of health-related quality of life, although the participants’ responses of SWAL-QOL were unable to fully provide the independent effect of swallowing through the OSE. The qualitative data using SWAL-QOL questionnaire addressed the impact of the OSE beyond objective measures of tongue strength and submental activity. This investigation suggested one of the possibilities to assess swallowing in terms of individuals’ perspectives with intervention. Especially for those with a combination of several diagnoses, both objective and subjective assessment support to understand patients with swallowing difficulties from various angles.

Considering improved tongue strength, changes in overall performance due to a 4-week OSE would carry over to improved swallowing quality of life and physical symptoms of swallowing.

**Swallowing Reserve**

Neuromuscular function and physical changes in older individuals are associated with increased risks for disordered swallowing (Doggett et al., 2002; Feinberg et al., 1990;
Ney et al., 2009). Maximum tongue pressure of participants at baseline (37.51 kPa) was lower than that of younger individuals (approximately 62 kPa) from previous studies (Lazarus, Logemann, Huang, Rademaker, 2003; Robbins et al., 1995; Stierwalt & Youmans, 2007; Youmans & Stierwalt, 2006; Youmans et al., 2009). This result supported the idea that older individuals have lower tongue pressure than younger individuals as compared to different age groups from previous studies. Older individuals in our study had weak tongue strength, although participants in this investigation did not present with swallowing disorders.

Forty percent of healthy older individuals show symptoms of dysphagia (Doggett et al., 2002; Feinberg et al., 1990). Maximum tongue pressure was similar between participants at baseline in this study and patients with oral dysphagia in the study by Stierwalt and Youmans (2007). They reported that oral dysphagic patients who had similar levels of maximum tongue pressure as in this investigation showed poor bolus formation and manipulation, reduced containment in the oral cavity, impaired mastication, and weakened or absent lingual propulsion of bolus. It is possible that older individuals with low maximum tongue pressure would have difficulties in the oral stage of swallowing such as bolus manipulation or transfer of bolus toward the pharynx (Logemann, 1998). In addition, although participants in this study did not have a history of swallowing difficulties, some participants may use more muscular effort for swallowing, particularly for more viscous consistencies. Youmans et al. (2009) reported maximum swallowing pressure was 40.38 kPa with puree. The mean of maximum swallowing pressure with puree was greater than the mean of maximum tongue pressure
at baseline in this investigation. Additional tongue strength is required to transfer more viscous boluses. This may imply that some participants with less pressure than the capacity of swallowing have difficulty propelling more viscous boluses and/or hesitate being on a viscous diet. This finding supports the idea that older individuals are considerably more vulnerable and that careful diagnosis of dysphagia related to tongue weakness is needed. It is necessary to develop interventions to prevent dysphagia for older individuals with vulnerable swallowing function.

The OSE in this investigation showed increased swallowing reserve in terms of tongue pressure in older individuals. With adequate reserve, older individuals are able to swallow safely after an incidence of disease or accident (Logemann et al., 2002). In the OSE program, one of the specifically targeted reserves for swallowing was tongue strength reserve. Increased tongue strength reserve in this study was measured by the difference of maximum tongue pressure between baseline and after a 4-week OSE. Maximum tongue pressure after a 4-week OSE was much higher than at baseline. Tongue strength reserve in older individuals may also be increased through the OSE. With increased reserve through intervention, individuals may be able to swallow safely after an incidence of disease or accident.

The findings in this investigation showed promising potential on preventative approach for older individuals. Earlier direct intervention such as the OSE might improve tongue function which ultimately has an effect on swallowing (Robbins et al., 2005; Stierwalt & Youmans, 2007; Youmans & Stierwalt, 2006). Further research will need to
follow up on how preserved or improved reserve of tongue strength will benefit or prevent dysphagia in older individuals after incidence of disease or illness.

**Principles of Neuroadaptation and Exercise Principles of OSE**

The ultimate goal of oropharyngeal strengthening exercise (OSE) is to improve neural activity, tongue strength, and the quality of life in older individuals who are vulnerable to swallowing disorders and patients who suffer from swallowing disorders. To accomplish this goal, the OSE is designed to follow neuroadaptation and exercise physiology principles.

The conceptual framework of the OSE is based on neuroadaptation in order to maintain or restore neuromuscular strength and activity in older individuals. Neuroadaptation from the OSE in this investigation would influence the structure of the intervention and expected outcome after the OSE. The OSE may lead to improvement of activation of the neuromuscular system related to oropharyngeal swallowing. The motor and sensory cortex may be stimulated during the OSE. The motor cortex may be involved in the movement of swallowing structures such as the tongue, hyoid, larynx, and UES. The sensory cortex may be involved in feedback to control the contraction of the tongue and submental muscles and the squeezing of pharyngeal muscles during the OSE. These neural activations may facilitate efficient functions which may be related to diminished cortical activities with aging. Additionally, the stimulation in the motor and sensory cortex may reach the central pattern generator for swallowing which may indicate neural activation through the OSE. Stimulation of the central pattern generator during the OSE may contribute to efficient swallowing for older individuals. Fibers of oropharyngeal
muscles may be concurrently recruited in addition to neuromuscular activation. In this investigation, the OSE showed improved strength of the tongue. Impact of the OSE may not only be related to muscle physiology of swallowing but also improve interaction of neurophysiology for efficient and safe swallowing. Figure 11 presents diagram of concept of neuroadaptation and OSE.

![Diagram of concept of neuroadaptation and OSE.](image)

*Figure 11. Diagram of concept of neuroadaptation and OSE.*

Table 6 provides 10 principles of neuroadaptation and interpretation of the OSE.
## Neuroadaptation of OSE

<table>
<thead>
<tr>
<th>Principle</th>
<th>Application/hypothesis of OSE</th>
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| Use it or lose it             | • Older individuals may have diminished cortical activity  
• Older individuals presented lower tongue strength before OSE  
• OSE will help preserve or enhance cortical and subcortical representation                                                                                     |
| Use it and improve it         | • Stronger muscles provide the behavioral framework for increased skill  
• OSE may lead to improved swallowing or establishment of greater potential for skills                                                                            |
| Plasticity is experience specific | • OSE includes tongue strengthening exercise and effortful swallow                                                                                                 |
| Intensity matters             | • 10 Times per sessions, three times a day, 3 days per week                                                                                                          |
| Repetition matters            | • 4 weeks of OSE                                                                                                                                                     |
| Time Matters                  | • 4-week OSE program contributed to improving tongue strength  
• Home-based and self-training                                                                                                                                       |
| Salience matter               | • OSE may not change neural structures of functional swallowing; however, it may be used as needed in targeted function of swallowing                                      |
| Age matter                    | • Older individuals (age range was 58 to 85 years old) may demonstrate potential for neural plasticity                                                            |
| Transference                  | • Possibility of improvement of airway protection with increasing tongue strength                                                                                       |
| Interference                  | • Some participants showed improvement of tongue strength and swallowing quality of life, but others were not                                                      |
Older individuals continue to lose strength without training. Previous studies showed that older individuals experience the loss of peripheral input to the sensory cortex (Kaas, Merzenich, & Killackey, 1983; Merzenich et al., 1983). The swallowing mechanism involving diminished cortical presentation in older individuals may apply. However, the decreased cortical representation would be altered or delayed by intervention such as strength exercise. Strength exercise can drive improvement of function and the underlying neural mechanisms associated with the exercise (Cohen et al., 1998; Friedman, & Donoghue, 2000; Nudo, 2003; Rioult-Pedotti et al., 1998). The OSE for older individuals aimed to improve strength of swallowing muscles including tongue and submental muscles. Although older individuals did not have difficulty of swallowing, some showed weak tongue strength before the OSE program. Also, older individuals in this investigation presented improved tongue strength. Stronger tongue strength after OSE may lead to neural changes related to swallowing.

Particular training occurs to facilitate specific physiological and neurological changes (Kleim et al., 2002). The OSE consisted of tongue strength exercise and effortful swallow to improve tongue and submental muscle strength. The OSE was repeated 10 times per session, 3 sessions a day, and 3 days per week for 4 weeks. The OSE was efficiently executed in terms of time because the OSE was home-based and utilized self-administered training. Participants were able to manage their training time, and the OSE did not require participants to commute to a clinic. In this investigation, the OSE was designed for older individuals who were older than 60 years old and vulnerable to swallowing disorders.
Tongue strength training does not improve skilled movement and lead to changes in neural function. However, if skilled movement and neural changes are required, they occur (Ludlow et al., 2007). For the OSE, swallowing function was not measured directly; however, participants in this investigation reported improved swallowing function, which may be helpful to later improve reserved capacity of swallowing. Additionally, changes of neural function accompany changes in the circuits of swallowing (Kleim & Jones, 2008). This indicates that perhaps the OSE may have effects on other functions related to swallowing such as airway protection, although the OSE targets tongue and oropharyngeal muscles. Impact beyond measurements of the OSE would be functions of swallowing. It is necessary to investigate videofluoroscopically how swallowing function is improved.

In addition, the OSE follows three principles of exercise physiology: specificity, intensity, and transference. For three principles of exercise for the OSE, (a) specificity: the OSE consisted of tongue strengthening exercise and effortful swallow to improve tongue and submental muscles and quality of life, (b) intensity: the OSE in this investigation was performed 10 times per session, three sessions a day, three days per week. The OSE in this investigation was only 4 weeks. It is necessary to investigate how long the OSE program should last to see effective improvement in tongue strength. In addition, submental muscle activity did not show significant improvement. It is necessary to have the full 8 weeks of exercise to further investigate improvement in submental activities. The ultimate goal of the OSE was (c) transference: in order to improve swallowing function and quality of life in older individuals. The OSE with these
principles has positive effects on targeted physiological changes and the neuromuscular system. The physiological changes include strength and coordination of muscles and nerve firing (Drubach et al., 2004).

**Home-Based and Self-Administered Model**

The OSE presented a new model of a preventative approach with home-based and self-administered procedures in swallowing intervention. A home-based model of the OSE would provide participants with a highly accessible intervention for those who may not afford swallowing intervention due to physical disability, restricted transportation, or high cost. Previous studies reported that many older individuals prefer to have services in their own home (Leff et al., 2005; Whitten, 2006). This indicates that the OSE may be a preferred intervention for older individuals, even though some older individuals are able to go to a clinic. Outcomes of the OSE demonstrated feasibility of home-based intervention to improve tongue muscle strength and safety of swallowing in older individuals. In addition, the effects of OSE with self-training showed improvement of tongue strength and participants’ perspectives of swallowing without direct clinical contact. However, it is important to have thorough instruction and monitoring for self-training. During the orientation in this investigation, clinicians and research assistants had an intensive training with the participants in order to make sure each participant mastered the intervention procedures. In addition, the OSE included weekly emails and calls to participants from college students majoring in communication sciences and disorders. Weekly emails or calls were used to track and confirm that older participants completed the OSE without any difficulty. The feedback from weekly emails and calls encouraged
participants to get involved in daily exercises and helped the researcher and clinicians to determine the appropriate OSE regimen such as frequency and break time to avoid fatigue. In summary, this investigation has identified that home-based and self-administered training of the OSE are practical for older individuals and projected to have positive outcomes in swallowing safety and muscle strength.

**Clinical Implications of the OSE**

The OSE showed promising outcomes for improving tongue strength and swallowing quality of life in older individuals. As the OSE has value as a form of preventative intervention for older individuals who may be vulnerable to swallowing problems, it is important to consider who will be the candidates of the OSE. In this investigation, all participants were healthy and had normal swallowing. As expected, some participants with normal tongue strength and swallowing quality of life did not show significant improvement after the OSE. However, some participants who had weak tongue showed significant improvement in tongue strength. These individuals may be good candidates for the OSE. It is important to develop a screening program to measure the tongue strength in older individuals before the intervention. Candidates may experience difficulty in dealing with food in the oropharyngeal stage of swallowing such as in bolus formation, oropharyngeal residue, and avoidance of certain consistencies of food. Stronger tongue muscle after the OSE may help reduce residue and improve bolus control in the oropharyngeal stage of swallowing. It is necessary to confirm these changes using temporal and biomechanical measurements after the OSE using videofluoroscopic swallowing exams. In summary, the OSE may have positive effects on signs and
symptoms associated with swallowing quality of life such as reducing cough during eating in older individuals.

The OSE can be applied to patients with dysphagia to improve tongue strength and swallowing quality of life. Patients with dysphagia from neurogenic disorders such as stroke or Parkinson’s disease can have difficulties in the formation and transfer of the bolus in the oropharyngeal stage of swallowing with weak tongue strength (Calne, Shaw, Spiers, & Stern, 1970; Robbins & Levine, 1988; Robbins et al., 2007). Tongue strength can be increased by performing the OSE. Increased tongue strength due to the OSE may help reduce difficulties of the oropharyngeal stage of swallowing patients with dysphagia. Also, the OSE may contribute to swallowing quality of life in patients with dysphagia in terms of patient perspectives. Patients who perform the OSE may feel reduced symptoms related to swallowing such as frequency of choking during eating of food. The OSE can be beneficial to improve tongue strength and swallowing quality of life both for older individuals and for patients with dysphagia.

Limitations/Future Research

The OSE was designed to combine two interventions. It is expected to have dual effects from both tongue strengthening exercise and the effortful swallow. During tongue strengthening exercises, participants executed tongue elevation and pressure towards the hard palate. The effortful swallow involved muscle contraction during swallowing by the squeezing of oropharyngeal muscles. It is important to figure out appropriate measurements in order to identify specific effects of the OSE. Maximum tongue pressure can directly measure tongue strength by the IOPI, while sEMG may not be sensitive
enough to measure effects of the OSE in submental muscle activity and strength. Swallowing muscles used during the OSE are contracted differently in tongue strength exercise versus the effortful swallow. Increased tongue pressure not only involves more intrinsic tongue muscles but also other muscles such as submental muscles. SEMG signals from the submental muscles may not specifically represent detected submental muscle activity because sEMG also reflects intrinsic lingual activity (Huckabee & Steele, 2006). A future study needs to evaluate the effects of the intervention using wired EMG or other sensitive measurements.

Effortful swallow in the OSE may facilitate submental muscle activity to perform hyolaryngeal excursion. Submental muscles including the mylohyoid, geniohyoid, and anterior belly of the digastric (Vaiman et al., 2004), connect the hyoid to the mandible (Bosma, Donner, Tanaka, & Robertson, 1986). Connection of submental muscles to the hyoid is highly related to hyoid and laryngeal functions for swallowing. The hyolaryngeal excursion helps to protect the airway and open the UES. Previous studies report that effortful swallow facilitates reduced residue in the pharynx and airway protection as understood from analysis of videofluoroscopic swallowing exam (VFSE) in the pharyngeal stage of swallowing (Hind et al., 2001; Robbins et al., 2007). In future studies, it would be interesting to include evaluation of hyolaryngeal excursion using VFSE after the OSE.

One of the suggestions from this investigation would be to develop screening procedures to find individuals who need preventative intervention for swallowing. Older individuals and women who have weak tongue strength may potentially need intervention
for swallowing (Crow & Ship, 1996; Youmans & Stierwalt, 2006). Criteria to qualify under the screening would be related to skeletal size and muscle mass (Bassey & Harries, 1993; Frontera, Hughes, Lutz, & Evans, 1991). In this investigation, several older participants showed lower maximum tongue pressure at baseline than participants from other studies. Without screening, mixed participants with either significantly weak or relatively strong tongue strength may obscure the interpretation of outcomes.

Compared with other studies, the age range in this investigation was from 58 to 85 year olds and the mean age was 73 year olds, while the age range in Youmans and Stierwalt’s study in 2006 was from 60 to 79 year olds and the mean age was 68.81 year olds. This investigation had a wider range of age and higher mean age than previous studies. In addition to age, gender could be a factor in tongue pressure and submental muscle activities. Previous studies reported that women have lower maximum tongue pressure than men (Crow & Ship, 1996; Stierwalt & Youmans, 2007; Youmans & Stierwalt, 2006). The mean of maximum isometric pressure (MIP) in men was 62.69 kPa and the MIP in women was 57.56 kPa (Youmans & Stierwalt, 2006). The number of participants who were women in this investigation was 23 and the number of men was 4. This investigation would mainly present tongue strength of women because 85 percent of participants were women. It is necessary to further investigate the age and gender effects after the OSE.

Another suggestion for future research would be to determine optimal exercise regimen. Specific and detailed structured exercise regimen with specific number of sessions and repetitions may result in more specific performance gains (Burked et al.,
Questions regarding the OSE of load, volume, and intensity are important to move forward in the investigation of how both healthy and disordered oropharyngeal muscles respond to exercise training for maximal gains. Also, it is necessary to compare the effectiveness of the OSE between home-based and self-administered training procedures with on-site and face to face training procedures. Comparative effectiveness studies will support the reliability, feasibility, and acceptability of the OSE with home-based and self-administered procedures. Future research will focus on refining the OSE program for healthy older individuals and patients with dysphagia.

**Conclusion**

This investigation introduced a new swallowing intervention by the combination of tongue strength exercise and the effortful swallow, which was called the oropharyngeal strengthening exercise (OSE) with a home-based and self-administered training model. The OSE was developed for preventative swallowing intervention for older individuals. The purpose of this investigation was to examine whether the OSE has effects on tongue and submental muscle strength and swallowing quality of life by measuring maximum tongue pressure, peak amplitude of submental surface electromyography (sEMG), and changes of swallowing quality of life via questionnaire in older individuals. Maximum tongue pressure and swallowing quality of life from participants’ perspectives were improved after a 4 week OSE. However, there was no positive change in peak amplitude of submental sEMG.

This investigation will help promote earlier identification and preventative intervention of dysphagia in older individuals who are vulnerable to swallowing disorders.
The findings from this investigation suggested the feasibility of home-based and self-administered training for preventative swallowing intervention. This investigation also provides new direction for continued exercise to further refine the OSE including optimal volume and duration of the regimen and candidates. Additionally, patients with dysphagia resulting from neurogenic disorder could benefit from the OSE program.
References


Huckabee, M., & Steele, C. M. (2006). An analysis of lingual contribution to submental surface electromyographic measures and pharyngeal biomechanics during


Yeates, E. M., Steele, C. M., & Pelletier, C. A. (2010). Tongue pressure and submental surface electromyography measures during noneffortful and effortful saliva


Appendix A: Exercise Sheet

Participant Number:

**Instruction**

**Step 1.** Push tongue top of your mouth for 3 seconds

**Step 2.** Swallow squeezing all of your mouth and throat muscles as hard as possible as if your are trying to swallow a ping pong ball

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**Comment**

Thank you for participating in this study!
Appendix B: Screening Questionnaire

Thank you for your time and patience!

Participant Number:

1. Have you experienced any difficulty swallowing saliva, food, or liquid? (Yes/No)

If you answered ‘Yes’, answer question 1a through 1d, otherwise skip to question2.

   1a. How long have you experienced difficulty swallowing?

   1b. Describe the swallowing difficulties that you have experienced?
   (Example: Frequent coughing when drinking water, etc)

   1c. Have you consulted your doctor or been referred to a speech-language pathologist (SLP) for your swallowing impairment (dysphagia)?

   1d. Have you received any treatment for dysphagia?
   (Swallowing exercises, changes in food/liquid consistency, etc)

2. Have you had any neurological impairments and/or head and neck disorders, and/or neck injuries?

3. Do you have any medical condition, gastrointestinal conditions, or do you take any medication that affects the movement and function of your lips, tongue, jaw, and ability to swallow saliva, food, or liquid? (If yes, please describe/list)

4. Do you have oral sensitivity/oral pain that could affect placing the instrumentation in your mouth and completing the experiments?

5. Have you smoked over the past five years?

6. Please list any medical condition you may have.
## Appendix C: Oral Motor and Neurological Examination

<table>
<thead>
<tr>
<th>Participant Number:</th>
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<tbody>
<tr>
<td><strong>Face</strong></td>
<td>Assess anatomy of face (e.g., symmetry)</td>
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<td>Make a wrinkle the forehead and look up the ceiling</td>
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<td>Close the eyes as tight as possible</td>
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<td><strong>Jaw &amp; Teeth</strong></td>
<td>Opening and closing movements of the jaw</td>
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<td>Grinding lateral movements of chewing</td>
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<td>Bite down as hard as possible and then relaxes</td>
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<td>Dentition: all present/ dentures/ teeth missing</td>
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<td><strong>Lips</strong></td>
<td>Assess lip seal at rest</td>
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<td>Smile or pull back the corners of the lips</td>
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<td></td>
<td>Puff checks and hold air</td>
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<tr>
<td><strong>Tongue</strong></td>
<td>Assess anatomy of tongue (e.g., atrophy)</td>
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<td>Touch the corners of the mouth with tongue</td>
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<td>Touch the top lip and alveolar ridge with the tongue</td>
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<td>Sweep the sides of your mouth between your checks and gums with your tongue</td>
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<td><strong>Larynx</strong></td>
<td>Prolong a vowel such as /a/ to assess voice quality</td>
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<td></td>
<td>Rise and lower the pitch of a prolonged vowel</td>
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<td>A voluntary cough</td>
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<td>Throat clearing</td>
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<td><strong>Hard &amp; Soft palates</strong></td>
<td>Observe the palatal arches</td>
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<td>Observe the soft palate when phonating ‘ah’</td>
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<td></td>
<td>Touch the tongue blade against the palatal arches</td>
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<td><strong>Others</strong></td>
<td>Tastes (salty, sour, bitter, and sweet)</td>
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<td>Gag</td>
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<td>Mouth breathing</td>
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<td>Take a sip of water</td>
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Appendix D: Responses of SWAL-QOL

<table>
<thead>
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<th>Question</th>
<th>Baseline</th>
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<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td></td>
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</tr>
<tr>
<td>3</td>
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</tr>
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<td>5</td>
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</tr>
<tr>
<td>9</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>
Appendix E: Participant Feedback Form

Thank you for participating in this exercise. Your comments and input are greatly appreciated, and provide invaluable insight that will better develop swallowing exercise. Any comments provided and all personal information will remain confidential. Please keep comments concise, specific, and constructive.

Part I. General Information
What percent of exercises did you completed: □100% □75% □50% □25% □Drop
When did you do usually exercises (e.g., after meals, during watching TV etc.)

Part II. Exercise Design
Please rate, on a scale of 1 to 5, your overall assessment of the exercise relative to the statements provided, with 1 indicating strong disagreement and 5 indicating strong agreement.

<table>
<thead>
<tr>
<th>Assessment Factor</th>
<th>Strongly Disagree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation was informative and provided the necessary information for my role in the exercise.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>The exercise frequency was plausible and realistic.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Exercise participants included the right people in terms of level (I am a good candidate for this exercise)</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Participants were actively involved in the exercise.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>The exercise increased my understanding about tongue and throat for swallowing.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Weekly call is helpful in completing the training for 4 weeks.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Based on your experience, I want to keep doing this exercise.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>After this exercise, I have benefit in terms of swallowing</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>If you participate in this exercise in the session near to your community center, I am willing to participate in this exercise.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>
Please mark on your overall assessment of the exercise relative to the statements provided.

<table>
<thead>
<tr>
<th>Assessment Factor</th>
<th>5 min</th>
<th>10 min</th>
<th>20 min</th>
<th>more than 20 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>How long did you take to do this exercise per session?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What types of training do you prefer?</td>
<td></td>
<td></td>
<td></td>
<td>Home based</td>
</tr>
<tr>
<td>Did you feel that how many sessions/day are appropriate</td>
<td></td>
<td></td>
<td></td>
<td>Face to face</td>
</tr>
</tbody>
</table>

Part III. Participant Feedback
1. I observed any of following happen to you during the exercise

<table>
<thead>
<tr>
<th>Following Happen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

2. I observed the following strengths during this exercise

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td></td>
</tr>
<tr>
<td>Organization</td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td></td>
</tr>
<tr>
<td>Exercise</td>
<td></td>
</tr>
</tbody>
</table>

3. I observed the following areas for improvement during this exercise

<table>
<thead>
<tr>
<th>Areas for Improvement</th>
<th>Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td></td>
</tr>
<tr>
<td>Organization</td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td></td>
</tr>
<tr>
<td>Exercise</td>
<td></td>
</tr>
</tbody>
</table>

Many thanks for taking the time to complete this form!

Adapted from http://emergencymanagement.wi.gov/