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Lingual pressure generation in relation to saliva and water swallowing in healthy young adults

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LINGUAL PRESSURE GENERATION IN RELATION TO SALIVA AND WATER SWALLOWING IN HEALTHY YOUNG ADULTS

An Abstract of a Thesis

Submitted

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

Anna Joerger

University of Northern Iowa

December 2016

ABSTRACT

Lingual strength and swallowing pressures have been studied extensively in dysphagia rehabilitation literature; however, little research has considered how lingual pressure generation may relate to parameters of swallowing speed and endurance. Additionally, little is known about the ability of the tongue to generate pressure to a given target, known as lingual control. This project collected measures of lingual pressure and measures of swallowing speed and endurance in 10 healthy, young adults. Specifically it explored if lingual strength or control of the anterior and posterior tongue correlate with endurance or speed during saliva and water swallowing tasks. Significant relations among lingual pressures and water swallowing measures were found. Maximal isometric anterior lingual pressures (i.e., tongue strength) were positively correlated with swallowing speed and negatively correlated with endurance during water swallows; however, greater accuracy of lingual control by the anterior tongue to reach small pressure targets correlated with both greater speed and endurance during water swallowing. Results suggest that in healthy adults, both anterior tongue strength and control may contribute to swallowing performance. Therefore, both lingual strength and skill training have potential to advance swallowing rehabilitation, specifically when targeting factors of swallowing speed and endurance.

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This Study by: Anna Joerger, B.A.

Entitled: Lingual Pressure Generation in Relation to Saliva and Water Swallowing in Healthy Young Adults

has been approved as meeting the thesis requirement for the

Degree of Master of Arts

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CHAPTER 1

INTRODUCTION

Eating and drinking are highly complex actions involving an intricate swallowing mechanism. When the swallowing mechanism functions properly, food and drink are transported from the oral cavity to the stomach in a safe and efficient manner. This requires several precisely executed movements of various aerodigestive structures. A properly functioning mechanism protects the airway from invasion by the substances being swallowed; however, due to the necessary complexity of these coordinated movements, there are several opportunities for the process to go awry. Impaired safety or efficiency in swallowing, known as dysphagia, is a complex symptom for many persons.

Dysphagia is significant concern as it affects as many as 1 in 25 adults annually (Bhattacharyya, 2014), and is a significant cost to the healthcare system (Altman, Yu, & Schaefer, 2010). An affected individual may experience several associated medical complications, particularly aspiration pneumonia. Aspiration pneumonia occurs when traces of food or drink enter the lungs leading to infection and swelling of the lungs and airways (Logemann, 1986). Further consequences of dysphagia may include malnutrition, weight loss, dehydration, and death (Langmore et al., 1998).

In addition to these serious medical conditions, individuals with dysphagia may suffer from reduced quality of life (Plowman-Prine et al., 2009; Tibbling & Gustafsson, 1991). Dysphagia can lead to social isolation, depression, and low self-esteem. Social impacts of dysphagia may include discomfort or embarrassment that can interrupt an individual’s ability to participate in or enjoy social events. Individuals with dysphagia may also be prescribed a limited diet that excludes foods they enjoy eating, or requires them to drink thickened liquids, which they may dislike. Subsequently, dysphagia can reduce the pleasure of eating and overall enjoyment of life activities (Ekberg, Hamdy, Woisard, Wuttge–Hanni, & Orteg, 2002; Plowman-Prine et al., 2009). Early identification of dysphagia may reduce these negative medical and social implications (Ramsey, Smithard, & Kalra, 2003).

One clinical avenue for early identification of dysphagia is evaluating tongue function. Assessing lingual function and pressure generation is clinically valuable as the tongue generates the greatest propulsive pressures during swallowing, and lingual weakness is a known contributor to oropharyngeal dysphagia (Dodds, 1989; Stierwalt & Youmans, 2007). When the tongue does not function properly, there is an increased risk of disordered bolus flow and subsequent health consequences (Stierwalt & Youmans, 2007).

More specifically, the tongue plays an integral role throughout the swallow by containing the cohesive unit of food, called a bolus, in the oral cavity during processes of preparation, mastication, and propulsion of the bolus into the pharynx (Chi-Fishman, Stone, & McCall, 1998; Dodds, 1989). Lingual muscles attached to the hyolaryngeal complex then contract and aid in the elevation of the larynx. This upward movement protects the airway and routes the bolus onward towards the esophagus (Dodds, 1989). The tongue’s unique muscular-hydrostat structure allows it to be manipulated into several shapes necessary for carrying out these integral roles in the swallow (Miller, Watkin, & Chen, 2002).

Tongue function can be assessed by measuring pressure generation. Maximal isometric pressure or tongue strength has been highly investigated to establish benchmarks of lingual weakness (Butler et al., 2011; Gingrich, Stierwalt, Hageman, & LaPointe, 2012; Kennedy et al., 2010; Lazarus et al., 2000; Ono, Hori, & Nokubi, 2004; Pouderoux & Kahrilas, 1995; Stierwalt & Youmans, 2007; Youmans & Stierwalt, 2006). Comparatively less is known about healthy swallowing pressure generation and an individual's ability to reach a given pressure target or lingual control (Steele, Bailey, Molfenter, & Yeates, 2009; Yeates, Molfenter, Steele, 2008). This relatively new idea known as skill training, or learning and fine-tuning new movements, is emerging in the dysphagia rehabilitation literature (Adkins, Boychuk, Remple, & Kleim, 2006; Athukorala, Jones, Sella, & Huckabee, 2014; Perez, Lungholt, Nyborg, & Nielsen, 2004). It remains unknown to what extent lingual strength and control may relate to measures of swallowing efficiency (i.e., speed and endurance). The present study sought to investigate lingual strength and control in relation to swallowing speed and endurance performance in healthy adults to better understand the role of lingual pressure generation within the context of swallowing evaluation.

CHAPTER 2

LITERATURE REVIEW

Swallowing is a critical biological function necessary to sustain life. A healthy swallowing mechanism allows individuals to consume necessary nutrients while also protecting their airway from the ingested materials. Although eating is a routine event for the majority of the population, swallowing is a complex process that requires precise coordination and timing of several anatomical structures to ensure safety and efficiency throughout every stage of the swallow (Logemann, 1983).

Swallowing Stages

Multiple and overlapping stages are executed in a healthy swallow. The oral stage involves the placement of a mass of food in the oral cavity where is chewed and manipulated to form a cohesive unit called a bolus. The lips, teeth, tongue, jaw, cheeks, hard palate, and velum contribute to the oral stage. The bolus is then transported away from the oropharynx, through the pharynx, to the upper esophageal sphincter (UES) during the pharyngeal stage. Structures involved in this stage include the tongue, velum, epiglottis, hyoid bone, and pharyngeal and laryngeal muscles. Finally, during the esophageal stage, the bolus moves through the esophagus by a series of peristaltic contractions from its superior opening, the UES, to the inferior opening, the lower esophageal sphincter (LES). Adequate oral, pharyngeal and esophageal pressures (both positive and negative), along with timely closure and protection of the larynx, are critical to successfully propel the bolus along the digestive tract (Logemann, 1983; Groher & Crary, 2016).

Dysphagia and Its Consequences

Dysphagia, or swallowing impairment, can affect any or multiple stages of the swallowing process. Patients with oropharyngeal dysphagia may have difficulty preparing the bolus in the oral cavity or initiating or executing the safe transport of the bolus through the mouth and pharynx. These difficulties may result in airway invasion or post swallow residue that may remain in the oral cavity or pharynx in patients with oropharyngeal dysphagia (Wolf, 1990). Esophageal dysphagia can be caused by physiological and/or structural abnormalities of the esophagus or esophageal sphincters (Wolfe, 1990). Unfortunately, either oropharyngeal or esophageal dysfunction may result in a number of poor health outcomes including aspiration pneumonia (Logemann, 1983).

Aspiration pneumonia is an infection resulting from bacteria carried by food, liquid, gastric contents, or saliva to the lungs (Logemann, 1986). This is often due to oropharyngeal or esophageal swallowing dysfunction. When foreign material enters the lungs, bacteria may colonize in the lungs leading to inflammation, infection, and poor respiration. Additional medical complications may also result including dehydration, weight loss, malnutrition, and even death (Langmore et al., 1998).

In addition to these serious medical complications, individuals with dysphagia may also experience negative social implications and a reduced quality of life (Tibbling & Gustafsson, 1991). Social events often involve eating and embarrassment surrounding choking may cause an individual to withdraw from social gatherings leading to social isolation (Ekberg et al., 2002). Dysphagia may also reduce the pleasure associated with eating and subsequently reduce the desire to eat (Ekberg et al., 2002). Furthermore, increased time and effort is often required to prepare and consume meals (Simpson, Well, & Nelson, 2015) with the potential for developing depression, low self-esteem, and anxiety surrounding eating (Ekberg et al., 2002; Plowman-Prine et al., 2009). These quality of life issues, in addition to the health complications associated with swallowing dysfunction, can have a harmful impact on the overall well-being and life participation of individuals with dysphagia (Logemann, 1983).

Dysphagia and its consequences are prevalent in several populations including stroke survivors, persons with Parkinson's disease, persons with multiple sclerosis, and the elderly. The prevalence of dysphagia in each population varies. For example, it is estimated that dysphagia occurs in 29-64% of stroke patients (Barer, 1989; Gordon, Hewer, & Wade, 1987; Mann, Hankey, & Cameron, 2000), 24-34% of individuals with multiple sclerosis (Calcagno, Ruoppolo, Grasso, De Vincentiis, & Paolucci, 2002; De Pauw, Dejaeger, D'hooghe, & Carton, 2002), and 40-95% of persons with Parkinson's disease (Leopold & Kagel, 1997; Müller et al., 2001). Older adults are also likely to demonstrate swallowing changes as a result of natural aging or presbyphagia and are at increased risk for dysphagia (Ekberg & Feinberg, 1991; Feinberg, Knebl, Tully, & Segall, 1990).

Dysphagia Assessment

Current swallowing rehabilitation practices promote early identification of dysphagia to reduce the risk of subsequent medical and social consequences for these and other populations at risk for dysphagia. Unfortunately, not all patients have access to or are appropriate for thorough instrumental examinations, and many therapists solely rely on clinical bedside evaluations to establish diagnoses and management plans. However, clinical bedside evaluations are not widely established as early and accurate methods for the identification of dysphagia (Cohen, 2009; DePippo, Holas, & Reding, 1992; Mann, 2002; Martino et al., 2009). A potential supplemental measurement to provide additional objective measurement during clinical beside evaluation includes the measurement of lingual pressure generation (i.e., the amount of positive pressure generated by the tongue against the palate) since the tongue plays a critical role in swallowing and lingual dysfunction is a known contributor to oropharyngeal dysphagia (Stierwalt & Youmans, 2007).

The Role of the Tongue

The tongue plays a predominant role in generating the necessary pressures for a safe and effective swallow. During the oral stage, the tongue generates pressures that contain the bolus in the oral cavity and also pressure that helps form the bolus into a cohesive mass and manipulates the bolus during mastication (Dodds, 1989). The tongue then generates pressures to propel the bolus through the oropharynx.

Propulsion of the bolus into pharynx occurs due to an anterior to posterior contraction of the oral tongue, which anchors against the anterior hard palate moving the bolus posteriorly towards the pharynx (Chi-Fishman et al., 1998; Dodds, 1989). Finally, the posterior oral tongue depresses and the tongue base approximates the posterior pharyngeal wall, clearing the bolus from the oropharynx and preventing food from re-entering the oral cavity (Dodds, 1989; Robbins, Levine, Wood, Roecker, & Luschei, 1995). Precise timing and coordination of these various lingual pressures are necessary for a successful swallow. Since lingual dysfunction can significantly affect the swallowing mechanism and result in an increased risk of disordered bolus flow, the tongue is a potentially valuable target for dysphagia assessment and rehabilitation (Daniels, Brailey, & Foundas, 1999).

Lingual Structure

The tongue is considered a muscular hydrostat, meaning it can be shaped into an unlimited number of formations through the contraction of extrinsic and intrinsic muscles (Kier & Smith, 1985). Both extrinsic and intrinsic lingual muscles are active in the oropharyngeal phase of swallowing (Lenius, 2008). The extrinsic and intrinsic lingual muscles are responsible for coordinating and generating the appropriate swallowing pressures. Specifically, the extrinsic lingual muscles largely position the tongue within the space of the oral cavity, while the intrinsic lingual muscles shape the tongue (Felton et al., 2008; Napadow, Chen, Wedeen, & Gilbert, 1999).

The extrinsic lingual muscles, which attach to bone and insert into the base of tongue include the genioglossus, hyoglossus, styloglossus, and palatoglossus (Fried, 1980). The genioglossus runs from approximately the chin (i.e., mental spine of the mandible) to insert into the base of the tongue. When contracted, the genioglossus pulls the tongue forward. The hyoglossus originates at the hyoid bone and depresses the tongue. The tongue elevates and retracts when the styloglossus is contracted. Finally, the palatoglossus elevates the posterior tongue or depresses the velum and aids in the initiation of swallowing (McFarland, 2014).

The intrinsic lingual muscles, which have their origin and insertion within the tongue, include the superior longitudinal, inferior longitudinal, transverse, and vertical muscles (Fried, 1980). The superior longitudinal muscles courses along the superior aspect of the tongue, beginning from posterior submucous fibrous tissue and reaching the anterior edges of the tongue. When contracted, the superior longitudinal muscle shortens the tongue anteriorly to posteriorly, and turns the apex (the anterior tip of the tongue) upward (McFarland, 2014). The inferior longitudinal muscle's origin is at the root of the tongue and it courses to the apex of the tongue. This muscle aids in the shortening of the tongue, and it pulls the apex downward (McFarland, 2014). The transverse lingual muscles run from the median fibrous septum to the lateral margins of the tongue. When contracted, the transverse lingual muscles narrow and elongate the tongue (McFarland, 2014). Finally, the vertical lingual muscles, predominantly found in the anterior portion of the tongue, run from the superior surface to the inferior surface of the tongue. The vertical lingual muscles flatten and widen the tongue when contracted (McFarland, 2014). The complex arrangement of the intrinsic lingual muscles allow the tongue to be manipulated into several shapes necessary to manipulate the bolus and generate necessary pressures for swallowing (Miller et al., 2002).

Further functionality of the tongue is attributed to fiber orientation, tissue concentrations, and muscle fiber types across the anterior-posterior dimension of the tongue (Gilbert & Napadow, 2005; Miller et al., 2002). Recent investigations of lingual pressure generation have explored the function of both anterior and posterior lingual regions as differences in anatomical structure may influence pressure generation. These anatomical differences in the anterior and posterior tongue allow each region to fulfill its unique and integral role in the swallow (Felton et al., 2008; Gilbert & Napadow, 2005).

The orientation of muscle fibers differs along the anteroposterior dimension. As vertical muscle fibers are contained within the longitudinally oriented fibers of the superior and inferior longitudinal muscles (Gilbert & Napadow, 2005; Miller et al., 2002). The vertical fibers are especially concentrated in core of the anterior tongue allowing this region to shorten and widen when contracted. The complex orientation of lingual muscle fibers reflects the tongue's flexibility and differs from the orientation of striated muscles in the body (Miller et al., 2002).

In addition to differences in the orientation of muscle fibers, tissue concentration and motor fiber types vary along the anteroposterior lingual dimension. The posterior region of the tongue has a higher concentration of muscle tissue (57.3%) compared to the anterior region (25.9%; Miller et al., 2002). The concentrated muscular tissue in the posterior region allows for the tongue to retract and push against the posterior pharyngeal wall with force, aiding in the propulsion of the bolus to the pharynx (Dodds, 1989; Robbins et al., 1995).

In contrast, the anterior region of the tongue exhibits greater flexibility, a necessary characteristic for bolus manipulation and speech tasks. This may also be attributed to a higher density of elastic fibers and collagen sheaths. The fiber concentration of the anterior lingual region allows the shape of the tongue to be easily manipulated in a rapid fashion (Miller et al., 2002).

The types of muscle fibers in various regions of the tongue differ as well. Type I muscle fibers, which are large and fatigue-resistant, are found in higher concentration in the posterior lingual region. In the anterior lingual region, there is a prevalence of type IIA muscle fibers. Type IIA muscle fibers, or fast twitch muscle fibers, exhibit rapid contractility; however, they are more susceptible to fatigue (Kent, 2004; Stål, Marklund, Thornell, DePaul, & Erikson, 2003). Overall, the anatomical differences in various lingual regions allow the tongue to be molded into specific shapes, carry out distinct functions, and generate lingual pressures (Felton et al., 2008).

Assessment of Lingual Pressure

Various instruments exist to measure lingual pressures, including the commonly used Iowa Oral Performance Instrument (IOPI). The IOPI is a widely employed research and clinical device. It contains a pressure transducer connected to an air-filled bulb. It demonstrates excellent test-retest reliability (Youmans & Stierwalt, 2006; Youmans, Youmans, & Stierwalt, 2009), and captures a continuous readout of lingual pressure in kPa when using DI-155 Data Acquisition Software and a connected computer. The IOPI has a single sensor designed to mimic a bolus, is clinically feasible, and is a comparably cost effective way to measure lingual pressure. The IOPI has been used to measure the lingual pressures of both anterior and posterior tongue regions (Clark & Solomon, 2012; Gingrich et al., 2012; Kays, Hind, Gangnon, & Robbins, 2010).

Lingual Strength

Several studies have investigated maximal lingual pressures, or tongue strength, for both the anterior and posterior oral tongue in healthy adults (Adams, Mathisen, Baines, Lazarus, & Callister, 2013; Butler et al., 2011; Gingrich et al., 2012; Kennedy et al., 2010; Nicosia et al., 2000; Pouderoux & Kahrilas, 1995; Ono et al., 2004; Youmans & Stierwalt, 2006). The anterior lingual region is generally capable of producing greater pressures during both maximum isometric tasks (Butler et al., 2011; Gingrich et al., 2012) as well as during swallowing tasks (Butler et al., 2011; Gingrich et al., 2012; Kennedy et al., 2010; Ono et al., 2004; Pouderoux & Kahrilas, 1995); however, variation in strength may exist due to age, gender, lingual region, and oropalatal dimensions (Gingrich, 2011).

It has been well established that the maximum isometric lingual pressures produced by healthy adults decline with age (Crow & Ship, 1996; Gingrich, 2011; Lazarus et al., 2000; Nicosia et al., 2000; Robbins et al., 1995; Stierwalt & Youmans, 2007; Vanderwegen, Guns, Van Nuffelen, Elen, & De Bodt, 2013; Youmans & Stierwalt, 2006; Youmans et al., 2009). Gender differences in maximal isometric pressures have been inconsistently reported in the literature with some studies reporting significantly greater maximum isometric pressures of the anterior tongue in men (Crow & Ship, 1996; Stierwalt & Youmans, 2007; Vanderwegen et al., 2013; Youmans & Stierwalt, 2006) and others reporting no significant differences between genders (Clark & Solomon, 2012; Lazarus et al., 2000; Nicosia et al., 2000; Youmans et al., 2009). Age and gender may also demonstrate interactions in regard to generation of maximum isometric pressures (Utanohara et al., 2008).

Lingual Swallowing Pressures

Maximum isometric pressures have been more extensively studied in comparison to lingual pressures during swallowing. Lingual pressures generated by healthy adults during swallowing are submaximal (i.e., less pressure than that generated during maximal isometric tasks; Nicosia et al., 2000), and the magnitude of swallowing pressures are largely maintained in the context of aging (Nicosia et al., 2000; Robbins et al., 1995; Steele & Van Lieshout, 2009; Yeates, Steele, & Pelletier, 2010; Youmans & Stierwalt, 2006; Youmans et al., 2009). Notably, lingual pressures require precise coordination within a swallowing pattern (Hori et al., 2005). In regard to specific ranges of positive pressure generation, Gingrich (2011) reported the percentage of lingual strength (i.e., Maximum Isometric tongue Pressure; MIP) needed to swallow 10 mL boluses of thin, nectar, honey, and puree consistencies, range from approximately 30% to 50% of lingual strength in healthy adults across age ranges. Although research is accumulating to specifically defining the target range and timing of healthy lingual swallowing pressures, little is known about how accurate a healthy individual is when generating pressure to a given target (Steele et al., 2009).

Due to the precision and coordination needed for successful deglutition, swallowing is recognized as a skill (Palmer, Rudin, Lara, & Crompton, 1992). Recent rehabilitation literature emphasizes the important role of skilled swallowing training, which is defined as exercise focused on both timing and pressure targets of swallowing-specific behaviors (Huckabee & Macrae, 2014). To determine potential rehabilitation tasks and targets for skilled swallowing training, the accuracy of the tongue to reach given pressure targets (i.e., lingual control) within healthy individuals needs to be further investigated. Not only will investigations of pressure accuracy determine the range of healthy performance but may also delineate rehabilitation goals. Secondly, the relation among lingual strength, control, and functional aspects of swallowing (e.g., speed or endurance) should be further explored to suggest what parameters of the swallow may be influenced by skilled training of lingual pressure generation.

Present Investigation of Lingual Control

The present investigation explored normal variability in swallowing pressure accuracy or lingual control in healthy adults. It also explored whether either lingual strength or control may relate to performance measures of swallowing efficiency (i.e., speed and endurance) as measured by power tests in healthy, young adults.

Swallowing power tests give quantifiable data on aspects of swallowing including speed and endurance. The 5 Swallows Speed Test (5SST; Neely, 2016) measures swallowing speed, by recording the time in which an individual completes five consecutive swallows. Swallowing endurance can be measured by recording number of consecutive swallows during a 30 second interval (Baranska, 2016; Horiguchi & Suzuki, 2011). Both power tests provide insight into the efficiency of an individual’s swallow and were applied in this study.

The findings may provide preliminary support of further investigations utilizing lingual “fine motor control” tasks to assess and rehabilitate dysphagia. Specifically, this project seeks to address the following research questions: First, how do healthy young adults perform on tasks of lingual strength and tasks of lingual control to reach a given pressure target? Second, does either lingual control or tongue strength of the anterior and posterior tongue correlate with swallowing speed and endurance tasks in young, healthy adults? Based on previous investigation of IOPI measures in healthy adults which have shown high degree of internal consistency (Adams et al., 2013; Gingrich et al., 2012; Youmans et al., 2009), we hypothesized that lingual control in young, healthy adults will be highly accurate to a target and that strength and control will significantly correlate with swallowing efficiency measures.

CHAPTER 3

METHODS

Institutional Review Board (IRB) approval was obtained from the University of Northern Iowa. All researchers completed human subjects training.

Twelve participants (six males and six females, aged *M* = 22.8 years, SD = 2.9 with age range = 20 to 30 years-old) were consented for the study. All participants were given the opportunity to independently review the informed consent document, to discuss the informed consent document with a trained examiner, and were provided an opportunity to ask any questions regarding the study.

Participants were required to be within 18-35 years of age and to pass an oral mechanism examination. Prior to participation in the study, participants were screened for exclusionary criteria. Exclusionary criteria included: neurological disorders or conditions, gastrointestinal disease, gastroesophageal reflux disease (GERD), gastroesophageal surgery, head and neck cancer, previous surgery affecting swallowing or swallowing structures, bleeding disorders, frequent nosebleeds, stricture of nasal passage limiting pass of scope, sleep apnea, anxiety, seizure, vasovagal syncope, and/or speech and swallowing disorders beyond a remediated childhood articulation disorder.

Participants completed a Past Medical History Questionnaire and interview (PMHQ; Appendix A). Two participants (one female and one male) were excluded based on PMHQ that identified one or more of the aforementioned exclusionary criteria (i.e., known nasal stricture and a previous childhood swallowing disorder).

Following intake procedures (i.e., informed consent, PMHQ, and interview), researchers completed a brief oral mechanism examination on each participant (Appendix B). At the conclusion of the oral mechanism exam, the examiner palpated the anterior neck of the participant to identify the notch of the thyroid cartilage. At the inferior border of the thyroid notch, the examiner made a mark using a permanent marker on the skin of the participant's neck to aid in visualization of hyolaryngeal excursion on video recording of the participant's external neck during bedside evaluation of swallowing tasks.

Participants completed the following swallowing tasks which were counterbalanced to control for order effects: (1) Swallowing power tests without instrumental visualization (bedside evaluation by palpation and external video recording); (2) Swallowing power tests and bolus swallows of food and liquid during a Fiberoptic Endoscopic Evaluation of Swallowing (FEES); and (3) Tongue pressure measures using the Iowa Oral Performance Instrument (IOPI). Appendix C demonstrates the task order across all participants; however, the present study focused on analyzing the performance on swallow power tests as recorded endoscopically during the FEES procedure and not during the bedside evaluation, which was part of a larger investigation. Therefore, the swallowing power tests and bolus trials during FEES will be described.

Swallowing Power Tests and Bolus Trials during FEES

Two bedside swallowing power tests (i.e., 5SST and a 30-second swallowing endurance task) were performed simultaneously within a one-minute interval during a FEES examination utilizing the HighLight LED Portable Stroboscopy system. Swallowing power tests were completed under two conditions: (1) during saliva swallows only and (2) during swallows of small amounts of water delivered at a constant, slow flow rate of .3 mL/second from a Covidien Kangaroo$_{TM}$ Gravity Feeding Bag (1000 mL) attached to an IV pole to the participant through airline tubing (3/16 inch diameter) cut to approximately 6 inches in length attached to the feeding bag port to serve as a straw. Prior to every swallowing power test, participants were given a single sip of water.

During the saliva swallowing condition, the examiner instructed the participant: “When I say ‘Go’ I want you to swallow your saliva as many times as you can until I tell you to stop.” During the water swallow condition the examiner instructed the participant: “Water will be iven to you through the straw through the test. With the straw in your mouth, and when I say ‘Go,’ I want you to swallow as many times as you can until I tell you to stop. I want you to put this straw inside your cheek. Do not suck on the straw. Please swallow once for practice.”

FEES images were obtained with DigiCAM with JEDMED Highlight system. The Highlight system utilizes a white LED light source and 3.4 mm diameter Ergo-Flex nasopharyngoscope. Despite participant screening for candidacy to complete FEES using a brief oral mechanism examination and a past medical history questionnaire, one participant was excluded from FEES due to nasal stricture prohibiting a comfortable pass of the endoscope; therefore, a total of nine participants completed the swallowing power tests with FEES. The examiner monitored the FEES screen and recorded the video for subsequent analysis. During the 5SST, the timing started when the examiner said, ‘Go,’ and terminated when the epiglottis returned to resting position following the fifth swallow. For the 30-second swallowing endurance task, the number of full swallows visually completed following the examiner’s “Go” command within a 30-second time frame were counted. The 30-second swallowing endurance task is largely based upon work done by Horiguchi and Suzuki (2011).

The examiner was one of three graduate-level students accompanied by a certified and licensed SLP with advanced training in FEES who passed the scope. All three graduate-level examiners received training through a graduate-level FEES course at the University of Northern Iowa prior to assisting with research FEES evaluations. The FEES protocol followed the methods described by Warnecke et al. (2008). Each participant was seated in a 90-degree upright position. The examiner passed the endoscope through the participant’s least restricted nostril without the use of topical anesthetic, and continued along the floor of the nasal cavity through the velopharyngeal port. The tip of the endoscope then passed into the hypopharynx and the camera was placed above the level of the epiglottis (Warnecke et al., 2008).

Once the scope was in place, the swallowing power tests were completed. Each participant also completed the following bolus trials: two trials of 5 mL thin liquid (skim milk), two trials of single cup sips of thin liquid, and two trials of 5 cc puree (non-dyed applesauce). Prior to and directly after cup sip trials, cup weight was measured in grams using a digital scale. The above bolus order is based upon reducing the risk of aspiration during FEES assessments and no participants demonstrated swallowing impairment during bolus trials.

Tongue Pressure Measures

The Iowa Oral Performance Instrument (IOPI) Model 2.2 was utilized to analyze lingual-palatal pressure (IOPI Medical LLC., 2013). The IOPI is a clinical device that uses an air-filled bulb lined with pressure sensors to measure tongue strength and endurance. When connected to a computer, the IOPI can capture an uninterrupted readout of lingual pressure in kilopascals (kPa). Evidence supports the IOPI as an appropriate clinical tool in measuring tongue strength and endurance in adults (Adams et al., 2013).

Three trials of maximum isometric tongue pressure (MIP; i.e., tongue strength) were obtained in a counterbalanced order at both the anterior and posterior regions of the tongue (Gingrich et al., 2012). MIP is the maximal positive pressure exerted on the tongue bulb in kPa for the anterior (MIPA) or the posterior (MIPP) tongue. Participants were given the following instructions: “When I say “go” press with your tongue as hard as you can towards the roof of your mouth with the front/back of your tongue to flatten the bulb. Ready? Go.” Participants were encouraged during the MIP trials to ensure maximal exertion. Trials were separated by rest periods of 15-20 seconds.

The examiner then calculated 30% and 50% of the MIP. Pressure targets were then defined as: 30% of maximum tongue pressure at the anterior tongue (PMTPA 30), 50% of maximum tongue pressure at the anterior tongue (PMTPA 50), 30% of maximum tongue pressure at the posterior tongue (PMTPP 30), and 50% of maximum tongue pressure at the posterior tongue (PMTPP 50). These targets for saliva swallows were selected based on preliminary analysis of lingual pressures in healthy young adults, which indicated mean swallowing pressures across multiple consistencies typically occur below 50% of MIP (Gingrich, 2011).

Participants were asked to complete a task of “lingual control” by completing five saliva swallowing trials (SSTs) at each of the four targets (i.e., PMTPA 30, PMTPA 50, PMTPP 30, PMTPP 50). The saliva swallowing trials (SSTs) were completed in a block of 10 trials at either the anterior (PMTPA 30 and PMTPA 50) or posterior (PMTPP 30 and PMTPP 50) lingual region. Within the block, PMTP pressure targets (either 30% or 50% of MIP) were presented in a randomized order. Participants were provided online visual biofeedback of the applied pressure using DATAQ software on a laptop. The order of the first lingual region to be tested within a block was counterbalanced across participants. During SSTs, participants were given the following instructions: “When you are ready, swallow your saliva with the bulb in your mouth with enough pressure to get exactly a (target number) on the screen. Try not to swallow with more or less pressure than a (target number), and keep your swallow at a normal speed. Remember to not bite the tube. Ready? Go.”

Participant performance (i.e., pressures generated in kPa) were recorded as either saliva swallow target at the anterior position for PMTPA 30 (SSTA 30), saliva swallow target at the anterior position for PMTPA 50 (SSTA 50), saliva swallow target at the posterior position for PMTPP 30 (SSTP 30), and saliva swallow target at the posterior position for PMTPP 50 (SSTP 50).

Analysis

Each individual trial was measured for time and pressure reading at the onset of trial, at the peak pressure of the trial, and at the offset of the trial. Onset was defined as the point in which lingual pressure measurements began to rise from the baseline. Offset was defined as the point in which lingual pressure measurements returned to baseline. Time to peak pressure (in seconds), time from peak pressure to offset (in seconds), total duration of trial (in seconds) and magnitude of over- and/or under-shoot of target pressure (kPa) during lingual control trials were then calculated. The maximal and averaged absolute differences in saliva swallowing pressure (SST) from target pressure (PMTP) were calculated across the 5 trials for each pressure target (PMTPA 30, PMTPA 50, PMTPP 30, and PMTPP 50.

Statistical analysis was performed using the statistical package IBM SPSS 22.0. Intra- and inter-rater reliability were calculated for two randomly selected participants for FEES and IOPI measurements. Mann-Whitney *U* tests were conducted to explore gender differences and Wilcoxon Signed Rank Tests were conducted to explore differences in lingual pressure generation between anterior and posterior lingual regions. Correlational analyses explored the relation among MIP (i.e., tongue strength), STT (i.e., lingual control), and swallow power tests (i.e., 5SST and 30-second swallowing endurance task) in healthy adults.

CHAPTER 4

RESULTS

Out of the complete data set of 1560 data points for IOPI, 1491 were collected resulting in a 95.6% complete data set. Missing data points were due to incomplete or absent IOPI recordings. For the scope of this project, the results pertaining to lingual strength and lingual control (i.e., maximum and average magnitude of difference from targets) will be reported.

Out of the complete data set of 78 data points for the 5SST under FEES, a total of two data points were missing. The missing data points occurred secondary to delayed initiation of the video recording on a single trial with one participant. This resulted in a 97.4% complete data set.

Out of the full data set for the 30-second swallowing endurance task during FEES evaluation under both wet and dry conditions, one participant was unable to complete FEES due to nasal stricture prohibiting the passage of the scope, thus 42 data points were complete out of a potential 44 data points, resulting in a 95.5% complete data set. Missing data points during FEES occurred due to loss of laryngeal visualization during a saliva swallowing trial with one participant and due to a programming error of the FEES light source resulting in incomplete video capture for one participant during the saliva swallowing trial only. The programming error was addressed and the remaining data set was complete.

Intrarater and interrater reliability were evaluated for a random 20% of the total IOPI sample (two participants). Intrarater reliability was high for IOPI measures at

Cronbach's α = .998 and interrater reliability was strong with an intraclass correlation coefficient (ICC) of .995 with a 95% confidence interval from .994 to .996 ($F(301,301)= 428.508$, $p < .001$). Intrarater and interrater reliability were also evaluated for a random 22% of the total FEES sample (two participants). Intrarater reliability was high for FEES evaluations (α = .981). Interrater reliability for bedside evaluation tasks was strong with an ICC of .968 with a 95% confidence interval from .928 to .986 ($F(23,23)= 61.745$, $p < .001$). Interrater reliability for FEES evaluation tasks was also strong with an intraclass correlation (ICC) of .962 with a 95% confidence interval from .874 to .989 ($F(11,11)= 51.848$, $p < .001$).

Lingual Strength

Descriptive statistics including means and standard deviations for the following variables of MIP are reported in Table 1. No significant differences in strength were found between genders or between the anterior and posterior lingual region ($p > .05$) and therefore the data is collapsed across the sample. Notably, there was a moderate correlation between the strength of the anterior and posterior tongue ($r_s = .635$; $p = .049$).

Table 1

Descriptive Statistics for Lingual Strength

	Mean	SD
Anterior Lingual Strength (MIPA; kPa)	73.57	8.93
MIPA Average Duration (seconds)	3.77	1.00
Posterior Lingual Strength (MIPP; kPa)	69.71	9.02
MIPP Average Duration (seconds)	3.79	.71

Lingual Control

Saliva swallowing pressure targets (PMTPs) were calculated based on individual MIP performance for both the anterior (PMTPA30 and PMTPA50) and posterior (PMTPP30 and PMTPP50) lingual regions. Descriptive statistics, including means, standard deviations, and ranges, were calculated for lingual control (i.e., absolute deviation in kPA during SST from PMTP target) for each of the 5 trials at 30% and 50% of MIP at anterior (SSTA) and posterior (SSTP) lingual regions. Results are reported in Table 2.

Table 2

Descriptive Statistics for Lingual Control

	Min.	Max.	Mean	SD
SSTA 30				
Trial 1	.00	40.80	11.19	13.94
Trial 2	.30	20.70	5.70	6.55
Trial 3	.00	15.50	6.45	6.04
Trial 4	.50	25.80	6.83	8.24
Trial 5	.00	7.30	3.14	2.54
SSTA 50				
Trial 1	.60	24.00	6.48	6.84
Trial 2	1.00	8.00	4.33	2.37
Trial 3	.20	16.00	7.16	4.94
Trial 4	1.90	8.80	4.71	2.29
Trial 5	2.20	7.50	4.87	1.71
SSTP 30				
Trial 1	.30	17.30	5.33	5.65
Trial 2	.30	12.50	5.78	4.55
Trial 3	.20	28.70	6.55	8.60
Trial 4	.60	22.50	5.71	6.91
Trial 5	.00	16.10	6.23	6.26
SSTP 50				
Trial 1	1.10	19.00	8.79	6.45
Trial 2	.50	24.10	7.34	7.96
Trial 3	.00	15.60	4.04	4.68
Trial 4	.00	9.60	4.21	3.68
Trial 5	.00	10.70	2.30	3.21

Note: Differences are reported as absolute deviation in kPA from target (PMTP)

Swallowing Efficiency: Swallowing Power Tests

Descriptive statistics were calculated for the 5SST and the 30-second swallowing endurance task during both saliva swallowing (dry) and water swallowing (wet) conditions during FEES evaluation and are reported in Table 3.

Table 3

Descriptive Statistics for 5SST and 30-Second Swallowing Endurance Task

	Mean	SD	Range
5SST Dry (seconds)	11.57	4.30	11.53
5SST Wet (seconds)	9.81	3.55	9.79
30-sec Dry (frequency count)	10.43	9.81	9
30 sec Wet (frequency count)	13.89	13.89	13

Inferential Statistics

Significant correlations between lingual pressure measurements and participant performance on the 5SST or the 30-second swallowing endurance task are summarized in Table 4.

Anterior Lingual Strength and Swallowing Efficiency

There was a significant, positive relation between MIPA and the time to complete the 5SST during water swallowing (r_s = .783; p = .013) and a significant, negative relation between MIPA and the frequency count of swallows completed during the 30-second swallowing endurance task under wet conditions (r_s = -.731; p = .025); however, MIPA was not significantly correlated with either the 5SST or 30-second swallowing endurance task performance under saliva swallowing conditions ($p > .05$).

Posterior Lingual Strength and Swallowing Efficiency

There was no significant relation among MIPP, 5SST, or the 30-second swallowing endurance task during either the water swallowing or saliva swallowing conditions ($p > .05$).

Anterior Lingual Control and Swallowing Efficiency

30% target (SSTA 30): There was a significant positive relation between the maximum difference in SSTA 30 from target (i.e., the greatest absolute errors across all 5 trials) and an increase in time required to complete the 5SST during water swallowing ($r_s(9) = .767$; $p = .016$) and a significant negative relation between maximum difference SSTA 30 and the frequency count of swallows completed during the 30-second swallowing endurance task during water swallowing ($r_s = -.731$; $p = .025$); however, the maximum difference in SSTA 30 from target was not significantly correlated with either the 5SST or 30-second swallowing endurance task performance during saliva swallowing conditions ($p > .05$). There was a significant positive relation between averaged difference from the target for SSTA 30% (i.e., the averaged absolute difference of SST from target pressure across all 5 trials) and the 5SST during water swallowing ($r_s(9) = .683$; $p = .042$) and a significant negative relation between averaged difference on SSTA 30% and the 30-second swallowing endurance task during water swallowing ($r_s = -.681$; $p = .044$); however, the averaged difference in SSTA 30% was not significantly correlated with either the 5SST or the 30-second swallowing endurance task during saliva swallowing conditions ($p > .05$).

50% target (SSTA 50): There were no significant relations among maximum difference in SSTA 50% from target, 5SST performance, or the 30-second swallowing endurance task performance during either water swallowing or saliva swallowing ($p > .05$). There were also no significant relations among the averaged difference of SSTA 50% from target, 5SST, or the 30-second swallowing endurance task during either water swallowing or saliva swallowing ($p > .05$).

Posterior Lingual Control and Swallowing Efficiency

30% target (SSTP 30): There were no significant relations among maximum difference of SSTP 30% from target, 5SST, or the 30-second swallowing endurance task during either water swallowing or saliva swallowing ($p > .05$). There were no significant relations among the averaged difference of SSTP 30% from target, 5SST, or the 30-second swallowing endurance task during either water swallowing or saliva swallowing ($p > .05$).

50% target (SSTP 50): There were no significant relations among maximum difference of SSTP 50% from target, 5SST, or the 30-second swallowing endurance task during either water swallowing or saliva swallowing ($p > .05$). There were no significant relations among average difference of SSTP 50% from target, 5SST, or the 30-second swallowing endurance task during either water swallowing or saliva swallowing ($p > .05$). Significant correlations among lingual control and swallowing efficiency measures are summarized in Table 4.

Table 4

Significant Correlations among Lingual Pressure Measures and Swallowing Efficiency

	5SST during Water Swallowing	30-second Swallowing Endurance Task during Water Swallowing
MIPA	$r_s = .783$; $p = .013$	$r_s = -.731$; $p = .025$
SSTA 30 maximum difference from target	$r_s = .767$; $p = .016$	$r_s = -.731$; $p = .025$
SSTA 30 averaged difference from target	$r_s = .683$; $p = .042$	$r_s = -.681$; $p = .044$

Lingual Control across Multiple Trials

Improvement in an individual's ability to accurately generate lingual pressures to a given target during saliva swallowing was descriptively noted in the mean group performance across the five trials for SSTA 30, SSTA 50, SSTP 30, and SSTP 50; however, a post-hoc Friedman's One-way ANOVA found no significant improvements in averaged difference from the target across the five trials for any of the tasks for SSTA 30, SSTA 50, SSTP 30, or SSTP 50 ($p > .05$).

CHAPTER 5

DISCUSSION

The purpose of this study was to explore the range of performance in healthy, young adults on both lingual strength and lingual control tasks. We also explored the relation between a person's accuracy of lingual control and an individual's swallowing efficiency (i.e., 5SST and the 30-second swallowing endurance task). Specifically, research questions included: How do healthy young adults perform on tests of lingual strength and control when asked to reach a given pressure target? Does either lingual strength or control of the anterior and posterior tongue correlate with swallowing efficiency as measured by speed and endurance tasks in young, healthy adults?

Performance of Young, Healthy Adults on Lingual Strength and Control

Lingual Strength

Overall strength measures in the sample were consistent with previous reports of typical healthy, young adults. Obtained isometric pressures were within reported ranges of previous studies (Gingrich et al., 2012; Youmans et al., 2009), and there were no significant differences in strength between anterior and posterior lingual pressures (Gingrich et al., 2012). Although other previous studies have demonstrated anterior and posterior differences in strength (Butler et al., 2011; Kays et al., 2010); however, these differences may be attributed to variations in sensor placement, participant demographics, or in the duration that the participant generated lingual pressure to complete the task. Additionally, there were no significant gender differences, which is also consistent with multiple investigations of tongue strength (Clark & Solomon, 2012, Lazarus et al., 2000; Nicosia et al., 2000; Youmans et al., 2009).

Lingual Control

It was hypothesized that lingual control in healthy adults would be closely accurate to the target (within 3 kPa). In the present study, the average deviation from pressure target (accuracy) was greater than hypothesized and averaged between 2.3 and 11.2 kPa on trials. The group mean difference from the target demonstrated a trend to decrease across the five trials of each pressure target; however, these changes were not statistically significant. Nevertheless, the overall trend of improved accuracy across successive trials suggests skilled motor learning. Future research may benefit from incorporating multiple trials to further explore motor learning effects during lingual control tasks.

Notably, participants displayed a wide range of performance in early lingual control trials (standard deviations ranging from 5.6 and 13.9 kPa); however, the standard deviations also demonstrated a trend of convergence across later trials. This may suggest a more stable and reliable description of normative performance follows initial acquisition trials or learning of task. Multiple trial of lingual pressure generation to a target and smaller deviations in normal performance may allow for better delineation between normal and disordered performance.

Relation of Lingual Strength and Control to Measures of Swallowing Efficiency

Maximal isometric lingual pressure of the anterior tongue was positively correlated with swallowing speed (i.e., duration to complete 5 swallows) and negatively correlated with endurance (i.e., frequency count of swallows completed) during water swallows. Therefore, persons with greater anterior tongue strength exhibited slower water swallows at the beginning of the 30-second interval, but faster swallows later in the interval when compared to peers with lower anterior tongue strength. This finding may suggest that persons with greater anterior tongue strength may differentially utilize speed during consecutive water swallowing compared to persons with lower anterior tongue strength. Perhaps this finding could be attributed to higher swallowing pressures utilized by individuals with greater anterior tongue strength. This hypothesis would need to be confirmed by measuring lingual pressures during the swallowing power tests.

It was hypothesized that lingual control would positively correlate with endurance and speed performance on swallowing efficiency measures. A significant positive relation between both the averaged and maximum difference during small pressure targets of the anterior tongue (SSTA 30) and patient performance on the 5SST and the 30-second swallowing task was found during the water swallowing condition. This suggests participants who performed more poorly on anterior lingual control tasks also required more time to complete sequences of water swallows, which may reflect the precise control of the tongue at low, submaximal lingual pressures contributes to swallowing efficiency.

In contrast, swallowing efficiency measures during saliva swallowing tasks were not significantly related to either measures of lingual strength or control, potentially due to the variable nature of saliva swallowing (Rudney, Ji, & Larson, 1995). Posterior tongue strength was not significantly related to these specific measures of swallowing efficiency, which may be due to the difference between muscle fibers in the anterior and posterior tongue. Recall, there is a concentration of Type I muscle fibers located in the posterior portion of the tongue, which are large and fatigue-resistant. The Type IIA fast twitch muscle fibers in the anterior tongue may be better predictors of performance on swallowing power tests.

Moderate correlations between anterior lingual controls and swallowing power tests supports the notion that skill training, and even more specifically lingual skill training, may influence swallowing efficiency and could advance swallowing rehabilitation. Should future research determine that persons with dysphagia demonstrate significant deviation in lingual pressure from given targets beyond that seen in healthy controls, applications of skilled swallowing training of low submaximal lingual pressures may be further explored. Should skilled lingual pressure training continue to demonstrate relation to swallowing efficiency, it will lead to novel interventions designed to enhance lingual control. Skilled training promotes learning of and fine-tunes a desired task (Adkins et al., 2007), and although strength training is a more established technique in swallowing rehabilitation, skill training continues to emerge alongside strengthening protocols in the dysphagia rehabilitation literature (Athukorala et al., 2014; Perezet al., 2004).

Limitations

Although this is a novel investigation of lingual control in relation to swallowing power tests in healthy adults, a few notable limitations exist. Due to the inclusionary criteria and need for participant willingness to complete an invasive procedure such as

FEES, our sample size was small and a larger sample size would increase power and strengthen results.

Additionally, while the laryngeal elevation of each participant during swallowing tasks was monitored by an investigator using established palpation methods and visualization from video recording, frequency counts of swallowing events could have been further validated by using instrumental measurements (e.g., accelerometry) or submental muscle contraction (e.g., electromyography [EMG]). Furthermore, it would be advantageous to simultaneously record lingual pressures during swallowing power tests.

Prior to completing the 30-second swallowing endurance tasks, participants were given a single sip of thin liquids to moisten the mouth per an established protocol (Oguchi et al., 2000); however, future research may consider measuring individual saliva production as a covariant in efficiency of completing consecutive swallows. Finally, because participants were not provided with water during the IOPI tasks, changes in oral moisture may have affected performance. Notably, no participants complained of dry mouth or requested water during the IOPI evaluation.

Future Research

To advance our knowledge regarding the characteristics of healthy lingual control, which is the accuracy of lingual pressure to reach given, randomized pressure targets, future studies may consider recruiting a larger sample size across a variety of ages and obtaining lingual pressures simultaneously during swallowing power tests. This would support the establishment of normative data for these tasks and their use in clinical swallowing evaluations. Additionally, future studies may evaluate the relation of lingual control to other swallowing measure from FEES or videofluoroscopic evaluation of swallowing in healthy adults. Finally, the evaluation lingual strength and control in populations with dysphagia is needed to determine the relation of lingual strength and control to specific- aspects of disordered swallowing physiology.

Conclusion

Overall, this investigation contributes to the understanding of healthy lingual pressure generation, and specifically of lingual control through a pilot study of young, healthy adults. Although individual variation in lingual control may exist, as seen in our descriptive data, the more consistent standard deviations on later trials suggest that following a learning and/or convergence effect, pathological conditions may demonstrate significant deviation from normal performance. Should future research with persons with dysphagia elucidate pathological deficits in lingual control have a negative impact on functional swallowing physiology, such targeted swallowing pressure tasks may advance early and accurate diagnosis and inspire novel rehabilitation protocols.

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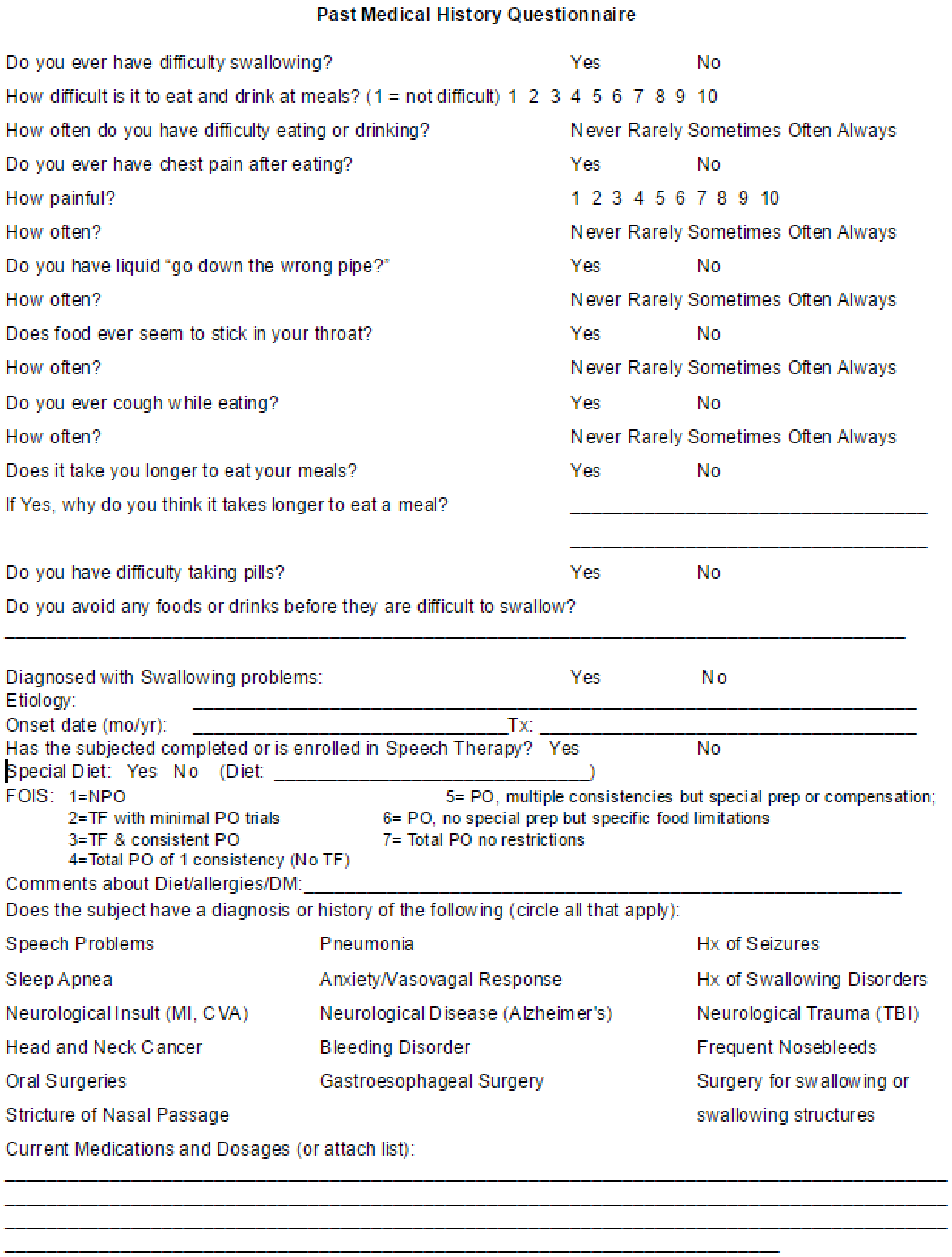
APPENDIX A

PAST MEDICAL HISTORY QUESTIONNAIRE



Past Medical History Questionnaire

Do you ever have difficulty swallowing?	Yes	No
How difficult is it to eat and drink at meals? (1 = not difficult) 1 2 3 4 5 6 7 8 9 10		
How often do you have difficulty eating or drinking?	Never Rarely Sometimes Often Always	
Do you ever have chest pain after eating?	Yes	No
How painful?	1 2 3 4 5 6 7 8 9 10	
How often?	Never Rarely Sometimes Often Always	
Do you have liquid "go down the wrong pipe?"	Yes	No
How often?	Never Rarely Sometimes Often Always	
Does food ever seem to stick in your throat?	Yes	No
How often?	Never Rarely Sometimes Often Always	
Do you ever cough while eating?	Yes	No
How often?	Never Rarely Sometimes Often Always	
Does it take you longer to eat your meals?	Yes	No
If Yes, why do you think it takes longer to eat a meal?	______________________________ ______________________________	
Do you have difficulty taking pills?	Yes	No

Do you avoid any foods or drinks before they are difficult to swallow?

____

Diagnosed with Swallowing problems: Yes No

Etiology: ____

Onset date (mo/yr): __________________________Tx: ______________________________

Has the subjected completed or is enrolled in Speech Therapy? Yes No

Special Diet: Yes No (Diet: __________________________)

FOIS: 1=NPO
2=TF with minimal PO trials
3=TF & consistent PO
4=Total PO of 1 consistency (No TF)
5= PO, multiple consistencies but special prep or compensation;
6= PO, no special prep but specific food limitations
7= Total PO no restrictions

Comments about Diet/allergies/DM:____

Does the subject have a diagnosis or history of the following (circle all that apply):

Speech Problems
Sleep Apnea
Neurological Insult (MI, CVA)
Head and Neck Cancer
Oral Surgeries
Stricture of Nasal Passage
Pneumonia
Anxiety/Vasovagal Response
Neurological Disease (Alzheimer's)
Bleeding Disorder
Gastroesophageal Surgery
Hx of Seizures
Hx of Swallowing Disorders
Neurological Trauma (TBI)
Frequent Nosebleeds
Surgery for swallowing or swallowing structures

Current Medications and Dosages (or attach list):

____
____
____
____

APPENDIX B

ORAL MECHANISM EXAMINATION

Modified Oral Mechanism Examination

Participant: ________________________
Examiner: ________________________
Date: ___/___/______

LIPS		
Adequate Closure	Yes	No
MANDIBLE		
Adequate Mobility (mastication)	Yes	No
DENTITION		
Adequate Condition	Yes	No
Normal Spacing	Yes	No
*Missing Teeth	Yes	No
TONGUE		
Adequate Protrusion/Retraction	Yes	No
PALATE		
*Presence of Cleft Palate	Yes	No