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EXAMINGING THE EFFECTS OF ANKYLOGLOSSIA ON SWALLOWING FUNCTION

by

Kliss Moulton

A thesis

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Committee Approval

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November 9, 2016

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Sincerely,

Ralph Baergen, PhD, MPH, CIP
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Table of Contents

List of Figures

List of Tables

Examining the Effects of Ankyloglossia on Swallowing Function

Abstract – Idaho State University (2017)

This study was conducted to obtain data about the possible relationship between tongue tie and oral-pharyngeal dysphagia (OPD). Data was gathered on 8 participants, 5 females and 3 males, between the ages of 12- 43 years. The *Lingual Frenulum Protocol* (2012) was used to determine tongue tie. The measurements collected were tongue tip and dorsum, and lip strength using an Iowa Oral Pressure Instrument, and masseter contraction and laryngeal timing using a combination of electromyography and the five-finger palpation method. Measurements were compared with normative data found in Holzer (2011).

Results revealed a trend between variables of ankyloglossia and oral-pharyngeal dysphagia. Specifically, reduced articulator strength (tongue tip and dorsum, and lips) and reduced masseter activity. Subjects did not present with statistically significantly prolonged oral-pharyngeal transit times when compared to the normative data. Yet, reduced oral musculature strength is a risk factor associated with oral-pharyngeal dysphagia.

Key words: tongue tie, oral-pharyngeal dysphagia

Chapter 1: Literature Review

Introduction

The processes of mastication and deglutition, or chewing and swallowing, seem simple for most people, as they are done without any conscious effort. Yet, each swallow needs the orchestration of over 55 pairs of muscles, including facial, lingual, velar, pharyngeal, and laryngeal muscles. Signals from the brain, via five cranial nerves, activate the combination of these muscles to execute a functional and precise swallow (Seikel, King, & Drumright, 2010).

A deficit in any of the four stages of the swallow—oral preparatory, oral, pharyngeal, or esophageal—can have functional, social, and emotional impacts for all ages. The events of the swallow must be precisely coordinated to allow for sufficient amounts of food or liquid to reach the stomach (Logemann, 1998). For the purpose of this paper, it is important to distinguish between signs or symptoms of a swallowing problem, or dysphagia, and the actual deficit in the swallow. A sign or symptom is the physical manifestation that indicates that there is a deficit. The deficit is the abnormality in a structure, if any, that affects the function of the structure. Some common signs of dysphagia are pocketing food in the lateral or anterior sulci, increased oral-pharyngeal transit time of the bolus, and nasal regurgitation. For these signs the respective deficits may be weak buccal musculature, weakened tongue muscles, and slowed velar elevation (Seikel et al., 2010).

This study examines the relationship between a structure variations in humans, ankyloglossia, and swallow function. A review of the literature surrounding ankyloglossia including diagnosis criteria, demographics, and consequences of tongue-tie

will be discussed. Then the stages of the swallow, the development of the swallow function, oropharyngeal dysphagia (OPD), and the relationship between tongue-tie and OPD will be described.

Ankyloglossia

Ankyloglossia is a genetic oral variance characterized by an abnormally short lingual frenulum (Messner, Lalakea, Aby, Macmahon, & Bair, 2000). There are several common terms that refer to ankyloglossia, such as tongue-tie, oral tethered tissue, and shortened frenulum. During this discussion these terms will be used interchangeably. In the fourth week of gestation a fetus' tongue arises from the pharyngeal arches. Originally a U-shaped sulcus is formed on both sides of the tongue, which permits the tongue to move freely except at the attachment of the lingual frenulum. During development the lingual frenulum cells die, which retracts the lingual frenulum away from the tip of the tongue. A disturbance in this stage of development results in tongue-tie. The position and thickness of the frenulum changes from birth to puberty. Newborns typically have a short, thick frenulum. With the increase of age the thickness of the frenulum decreases, causing a long and narrow tongue which results in a completely developed tongue at eight years of age (Meenakshi & Jagannathan, 2014). However, people with tongue-tie will continue to have a short or thick frenulum throughout their life. Martinelli et al. (2014) found that frenulums of people with ankyloglossia were made up of a significant amount of striated skeletal muscle fibers and type I collagen fibers, which may contribute to the restriction of tongue movement in individauls with tongue tie.

The tongue is attached in two locations; anteriorly by the lingual frenum and posteriorly to the hyoid bone via the genioglossus muscle (WebMD 2005-2015). These

two points of attachment result in two types of tongue-tie: anterior tongue-tie and posterior tongue-tie. Common characteristics of an anterior tongue-tie are a prominent lingual frenum, reduced protrusion, and a notch at tongue tip. Posterior tongue-tie occurs when there is a less prominent lingual frenum that is thick, short, or tight (Hong et al., 2010).

There are many characteristics associated with tongue-tie. Kotlow (1999) uses four classes when diagnosing tongue-tie in children ages 18 months to 14 years, which range from mild to severe tongue-tie. The varying classes of ankyloglossia result in a range of characteristics that differ by patient. Some common characteristics include: a thick and fibrous frenulum or a thin and membranous frenulum, an abnormally short frenulum that inserts at or near the tongue tip, an impaired side-to-side motion of the tongue, space between the lower teeth, difficulty elevating tip of tongue, and a notch at tongue tip during protrusion (Lalakea & Messner, 2003). The variance in symptoms and the range of severity of tongue-tie are two of the major difficulties in diagnosing it. There is not a standard criterion for diagnosing tongue-tie, and thus many professionals have developed their own criteria. This has resulted in a range of prevalance rates. Before prevalance rates are discussed, I will describe four diagnostic methods.

Kotlow (1999) identified four classes of tongue-tie. He uses the length of the free-tongue to establish the presence of tongue-tie, which is the distance from the insertion of the lingual frenum into the base of the tongue to the tip of the tongue. Class I is mild ankyloglossia with a free-tongue length between 12 to 16 mm; class II is moderate ankyloglossia with 8 to 11 mm free-tongue length; class III is severe ankyloglossia with free-tongue length between 3 and 7 mm; and class IV is complete ankyloglossia with a

free-tongue length of less than 3 mm. Kotlow then examines different functions of the tongue to determine if treatment is warrented. Some of the functions examined are force of the tongue on mandibular anterior teeth, swallow pattern, and the tongue's ability to sweep the upper and lower lip. Treatment is recommended for all patients with class III and IV ankyloglossia (Bai & Vaz, 2014).

Many medical facilites use subjective determination by the examiner to diagnose ankyloglossia. Messner et al. (2000) had examiners look at limitations of tongue movement and prominence of the frenulum to diagnose tongue-tie, whereas Hogan, Westcott, and Griffith (2005) provided examiners with a formal class teaching them to identify tongue-tie during newborn checks and provided 6 pictures of examples of tongue-tie to be used during diagnosis. Other facilities use quantitive measures when diagnosing tongue-tie. The Hazelbaker Assessment Tool for Lingual Frenulum Function (HATLFF) assesses both the function and the appearance of the tongue. Items relating to function are lateralization of tongue, lift of tongue, extension of tongue, spread of anterior tongue, cupping, peristalsis, and snapback (Ballard, Auer, & Khoury, 2002). Appearance of the tongue is rated on tongue appearance when lifted, elasticity of frenulum, length of lingual frenulum when tongue is lifted, attachment of lingual frenulum to tongue, and attachment of lingual frenulum to inferior alveolar ridge. All items are rated on a 0-2 point scale with separate sums for function and appearance. An appearance score of eight or less and/or function score of eleven or less is diagnosed as significant ankyloglossia (Ballard et al., 2002). Face and content validity were established for this assessment (Buryk, Bloom, & Shope, 2011).

Measuring interincisal distance, which is the distance between the upper and lower central teeth in millimeters, is a proposed method of determining the presence of ankyloglossia as it is used as a measure of tongue elevation ability (Messner & Lalakea, 2003; Williams & Waldron, 1985). To obtain this measurement the patient touches the tip of his or her tongue to the upper teeth and opens the mouth as wide as possible while maintaining contact. Unfortunately, there are no normative data for this measurement (Lalakea & Messner, 2003).

Lack of a uniform diagnostic criteria of tongue-tie has resulted in a range of prevalence estimations, from 3.2% - 16.4%. Ballard et al. (2002) used the HATLFF and obtained a prevalance rate of 3.2% out of 2763 infants. Similarly, Messner et al. (2000) reported a prevalance rate of 4.8% out of 1041 newborns, although they used subjective examiner observation to diagnose ankyloglossia. Hogan et al. (2005) also used subjective examination for diagnosis but reported a prevalance rate of 10.7% out of 1866 newborns. The highest prevalence rate was found by Bai and Vaz (2014) using the Kotlow scale, with a prevalence of 16.4% out of 700 nine to seventeen-year-olds. However, this higher prevalence rate may be attributed to the inclusion of multiple classes of ankyloglossia. When only class IV ankyloglossia was considered there was a prevalence rating of 8.85%. All studies found males were more likely to have ankyloglossia than females with a range of ratios males to females of 1.5:1 (Ballard et al., 2002) to 2.6:1.0 (Messner et al., 2000). The lack of consistency in rate of prevalence is an example of the lack of unity among professionals in the assessment of tongue-tie.

Effects of Tongue-tie

As in all areas of research regarding tongue-tie there is limited information; this includes the impact of tongue-tie on other functions. Degrees of impact have been reported on breastfeeding, speech, and social issues. Messner and Lalakea (2000), published a prospective study which documented breastfeeding difficulties with tongue-tie. Mothers of 36 infants with ankyloglossia and mothers of a matched control group of newborns were followed for 6 months to determine the incidence of breast-feeding problems, including nipple pain lasting longer than 6 weeks and/or infant difficulty latching onto breast. Breastfeeding problems occurred significantly more frequently in the ankyloglossia group with 25% of patients experiencing problems versus 3% for the control group (Messner & Lalakea, 2000). These results were supported in a randomized trial conducted by Buryk et al. (2011) which looked at the results of performing a frenotomy, or surgical release of the tongue-tie, on infants. Mothers of infants with ankyloglossia were placed in either a frenotomy group, or control group, which did not have a frenotomy. Those whose infants underwent frenotomy had significantly improved scores on a breastfeeding rating and reported reduced nipple-pain (Buryk et al., 2011). These studies have concluded that ankyloglossia correlates with breast-feeding problems in some infants.

The connection between speech and ankyloglossia has not been clearly defined, and opinions of professionals vary widely. In a survey conducted by Messner and Lalakea (2000), 49% of speech therapists felt that ankyloglossia was never or rarely associated with speech problems, while the other half believed it was sometimes or frequently associated with speech problems. Some children are able to compensate for

limited tongue-tip mobility caused by the tongue-tie, and present with normal speech. Others may have articulation errors or difficulty with rate of articulation due to ankyloglossia, which reduces speech intelligibility (Messner & Lalakea, 2000). Messner and Lalakea (2000) note the sounds /t, d, z, s, th-, n, and l/ as potentially being affected by tongue-tie. Furthermore, Marchesan (2004) found that 48.8% of 127 participants with tongue-tie exhibited speech disorders. It appears that speech difficulties vary by individuals with tongue-tie and SLPs have varying opinions about the effects of tongue-tie on speech.

Recent research on ankyloglossia has involved its impact on sleep disordered breathing. Tongue tie alters orofacial growth due to the low placement of the tongue in the mouth. This may lead to the development of a narrow and high hard palate and mouth breathing at night. These changes increase the collapsibility of the upper airway during sleep, which causes the sleep disordered breathing (Huang, Quo, Berkowski, & Guilleminault, 2015).

Medical literature has focused little attention on mechanical and social consequences of tongue-tie, though they do exist. Mechanical problems may include difficulty with licking lips or sweeping the teeth to clean food debris, cuts beneath the tongue, and difficulty wearing dentures. Limited lingual range of motion may cause difficulty playing a wind instrument, licking an ice cream cone, and “French” kissing (Messner & Lalakea, 2000). These signs and symptoms may be accompanied with social embarrassment. Messner and Lalaeka (2000) reported that approximately 50% of older children and adults with ankyloglossia reported, in a medical history, one or more of the

above complaints. Despite the limited documentation of such consequences, tongue-tie can have a social impact.

Swallowing

The tongue is a primary muscle in the process of deglutition, or swallowing, which is a crucial part of obtaining life-sustaining nutrients. It is done voluntarily, during meals, and involuntarily, while controlling salivation. Medically it is defined as the transportation of food or liquid from the oral cavity through the esophagus (Saitoh et al., 2007). The swallow is often broken up into four stages: oral preparatory, oral, pharyngeal, and esophageal stages. During the oral preparatory stage food is presented to the mouth. The lips occlude and the soft palate lowers which, with the help of the tongue, keeps the food in the oral cavity. The tongue moves the food on and off of the teeth during the process of chewing and mixing saliva with the food to create a coherent and slippery bolus (Kim & Han, 2005; Logemann, 1998; Seikel et al., 2010). Once the bolus reaches the correct consistency the oral stage begins. When mastication stops the tongue base drops down and pulls posteriorly as the anterior tongue elevates to the hard palate. The tongue tip and dorsum move front to back, squeezing the bolus towards the faucial pillars (Seikel et al., 2010; van den Engel-Hoek et al., 2012). The pharyngeal stage lasts one second or less and begins when the pharyngeal swallow is triggered by the bolus contacting the faucial pillars, soft palate, or posterior tongue (Logemann, 1998). When the pharyngeal swallow is triggered it causes six neuromotor activities: (a) ceased respiration; (b) protection of the airway through adduction of true and false vocal folds and the inversion of the epiglottis; (c) laryngeal elevation and protraction; (d) velopharyngeal closure to close off the nasal cavity and generate swallow pressure; (e)

peristaltic contraction of the pharyngeal constrictors to propel bolus through the pharynx; (f) opening of the upper esophageal sphincter to allow the bolus to pass from the pharynx into the esophagus. None of these neuromotor activities last the entire pharyngeal stage. Instead, each action happens as the bolus passes the relevant portion of the pharynx. For example, the airway is protected only for the split second that the bolus passes the larynx. (Logemann, 1984; Logemann, 1998). The esophageal stage simply stated is the process of the bolus traveling from the upper esophageal sphincter through the lower esophageal sphincter into the stomach (Logemann, 1998).

Swallowing in Infants

Swallowing, however, changes from infancy to adulthood. The oral-pharyngeal structures of an infant are remarkably different from those of an adult. Infants have smaller oral cavities that are filled with their tongue. Also, their hyoid bone and larynx are much higher, and the velum hangs lower with the uvula resting inside the epiglottis (Logemann, 1998; Seikel et al., 2010). The lowered velum and higher larynx help to protect the airway during a swallow. As the jaw grows down and forward the oral cavity will enlarge and the larynx and hyoid bone will lower, elongating and enlarging the pharynx (Logemann, 1998).

The physiology of swallowing in infants differs greatly from adults. The tongue and mandible pump forward to bring milk into the oral cavity which collects at the faucial pillars. Normal infants use 2–7 tongue pumps to collect enough milk for a swallow (Logemann, 1998). When the collection of milk, or bolus, is large enough, a pharyngeal swallow is triggered. During the pharyngeal swallow the laryngeal elevation is much more reduced than that of adults because the larynx is already elevated and the

posterior pharyngeal wall moves much further forward (Logemann, 1998). In time dentition will block the anterior protrusion of the tongue which will support the retraction of the tongue during the swallow (Seikel et al., 2010). Logemann (1998) further explains that once the infant begins to swallow pureed foods, the oral and pharyngeal swallow physiology becomes similar to that of an adult.

Orofacial Myofunctional Disorders

Orofacial myofunctional disorders (OMD) are conditions or behaviors "that can have a negative impact on oral postures and functions" (Mason, 2008). Some common OMDs include tongue thrust, open mouth rest posture, and bruxism. The common factor for myofunctional disorders is a change in the dental freeway space, which is the vertical space between the dental arches at rest with the lips closed (Mason, 2008). OMDs can be compensatory behaviors that result from other problems. For example, tongue thrust is an OMD that is a compensatory behavior resulting from another problem. On the other hand, tongue-tie is a structural abnormality that may result in an OMD (IAOM, 2014). It is important to treat OMDs to limit the negative effect that they have on development of dentition and speech articulation patterns, and to limit the damage they cause to the temporomandibular joint apparatus. OMDs are treated through Orofacial myofunctional therapy procedures that focus on eliminating harmful habit patterns, normalizing resting posture, and retraining muscle patterns (IAOM, 2014).

Disorders of Swallowing

There are times when the process of swallowing does not work properly. Oral-pharyngeal dysphagia is the medical term for difficulty during one or more of the stages of swallowing that causes difficulty moving food from the mouth to the stomach (Logemann, 1998). There are many causes for oral-pharyngeal dysphagia. A few

common causes are cleft lip, cleft palate, and tongue thrust. In the case of cleft lip the functionality of the labial seal is reduced causing difficulty keeping food in the mouth during the oral prep stage. Cleft palate results in little pressure for sucking and bolus propulsion and increases the likelihood of nasal regurgitation (Prasse & Kikano, 2009). Tongue-thrust is often the result of holding the bolus in an abnormal position, against the front teeth, resulting in a forward movement of the tongue to accomplish the swallow. Oral-pharyngeal transit time, which is the time it takes to move the bolus from the anterior part of the mouth to the point of the initiation of the pharyngeal swallow, is increased with tongue-thrust (Seikel et al., 2015). These disorders may result in abnormal structures which affect the oral-pharyngeal swallow.

Bedside Evaluation of Swallow

A bedside evaluation is a clinical examination of swallowing conducted to determine if an in-depth diagnostic swallowing evaluation is needed. It provides a great deal of data about the anatomy and physiology of the patient's swallow including: information on medical history; medical status; oral anatomy; respiration function in regards to swallowing; lingual control; palatal function; pharyngeal wall contraction; laryngeal control; general cognitive ability; and reactions symptoms during swallow (Logemann, 1998). A disadvantage of the bedside evaluation is that it does not detect silent aspiration. Leder, Sasaki, and Burrell (1998) reported silent aspiration to occur in 40% of patients. Visualization is needed to accurately identify and confirm silent aspiration (Leder, Sasaki, & Burrell, 1998). The bedside evaluation consists of two parts: the preparatory examination, and the initial swallowing examination.

The preparatory examination begins with a review of the patient's chart taking note of things such as medical history, nutritional status, current medications, and history of dysphagia. Upon entering the patient's room the clinician should observe the patient's posture in bed, alertness, and presence or absence of tracheostomy tube (Logemann, 1998). The clinician continues to make informal observations of the patient's ability to follow directions, answer questions, and overall alertness as a case history is obtained. It is critical that the clinician assess the patient's respiratory rate at rest to ensure that swallowing therapy is appropriate (Logemann, 1998). Next a complete examination of the oral anatomy is preformed to observe all structures in the mouth. An oral-motor control examination includes: ability to open mouth, labial function, lingual function, soft palate function, and oral reflexes. The information obtained from the preparatory examination are considered to determine if trial swallows at the bedside should be attempted (Logemann, 1998).

If it is determined that swallow trials are safe the patient is given a series of liquids/foods to swallow as the clinician palpates their neck. Palpation is performed by placing the index finger on the patient's neck at the level of the base of tongue, the middle finger at the hyoid bone, the third finger at the top of the thyroid cartilage, and the fourth finger at the bottom of the thyroid cartilage (Logemann, 1998). This allows assessment of the submandibular movement, hyoid movement, and laryngeal movement during each swallow. The patient will be presented the following amounts of water: a 1/2 teaspoon (tsp), 1 tsp, a sip from a cup, sequential sips from a cup (Smith, 2016a). If water is tolerated a tsp of nectar thick liquid such as peach juice is presented. The rest of the consistencies are presented in the following order: pudding, peaches in juice, and a

cracker. After each swallow the client is instructed to say "ah" which tests for vocal quality and allows observation of food pocketing and residue. Signs of silent aspiration such as watery eyes, running nose, or delayed cough should be monitored. When presenting the cracker have the patient chew the food and show the bolus before swallowing (Smith, 2016a). This allows the clinician to assess bolus formation which can indicate control of tongue and mastication ability. The bedside evaluation allows the clinician to determine if further swallowing evaluation is indicated and set a diet level for the patient.

Instrumental Evaluation of Swallow

The gold standard assessment for evaluating the swallow is videofluoroscopy, also known as a modified barium study. During a videofluoroscopy assessment the patient is given measured amounts of liquid to drink from a cup; then food that is pudding consistency; and lastly a masticated bolus such as a piece of cookie. Each type of food and drink is mixed with a small amount of barium (Logemann, 1998). The videofluoroscopy allows the clinician to visualize the oral activity during chewing, the triggering of the pharyngeal swallow, and the motor movement of the pharyngeal swallow. The lateral view is used to assess transit times and observation of aspiration. The purpose of the videoflurosocpy is not to identify if someone aspirates but to determine why they aspirate (Logemann, 1998). The two main disadvantages to videofluoroscopy are the cost and the client being exposed to a small degree of radiation.

An imaging assessment of swallowing that is gaining popularity is videoendoscopy or flexible fiberoptic examination of swallowing (FEES). During FEES a scope is inserted through the nose to the level of the soft palate which allows

visualization of the pharyngeal and laryngeal anatomical structures during swallowing (Logemann, 1998). Thus, the clinician can determine silent aspiration that occurs before the swallow through premature spillage or aspiration that occurs after the swallow due to residue (Leder, Sasaki, & Burrell, 1998). A disadvantage to FEES is that the oral stage is not visualized (Smith, 2016b).

Electromyography (EMG) assesses the timing and relative amplitude of certain muscle contractions during swallowing (Logemann, 1998). This nonimaging procedure involves placing surface electrodes to the skin on specific muscles. Removing the top layer of dead skin cells helps to improve signal detection (Stepp, 2012). EMG has been used to mark the onset of the swallow by placing electrodes on the tissue under the chin and an electrode above the thyroid cartilage (Logemann, 1998). Muscles that are used in deglutition and are easily measured with EMG electrodes are the masseter, sternohyoid, and omohyoid (Stepp, 2012).

The Iowa Oral Performance Instrument (IOPI) is a portable device that measures the strength and endurance of tongue and lip strength (Stierwalt & Youmans, 2007). The IOPI uses a small air-filled bulb to measure pressure which is displayed digitally on a LCD screen. A study conducted by Stierwalt and Youmans (2007) compared tongue strength and endurance between two groups, the experimental group with dysphagia and the control group without dysphagia. Results for the control group showed greater tongue strength in women than men and in younger verses older participants. When comparing the experimental and control group, the experimental group had significantly lower tongue strength. No significant differences were found on tongue endurance (Stierwalt & Youmans, 2007). Stierwalt and Youmans' (2007) study supports the hypothesis that

individuals with dysphagia will have decreased tongue strength compared to individuals without dysphagia.

Relationship Between Tongue-tie and Oral-pharyngeal Dysphagia

As previously discussed, tongue-tie is an oral anomaly characterized by an abnormally short lingual frenulum. Ferres-Amat et al. (2016) states that:

> As regards swallowing, ankyloglossia causes atypical deglutition due to insufficient palatal support to produce a mature adult swallow. The physiological process of the child which goes from the childhood swallow to the adult one in the early years of life is interrupted due to the restricted driving force in the infant with hypertrophic lingual frenulum. (p. e40)

The tongue is the propelling muscle that pushes and squeezes the bolus to the faucial pillars during the oral stage of the swallow. A deficit in its mobility may affect the oral-pharyngeal transit time of the bolus. Francis, Krishnaswami, and McPheeters (2015) state, "Not all patients identified with ankylogolossia may have difficulties breastfeeding and/or need surgery. However, no data exists to differentiate how patients may fare later in life" (p. 1463). There is suggestion of a relationship between ankyloglossia and swallowing. Olive (2016) conducted a study of 8 participants with ankyloglossia comparing them to norms for the measurements of oral-pharyngeal transit time, masseter contraction, laryngeal timing, and measure of force based on IOPI of tongue tip, dorsum, and lips. Results reported all participants having a noticeable delay in oral-pharyngeal transit time for all bolus consistencies, a noticeable difference in masseter contraction, a marked delay in laryngeal timing, and reduced tongue tip, dorsum, and lip strength

(Olive, 2016). As this was the first study linking ankyloglossia and oral-pharyngeal dysphagia more studies in this area are needed.

Conclusion

Thus far, tongue-tie, the diagnosis of tongue-tie, developmental aspects of swallowing, oral-pharyngeal dysphagia, and the relationship between tongue-tie and the adult swallow have been discussed in detail to provide a foundation for this study. The question of the present study is: *Do individuals with tongue-tie differ from the norms of individuals without tongue-tie in the measure of oral-pharyngeal transit time?*

Chapter 2: Methodology

Because this study was a replication of a previous study (Olive, 2016), the following methodology was standardized from the Olive (2016) study and thus contains verbatim elements found in other studies. The purpose of the current study was to increase the evidence regarding whether or not individuals with ankyloglossia vary from the norm in measures of oral pharyngeal dysphagia. The following measures were examined: ankyloglossia, tongue strength, lip strength, masseter strength and contraction, oral pharyngeal transit time, and laryngeal elevation. This study included 8 subjects, ranging in age from 12-43 years.

Research Hypotheses

H_{0a}: No trend exists relating variables associated with oral pharyngeal dysphagia and those associated with ankyloglossia.

H_{1a}: A trend exists relating variables of oral pharyngeal dysphagia and ankyloglossia.

H_{0b}: No significant difference exists in masseter contraction based on side and/or bolus type as compared with norms.

H_{1b}: A significant difference exists in masseter contraction based on side and/or bolus type as compared with norms.

H_{0c}: No significant difference exists in laryngeal timing based on bolus type and/or measurement type as compared with norms.

H_{1c}: An significant difference exists in laryngeal timing based on bolus type and/or measurement type as compared with norms.

H_{0d}: No significant difference exists in force, as measured by IOPI, based on IOPI location as compared with norms.

H_{1d}: A significant difference exists in force, as measured by IOPI, based on IOPI location as compared with norms.

Participants

The participants were obtained through a convenience sample, and consisted of 8 individuals identified with ankyloglossia, ranging in age from 12-43 years. The *Lingual Frenulum Protocol* (LFP) developed by Marchesan (2012) (refer to Appendix A) was used to confirm the presence of ankyloglossia in all subjects, as well as to obtain case history. The case history included name, gender, examination date, age, personal information, how the participant was referred, main complaint, other complaints associated with ankyloglossia, family history of frenulum alteration, health and breathing problems, feeding (chewing and deglutition) difficulties, oral habits, speech alterations, social or professional issues due to speech alteration, voice alteration, and history of frenulum surgery. In addition, all subjects completed a demographic survey (refer to Appendix B) to obtain the following information: participants' birth date, gender, history of serious medical conditions or disorders, and preference of food types.

Exclusion criteria for the study were validated through subject report on the demographic survey. Participants with a history of craniofacial abnormalities, intellectual or motor limitations, neurogenic structural impairments to the head or neck, neurogenic disorders, or traumatic brain injury with coma were excluded from the sample.

Participants with a history of a concussion resulting in a period of unconsciousness lasting no more than 5 minutes, and who had no reduction in motor or cognitive function, were not excluded from the study.

Variables

Independent variables for this study were subject age, gender, and bolus characteristics. The following bolus consistencies and sizes were used when evaluating the participants: ½ teaspoon of pudding, 1 ½ teaspoon of pudding, subject-determined "typical" bite of Triscuit cracker, and 10 cc of water served in a cup.

Clinical observation and professional judgment were used to measure subjective variables, which consisted of presence of open or closed mouth at rest posture, presence of tongue protrusion during swallow, rated cohesion of bolus, and residue on the tongue after the swallow. Measures of superior tongue tip and dorsum strength, lip strength, and masseter strength were obtained through objective measures, including peak EMG and behaviorally measured oral pharyngeal transit time.

Instruments and Materials

Each participant was assessed using a demographic survey (refer to Appendix B), the *Lingual Frenulum Protocol* (refer to Appendix A), and a Clinical Evaluation Protocol (refer to Appendix C).

Superior tongue strength, lip strength, and masseter strength were measured using the Iowa Oral Performance Instrument (IOPI) (Breakthrough model 1.5). Degrees of masseter contraction and oral pharyngeal transit time were measured using a two channel Infiniti EMG (Thought Technology) using surface electrodes. Food and liquids which were administered to the participants included Snack Pack chocolate pudding, water, and

Triscuit crackers. A syringe calibrated for volume, measured in cubic centimeters, was used to measure pudding amounts and water. Other clinical materials that were used included gloves and tongue depressors.

Procedures

A counterbalanced order of presentation of measurement was used by developing three protocols. Participants were assigned one of the three groups (refer to Table 2.1). The counterbalanced order helped to control for measurement presentation effect such as fatigue or familiarity. The *Lingual Frenulum Protocol* was administered first for all three groups as it was critical for diagnosing an individual with tongue tie.

Table 2.1. Presentation Order of Measurement Tasks.

Group A	Group B	Group C
Lingual Frenulum Protocol	Lingual Frenulum Protocol	Lingual Frenulum Protocol
IOPI force	EMG masseter contraction	EMG laryngeal timing
EMG masseter contraction	EMG laryngeal timing	IOPI force
EMG laryngeal timing	IOPI force	EMG masseter contraction

Participants were evaluated in the Idaho State University Speech and Hearing Clinic (Pocatello, Idaho) or in their homes. All participants were tested in a quiet environment which was free of distractions. Subjects were seated in an upright, comfortable position. First, they were presented with the human subject consent form (refer to Appendix D) followed by the demographic survey (refer to Appendix B). Then the *Lingual Frenulum Protocol* was completed (refer to Appendix A). Upon completing the tongue-tie evaluation (see below), the stimuli (3 presentations of each stimulus) was presented according to the protocol of Appendix C, and described below. Participants were allowed to take a drink of water after each bolus upon completion of the trial.

The participants were informed that an IOPI bulb would be placed between their lips and their mouth, as well as electrodes on their throat and jaw. They were given the option of ending the procedure at any point during the process.

Tongue tie Diagnosis and Classification

The evaluation of tongue tie was divided into two parts: first, investigation of the general aspects of the frenulum and tongue, second, test of the function of tongue mobility. The general aspects of the frenulum and tongue were assessed using the Quick Tongue-Tie Assessment tool (the QTTA). To obtain the first measurement the QTTA was placed at the superior right or left incisor to inferior right or left incisor and the same tooth was considered for all measurements. The researcher recorded in millimeters the participant's ability to open his or her mouth wide (MOmax), and then open the mouth wide with the tongue tip touching the incisive papilla (MOtts). The researcher then determined the ratio between the two measurements (MOmax/MOtts). The next measurements were of alterations during tongue elevation. These were obtained by having the participant open his or her mouth wide while raising the tongue without touching the palate. The researcher took note of the shape of the tongue tip (oblong, square, or heart like). The frenulum was observed at the mouth floor and sublingually by the researcher to determine frenulum fixation. A clinical frenulum classification was assigned by the researcher as either normal, borderline, or altered. A score of zero was the best result of the general test with a score of eight signifying the most severe tongue-tie. A tongue-tie was assigned when the score is equal to or greater than three.

The functional test of tongue mobility was conducted by having the participant protrude and retract the tongue, touch the superior lip with the apex, touch the right and

left corners of the mouth, touch the upper and lower molars, and suck the tongue against the palate. Each movement was judged as either successful, partially successful, or unsuccessful. Tongue placement during rest was assessed as either not visible, on the floor of the mouth, protruding between the teeth, or laterally protruding between the teeth. Three speech tasks were performed by the participant, an informal speech measure, counting from 1 to 20, and naming pictures. Errors of omission, substitution, and distortion along with corresponding phonemes was recorded. Other aspects were observed during speech: mouth opening, tongue position, mandible movements, speech precision, and voice. All results were recorded on the protocol referred to in Appendix A. A score of zero was the best result of the functional portion, with a score of forty being the most severe result. The frenulum was considered altered when the score of the functional evaluation was equal to or greater than 25 (Marchesan, 2012).

Tongue, Lip, and Masseter Strength.

IOPI measurements were taken to measure tongue tip strength, tongue dorsum strength, and lip strength. First, the IOPI bulb was placed on the tongue tip. The participant was then instructed to occlude his or her teeth and lips and use their tongue to compress the bulb against the alveolar ridge with as much strength as possible for approximately two seconds. This was done three times, with the amount of force exerted being recorded. Next, the subject was asked to sustain phonation of the vowel /a/ to facilitate placement of the IOPI bulb on the tongue dorsum. The bulb was placed on the tongue dorsum inferior to the juncture of the hard and soft palates, as indicated by the peak of the tongue during the phonation of /a/. The subject was then instructed to occlude his or her teeth and lips while pushing the bulb against the hard palate as hard as they

could and held for approximately two seconds. This was completed three times with the bulb being repositioned after each attempt. The readings of the IOPI was recorded by the researcher.

Lastly, the bulb was placed between the participant's lips. He or she was instructed to press his or her lips together using full strength but without biting down on the bulb with his or her teeth. This was completed three times each for two seconds, with the bulb being repositioned after each attempt. The researcher will record the IOPI readings.

EMG Masseter Contraction

Masseter contractions were recorded using the EMG measurements, which were taken by EMG electrodes placed on the lateral facial surface. Electrodes were first placed to obtain a masseter baseline and to measure masseter contraction. Then the participants were instructed to clench their back teeth while the researcher palpates the masseter belly. The EMG electrodes were placed bilaterally on the masseter belly in a vertical plane. The right masseter was assigned Channel A, and the left masseter was assigned Channel B. The ground electrodes were placed on the subject's clavicle.

After all electrodes were placed the masseter contraction was measured. A masseter baseline was recorded and used for comparison during swallow trials. To obtain the baseline, participants were instructed to bite down with their back teeth as hard as possible and then to relax. This was repeated for a total of three trials. Subsequently, groups were presented each bolus (½ teaspoon of pudding, 1 ½ teaspoon of pudding, 10 cc of water, and a Triscuit cracker). Each subject was given the bolus and instructed to hold it in his or her mouth until told to swallow. The researcher palpated the lateral neck

and submental region, using the five-finger method of Logemann (1998). At the initiation of the swallow the researcher pushed the spacebar of the laptop computer, which placed a mark on the EMG recording. The Triscuit cracker was an exception to this; in this case, participants chewed until they were prepared to swallow, and then swallowed with their own timing. It was felt that this was minimally disruptive to the swallow timing itself. EMG was recorded for all boluses, and later measured. Again, the researcher marked timing of the swallow using the spacebar. Each stimulus was presented three times.

In a separate trial, the cohesion and residue of the bolus was examined for the Triscuit cracker. Subjects were instructed to chew the cracker until ready to swallow, then to open their mouths to allow the researcher to examine the bolus. The researcher used a 5-point scale to rate the cohesion of the bolus. The participants then swallowed and opened their mouth. The amount of residue on the tongue was rated on a 5-point scale. The masseter strength and start time of the swallow was recorded, with each stimuli being presented three times.

EMG and Behavioral Laryngeal Timing

Instrumental and behavioral measurements of oropharyngeal transit timing were used with the goal of identifying the initiation and termination of the swallow. Initiation of swallowing was defined as movement of the tongue and was instrumentally measured by recording the EMG of the submental region. Termination of the swallow was defined as the depression of the larynx following swallow, as the myogenic response of depression is variable. This was subsequently measured behaviorally using the 5-finger palpation method.

Channel A and Channel B electrodes were removed from the masseter and prepared to measure laryngeal elevation. On the submental region, approximating the mylohyoid muscle, Channel A was placed. The first electrode was placed approximately two centimeters posterior from the chin point, and the second electrode was placed two centimeters posterior to the first. Channel B had one electrode placed to the left of the thyroid notch with the other electrode placed two centimeters posterior to the first. Participants were presented with ½ teaspoon of pudding and instructed to clean the spoon and then to swallow when ready. This was repeated three times. The five-finger method of Logemann (1998) was used as a behavior measurement of laryngeal timing. The researcher also depressed the spacebar of the laptop computer at initiation of the swallow and at depression of the larynx, which placed a marker on the EMG recording.

The researcher then pulled down the subject's lower lip during a swallow to observe lingual function. The participant was presented with 1 ½ teaspoons of pudding and instructed to clean the entire spoon and swallow when ready. The researcher observed any tongue protrusion during the bolus preparation, the swallow and for completion of the task. Presence or absence of tongue protrusion was indicated on the protocol. The remaining boluses were sampled as well. Each stimulus was presented three times in a row with measurements being taken with each presentation.

Reliability

Inter-judge Reliability

Ten percent of laryngeal timing recordings of subjects were be re-measured by a second judge. The paired responses were compared using Pearson Product Moment Correlation Coefficients. The coefficient was .5748 indicating a positive correlation.

Intra-judge Reliability

To examine intra-judge reliability, the EMG of 10% of each participant's laryngeal timing measurements were be re-measured by the researcher and cast into a Pearson Product Moment Correlation. The coefficient obtained was 0.96 which shows a high correlation for intra-judge reliability.

Chapter 3: Results

The purpose of the study was to investigate if the possible relationship between tongue-tie and oral pharyngeal dysphagia exists. Eight participants with tongue-tie, diagnosed using the *Lingual Frenulum Protocol* (LFP), were assessed using EMG and IOPI instrumentation to determine tongue and lip strength, masseter strength, and swallowing time. Measurements were examined to determine variability between tongue-tie individuals and normative data of individuals without tongue-tie. Data from the study is included in Appendix E.

Demographic Survey

Eight subjects (3 males and 5 females) between the ages of 12-43 years participated in the study. The mean age of the subjects was 20.63 years (13.3 years for males, 25 years for females). Six of the participants were European American, one was White Hispanic, and one was other/Multi-racial. One participant reported having a history of the following categories; multiple sclerosis, mouth breathing, currently having open spaces in dentition, TMJ syndrome, and finger sucking. Two subjects reported having had other surgeries (both had ear tubes and one had gall bladder surgery). Three

subjects reported having tonsils/adenoids removal, oral surgery of wisdom teeth removal, and allergies. Four subjects reported having enlarged tonsils/adenoids. Five participants reported having foods that they avoid. Results of the demographic survey are summarized in Table 3.1. All other areas listed on the demographic survey (Appendix B) were reported as not having by participants.

Table 3.1. Demographic Survey Results.

	Males	**Females**	**Total**
European American	2	4	6
White Hispanic	1		1
Other/Multi-racial		1	1
Neuromedical conditions: head injury, stroke, brain masses, multiple sclerosis (1), cerebral palsy, dementia, brain surgery	0	1	1
Mouth Breather	1		1
Enlarged Tonsils/Adenoids	2	2	4
Tonsils/Adenoids Removed	1	2	3
Opened Space During Mixed Dentition		2	2
Current Open Spaces in Dentition		1	1
TMJ Syndrome		1	1
Allergies	2	1	3
Oral Surgery: wisdom teeth (3)		3	3
History of Finger Sucking	1		1
Other Surgery: ear tubes (2), gall bladder (1)	1	1	2

Subject 1

Subject 1 was an 18-year-old female diagnosed with tongue tie using the LFP. She participated as Group A order of presentation; LFP, IOPI, EMG masseter strength, EMG swallowing measurements. All measurements were completed in one session.

Table 3.2 contains behavioral and clinical results for Subject 1. She demonstrated difficulty touching the right and left commissura labiorum and sucking the tongue against the hard palate. During the speech sample, her tongue protruded forward periodically

when producing some words containing /l/. Examination of the tongue and frenulum exposed a tongue tip that was oblong and slightly heart shaped, the frenulum attached sublingually between the middle and the apex of the tongue. As part of the LFP, measurement of the mouth opened maximally (MOmax) and maximally opened with the tongue tip at the incisive papilla/to spot (Motts) are reported as follows; MOmax=62mm, Motts=22mm. The LFP states that when the ratio of MOmax and MOtts is smaller than 50% tongue-tie is indicated. The ratio of MOmax and MOtts was 33% indicting a significant tongue tie. Overall the results of the general test of the LFP was a score of 6 out of 8, indicating an altered lingual frenulum.

Table 3.2. Behavioral/Clinical Indicators, Subject 1.

Indicators	Results
Ratio of MOmax and Motts	33%, indicating tongue tie
Tip of tongue appearing oblong or square shaped	Present, tip of tongue appeared oblong
Tip of tongue appeared like a heart	Present, indicating tension from lingual frenulum
Sublingual frenulum attachment between the middle and apex of the tongue	Present, indicating an anterior point of attachment
General Test Results (A score equal or greater than 3 means the frenulum may be considered altered)	6/8 indicating the frenulum is altered
Touch the right and left commissura labiorum	Partially successful, tongue twisted
Sucking against palate	Partially successful
Tongue during speech	Occasionally protruding during production of /l/

Data for each objective variable (EMG and IOPI trials) were compared with the Holzer (2011) normative data using z-scores (Table 3.3). As can be seen in this table, all IOPI measurements except dorsum strength were significantly lower than the norms. Similarly, all masseter contraction measures were significantly lower than the norms. No

oropharyngeal timing measures were significantly longer than the norms. Figure 3.1 reveals that IOPI force was significantly lower for lip and tongue tip strength, not for tongue dorsum strength. The oral-pharyngeal transit times were not significantly longer than the norms (see Figure 3.2). Subject 1 also demonstrated forward tongue posture during deglutition for 78% of trials. During swallow trials the results for bolus formation was an average of 5 indicating that the bolus was disorganized or scattered on the tongue. There was minimal-to-no residue in the oral cavity following the swallows, as revealed in an average score of 1 on the residue ratings scale. The reduced masseter contractions, decreased bolus cohesion, reduced labial and tip strength, and tongue protrusion are indictors of an orofacial myofunctional disorder (OMD).

Table 3.3. Observed Data for Subject 1.

Measurement	Subject #1	Norms		Probability (<.05)
	Mean	Mean	SD	
Iopitipavg	47.67	41.56	17.31	0.00554
Iopidorsavg	34.33	36.07	13.51	0.20611 NS
Iopilipavg	5.33	23.67	12.59	0.00
mcbARMSavg	38.68	187.3	149.9	0.00
mcbBRMSavg	85.69	181.9	112.8	0.00
mcpud1ARMS	53.34	27.7	14.9	0.00
mcpud1BRMS	89.14	48.9	72.5	0.00
mcpud2ARMS	25.5	39.7	29.4	0.00
mcpud2BRMS	40.16	49.6	82.8	0.03593
mc10ccARMS	15.39	22	8.8	0.00
mc10ccBRMS	17.47	26.2	22.8	0.00076
mccrackARMS	61.26	108.9	79.6	0.00
mccrackBRMS	96.83	151.9	140.6	0.00
stcpud1avg	1.81	1.41	0.45	0.15151 NS
stcpud2avg	1.76	1.3	0.35	0.08851 NS
stc10ccavg	1.01	1.106	0.28	0.37828 NS
stccrackavg	1.25	1.22	0.27	0.46017 NS

Note: iopitipavg=average IOPI tongue tip strength; iopidorsavg= average IOPI dorsum strength; Iopilipavg= average IOPI lip strength; mcbARMSavg= right masseter contraction baseline average; mcbBRMSavg= left masseter contraction baseline average; mcpud1ARMS=right masseter contraction for ½ tsp. pudding trial; mcpud1BRMS=left masseter contraction for ½ tsp. pudding trials; mcpud2ARMS= right masseter contraction for 1 ½ tsp. pudding trials; mcpud2BRMS= left masseter contractions for 1 ½ tsp pudding trials; mc10ccARMS= right masseter contraction for 10cc water trials; mc10ccBRMS= left masseter contraction for 10cc water trials; mccrackARMS= right masseter contraction for Triscuit cracker trials; mccrackBRMS= left masseter contraction for Triscuit cracker trials; stcpud1avg = average swallowing timing with contraction for ½ tsp pudding trials; stcpud2avg= average swallowing timing with contraction for 1 ½ tsp pudding; stc10ccavg= average swallowing timing with contraction for 10cc water trials; stccrackavg= average swallowing timing with contraction for Triscuit cracker trials.

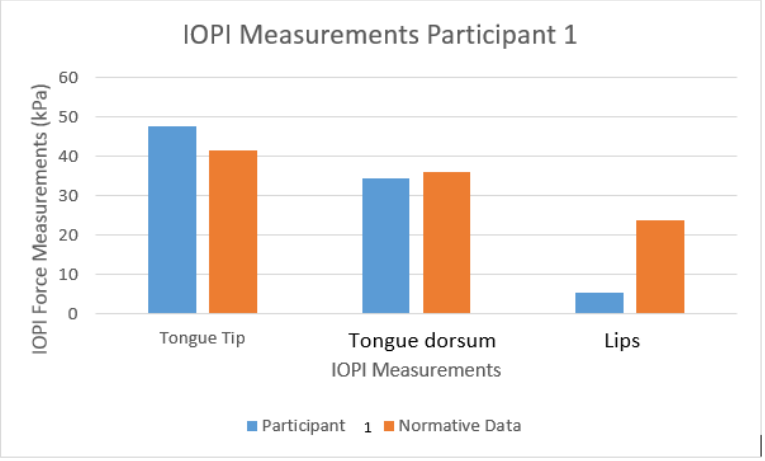

Figure 3.1. IOPI Measurements of Subject 1.

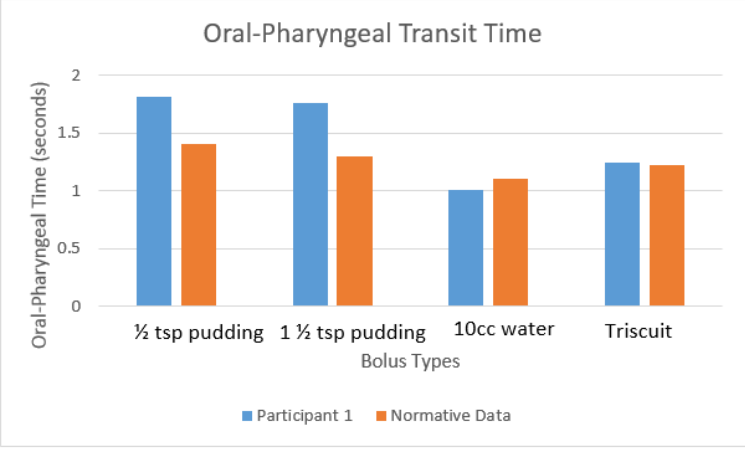

Figure 3.2. Oral-Pharyngeal Transit Time Participant 1

Subject 2

Subject 2 was a 14-year-old male diagnosed with tongue tie using the LFP. He participated as Group B order of presentation; LFP, EMG masseter strength, EMG swallowing measurements, and IOPI. All measurements were completed in one session.

Table 3.4 contains behavioral and clinical results for Subject 2. He demonstrated difficulty touching superior lip with the apex of the tongue, touching the right and left commissura labiorum, and touching his upper and lower molars. At rest his tongue was on the floor of his mouth. Examination of the tongue revealed the frenulum attached sublingually between the middle and the apex of the tongue and the mouth floor being visible from the inferior alveolar crest. His MOmax=38mm, MOtts=23mm. The ratio of MOmax and MOtts was 60% which is within normal limits but the function and appearance of his tongue indicate tongue tie. Furthermore, his results on the general test of the LFP was a 4/8 indicating an altered lingual frenulum.

Table 3.4. Behavioral/Clinical Indicators, Subject 2.

Indicators	Results
Ratio of MOmax and MOtts	60%
Mouth floor visible from inferior alveolar crest	Present
Sublingual frenulum attachment between the middle and apex of the tongue	Present, indicating an anterior point of attachment
General Test Results (A score equal or greater than 3 means the frenulum may be considered altered)	4/8 indicating the frenulum is altered
Touch the right and left commissura labiorum	Partially successful, tongue twisted
Touch the superior lip with the apex	Partially successful

Touch upper and lower molars with tongue	Partially successful
Tongue rest position on floor of mouth	Present

Data for each objective variable (EMG and IOPI trials) were compared with the Holzer (2011) normative data using z-scores (Table 3.5). As can be seen in this table, only the IOPI tip measurements differed from the norms. Similarly, all masseter contraction measures were significantly lower than the norms (note that two measures were anomalous and were excluded from the statistical calculations). No oropharyngeal timing measures were significantly longer than the norms. Table 3.5 presents the observable data for Subject 2 compared to Holzer (2011) norms. Subject 2 showed prolonged oral-pharyngeal transit times (Figure 3.4), but the differences were not significant (Data for the Triscuit swallow trials were not retrievable.) During swallow trials the results for bolus formation was an average of 5 indicating that the bolus was disorganized or scattered on the tongue. Results for presence of residue after deglutition was an average of 5 indicating a significant amount of residue. Conclusively, reduced masseter contractions, decreased bolus cohesion, reduced labial and tongue tip strength indicate an OMD.

Table 3.5. Observed Data, Subject 2.

Measurement	#2	Norms		Probability (<.05)
	Observed Mean	Mean	SD	
Iopitipavg	43	46.06	13.40	0.07353 NS
Iopidorsavg	41.33	41.28	13.2	0.49202 NS
Iopilipavg	10.33	32.45	15.61	0.00
mcbARMSavg	657.17	115.38	98.87	NA
mcbBRMSavg	652.46	107.31	96.34	NA
mcpud1ARMS	17.49	34.61	35.94	0.00

mcpud1BRMS	19.08	40.79	47.78	0.00
mcpud2ARMS	16.21	37.28	27.16	0.00
mcpud2BRMS	21.95	65.93	80.42	0.00
mc10ccARMS	16.76	112.75	307.34	0.00
mc10ccBRMS	20.47	200.28	340.03	0.00
mccrackARMS	26.78	108.13	117.34	0.00
mccrackBRMS	28.75	128.76	171.57	0.00
stcpud1avg	1.38	.97	.292	0.08692 NS
stcpud2avg	1.14	1.00	.329	0.33724 NS
stc10ccavg	1.03	.99	.298	0.44828 NS
stccrackavg	NA	1.00	.294	NA

Note: iopitipavg=average IOPI tongue tip strength; iopidorsavg= average IOPI dorsum strength; Iopilipavg= average IOPI lip strength; mcbARMSavg= right masseter contraction baseline average; mcbBRMSavg= left masseter contraction baseline average; mcpud1ARMS=right masseter contraction for ½ tsp. pudding trial; mcpud1BRMS=left masseter contraction for ½ tsp. pudding trials; mcpud2ARMS= right masseter contraction for 1 ½ tsp. pudding trials; mcpud2BRMS= left masseter contractions for 1 ½ tsp pudding trials; mc10ccARMS= right masseter contraction for 10cc water trials; mc10ccBRMS= left masseter contraction for 10cc water trials; mccrackARMS= right masseter contraction for Triscuit cracker trials; mccrackBRMS= left masseter contraction for Triscuit cracker trials; stcpud1avg = average swallowing timing with contraction for ½ tsp pudding trials; stcpud2avg= average swallowing timing with contraction for 1 ½ tsp pudding; stc10ccavg= average swallowing timing with contraction for 10cc water trials; stccrackavg= average swallowing timing with contraction for Triscuit cracker trials.

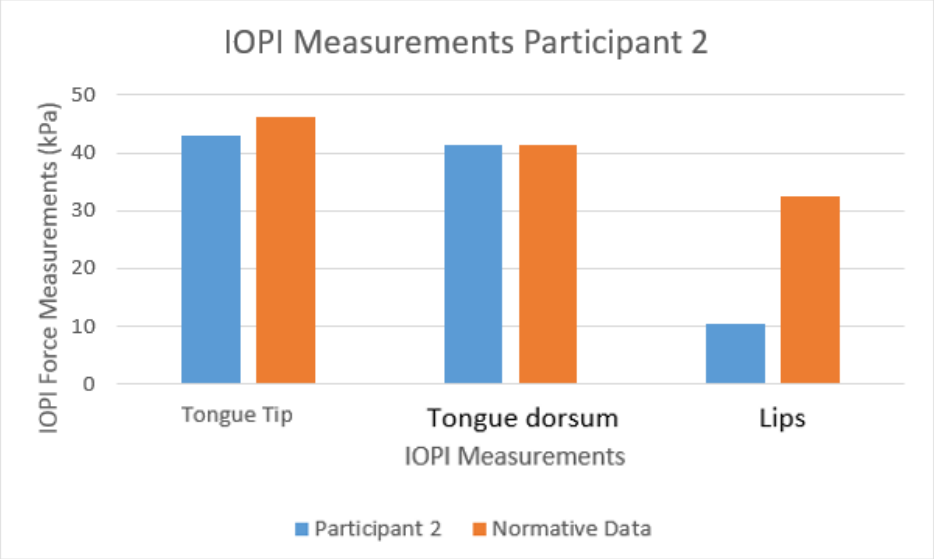

Figure 3.3. IOPI Measurements for Subject 2.

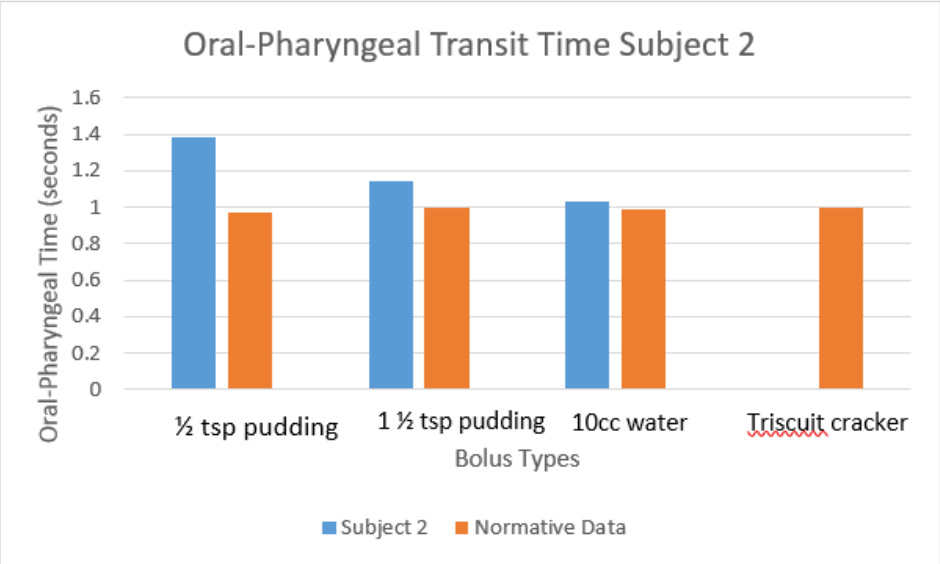

Figure 3.4. Oral-pharyngeal Transit Time Subject 2.

Subject 3

Subject 3 was a 13-year-old female diagnosed with tongue tie using the LFP. She participated as Group C order of presentation; LFP, EMG swallowing measurements, EMG masseter strength, and IOPI measurements. All measurements were completed in one session.

Table 3.6 reveals behavioral and clinical results for Subject 3. She demonstrated difficulty protruding and retracting her tongue and touching the right and left commissura labiorum with her tongue tip. Examination of the tongue and frenulum exposed a tongue tip that was oblong. Also, the frenulum attached sublingually at the apex of the tongue with the mouth floor being visible from the inferior alveolar crest. Her MOmax=39mm and MOtts=29mm. The ratio of MOmax and MOtts was 74%, which is within normal limits. Yet, the oblong tongue tip, sublingual attachment of the frenulum at the tip of the tongue and mouth floor being visible from the inferior alveolar crest all indicate tongue

tie. Overall the results of the general test of the LFP was a score of 5 indicating an altered lingual frenulum.

Table 3.6. Behavioral/Clinical Indicators Subject 3.

Indicators	Results
Ratio of MOmax and Motts	75%
Tip of tongue's shape	Oblong
Mouth floor visible from inferior alveolar crest	Present
Sublingual frenulum attachment at apex	Present, indicating an anterior point of attachment
General Test Results (A score equal or greater than 3 means the frenulum may be considered altered)	5/8 indicating the frenulum is altered
Protrude and retract	Partially successful, protrude barely past lip
Touch upper and lower molars with tongue	Partially successful

Data for each objective variable (EMG and IOPI trials) were compared with the Holzer (2011) normative data using z-scores (Table 3.7). As can be seen in this table, all IOPI measurements except lip strength were significantly lower than the norms. Similarly, all masseter contraction measures were significantly lower than the norms. Of the oropharyngeal transit measures, only the ½ tsp pudding bolus was significantly longer than the norms. Figure 3.5 reveals IOPI force was noticeably lower for tongue tip and dorsum strength and slightly lower for lip strength compared to the normative data. Figure 3.6 shows delayed oral-pharyngeal transit times during the swallow trials of ½ and 1 ½ teaspoons of pudding, and Triscuit crackers, although only the ½ tsp bolus reached significance. During swallowing trials the results for bolus formation was an average of 3 indicating that there was some evidence of cohesion of the bolus. Results for presence of residue after deglutition was an average of 3 indicating some evidence of residue. Tongue

protrusion was present in all trials. Overall, the reduced masseter contractions, decreased bolus cohesion, and reduced labial, tongue strength, and tongue protrusion indicate an OMD. The increased oral-pharyngeal transit time indicates risk of oral-pharyngeal dysphagia.

Table 3.7. Observed Data Subject 3.

Measurement	#3	Norms		
	Observed Mean	Mean	SD	Probability (p<.05)
Iopitipavg	16.67	46.06	13.40	0.00
Iopidorsavg	36.67	41.28	13.2	0.0139
Iopilipavg	31	32.45	15.61	0.26109 NS
mcbARMSavg	102.57	115.38	98.87	.04363
mcbBRMSavg	120.29	107.31	96.34	0.01101
mcpud1ARMS	26.5	34.61	35.94	0.00964
mcpud1BRMS	51.89	40.79	47.78	0.00272
mcpud2ARMS	30.61	37.28	27.16	0.00889
mcpud2BRMS	47.45	65.93	80.42	0.00018
mc10ccARMS	31.83	112.75	307.34	0.00
mc10ccBRMS	47.12	200.28	340.03	0.00
mccrackARMS	47.36	108.13	117.34	0.00
mccrackBRMS	100.73	128.76	171.57	0.0001
stcpud1avg	1.56	.97	.292	0.02938
stcpud2avg	1.35	1.00	.329	0.14457 NS
stc10ccavg	.99	.99	.298	.05 NS
stccrackavg	1.28	1.00	.294	0.05705 NS

Note: Probabilities indicated by dash (-) indicate variables that were significant but in the wrong direction for a one-tailed test. Note: iopitipavg=average IOPI tongue tip strength; iopidorsavg= average IOPI dorsum strength; Iopilipavg= average IOPI lip strength; mcbARMSavg= right masseter contraction baseline average; mcbBRMSavg= left masseter contraction baseline average; mcpud1ARMS=right masseter contraction for ½ tsp. pudding trial; mcpud1BRMS=left masseter contraction for ½ tsp. pudding trials; mcpud2ARMS= right masseter contraction for 1 ½ tsp. pudding trials; mcpud2BRMS= left masseter contractions for 1 ½ tsp pudding trials; mc10ccARMS= right masseter contraction for 10cc water trials; mc10ccBRMS= left masseter contraction for 10cc water trials; mccrackARMS= right masseter contraction for Triscuit cracker trials; mccrackBRMS= left masseter contraction for Triscuit cracker trials; stcpud1avg = average swallowing timing with contraction for ½ tsp pudding trials; stcpud2avg= average swallowing timing with contraction for 1 ½ tsp pudding; stc10ccavg= average

swallowing timing with contraction for 10cc water trials; stccrackavg= average swallowing timing with contraction for Triscuit cracker trials.

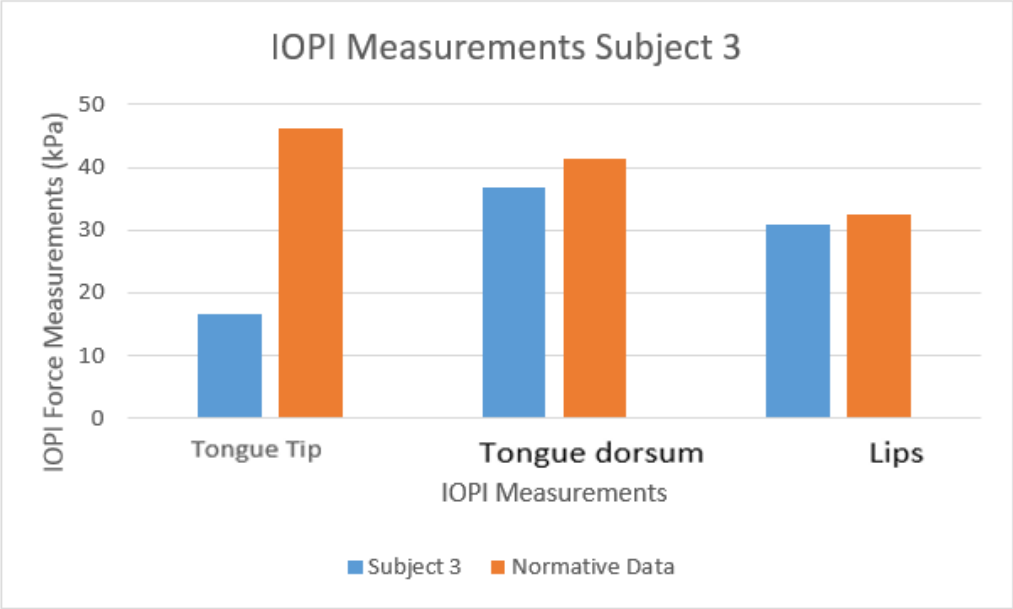

Figure 3.5. IOPI Measurements Subject 3.

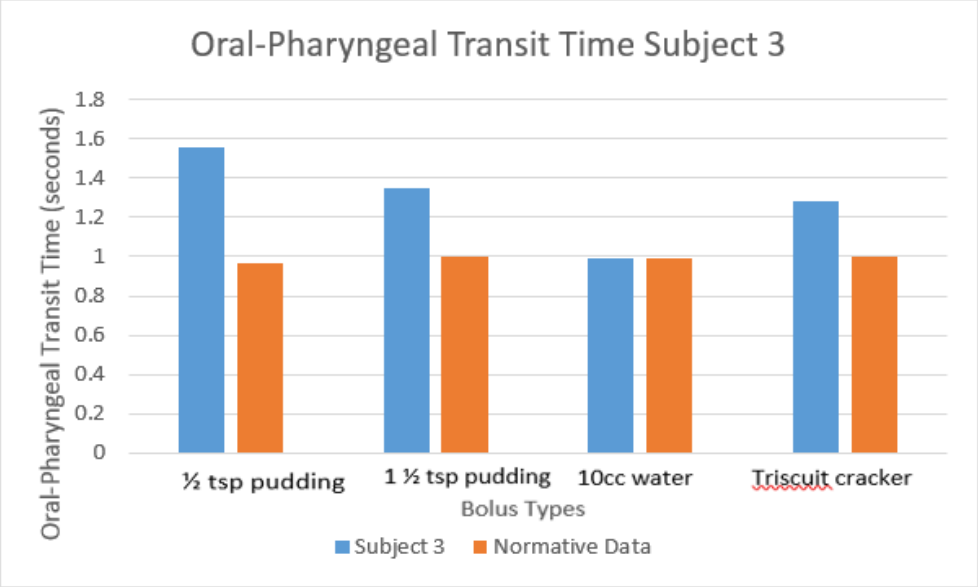

Figure 3.6. Oral-Pharyngeal Transit Time Subject 3.

Subject 4

Subject 4 was a 14-year-old male diagnosed with tongue tie using the LFP. He participated as Group A order of presentation; LFP, IOPI, EMG masseter strength, EMG swallowing measurements. All measurements were completed in one session.

In Table 3.8 the behavioral and clinical results for Subject 4 are presented. He demonstrated difficulty protruding and retracting his tongue and touching the right and left commissura labiorum. During the speech sample his mouth opening was reduced. Examination of the tongue and frenulum exposed a tongue tip that was oblong with the frenulum attached sublingually between the middle and the apex of the tongue. In addition, the mouth floor was visible from the inferior alveolar crest. His MOmax = 50 mm and Motts = 35 mm with a difference in percent of 70% which is within normal limits. Yet, observations of his tongue function and anatomy indicated tongue tie. Furthermore, his results on the general test of the LFP was a score of 4 indicating an altered lingual frenulum.

Table 3.8. Behavioral/Clinical Indicators Subject 4.

Indicators	Results
Ratio of MOtts / MOmax	70%
Mouth floor visible from inferior alveolar crest	Present
Tip of the tongue's shape	Oblong
Sublingual frenulum attachment between the middle and apex of the tongue	Present, indicating an anterior point of attachment
General Test Results (A score equal or greater than 3 means the frenulum may be considered altered)	4/8 indicating the frenulum is altered
Touch the right and left commissura labiorum	Partially successful, tongue twisted
Protrude and retract	Partially successful
Mouth opening during speech	Reduced

Data for each objective variable (EMG and IOPI trials) were compared with the Holzer (2011) normative data using z-scores (Table 3.9). As can be seen in this table, all IOPI measurements except tongue tip strength were significantly lower than the norms. Similarly, all masseter contraction measures were significantly lower than the norms. No oropharyngeal timing measures reached statistical significance. Figures 3.6 and 3.7 display the IOPI measurements and oral-pharyngeal transit times, respectively. IOPI force was noticeably lower for lip strength and slightly lower for tongue dorsum strength compared to the normative data (see Figure 3.7). Delayed oral-pharyngeal transit times were present in all swallow trials, as shown in Figure 3.8. During swallow trials the results for bolus formation was a mode of 5 indicating that the bolus was disorganized or scattered on the tongue. Results for presence of residue after deglutition was an average of 1 indicating minimal or no residue. A double swallow was recorded by EMG during trials of 1 ½ tsp pudding. The EMG revealed double swallows and preparatory swallows. Tongue protrusion during deglutition was present in all but one trial. Subject 4 demonstrated preparatory swallows and double swallows during many of the swallow trials. He also presented with tension in the neck during deglutition. Overall, the reduced masseter contractions, decreased bolus cohesion, reduced labial and dorsum strength, neck tension, and tongue protrusion are indictors of an OMD. Along with this, the trend toward increased oral-pharyngeal transit time, and presence of preparatory swallows and double swallows are an indicator of oral-pharyngeal dysphagia.

Table 3.9. Observed Data Subject 4.

Measurement	#4	Norms		
	Observed Mean	Mean	SD	Probability ($p<.05$)
Iopitipavg	48.33	46.06	13.40	0.14231 NS

Iopidorsavg	37.33	41.28	13.2	0.03005
Iopilipavg	12	32.45	15.61	0.00
mcbARMSavg	126.9	115.38	98.87	--
mcbBRMSavg	218.51	107.31	96.34	-
mcpud1ARMS	8.72	34.61	35.94	0.00
mcpud1BRMS	8.05	40.79	47.78	0.00
mcpud2ARMS	11.46	37.28	27.16	0.00
mcpud2BRMS	14.86	65.93	80.42	0.00
mc10ccARMS	8.37	112.75	307.34	0.00
mc10ccBRMS	9.33	200.28	340.03	0.00
mccrackARMS	50.61	108.13	117.34	0.00
mccrackBRMS	120.90	128.76	171.57	0.14917 NS
stcpud1avg	1.41	.97	.292	0.07927 NS
stcpud2avg	1.04	1.00	.329	45224 NS
stc10ccavg	1.05	.99	.298	0.42465 NS
Stccrackavg	1.29	1.00	.294	0.17619 NS

Note: Probabilities indicated by dash (-) indicate variables that were significant but in the wrong direction for a one-tailed test. Note: iopitipavg=average IOPI tongue tip strength; iopidorsavg= average IOPI dorsum strength; Iopilipavg= average IOPI lip strength; mcbARMSavg= right masseter contraction baseline average; mcbBRMSavg= left masseter contraction baseline average; mcpud1ARMS=right masseter contraction for ½ tsp. pudding trial; mcpud1BRMS=left masseter contraction for ½ tsp. pudding trials; mcpud2ARMS= right masseter contraction for 1 ½ tsp. pudding trials; mcpud2BRMS= left masseter contractions for 1 ½ tsp pudding trials; mc10ccARMS= right masseter contraction for 10cc water trials; mc10ccBRMS= left masseter contraction for 10cc water trials; mccrackARMS= right masseter contraction for Triscuit cracker trials; mccrackBRMS= left masseter contraction for Triscuit cracker trials; stcpud1avg = average swallowing timing with contraction for ½ tsp pudding trials; stcpud2avg= average swallowing timing with contraction for 1 ½ tsp pudding; stc10ccavg= average swallowing timing with contraction for 10cc water trials; stccrackavg= average swallowing timing with contraction for Triscuit cracker trials.

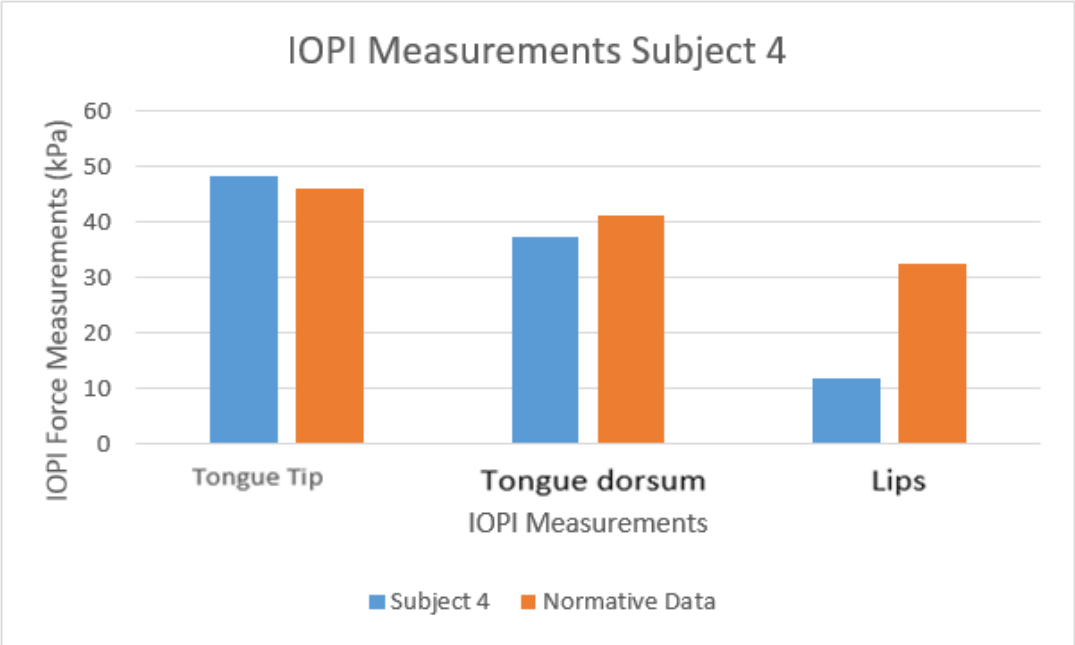

Figure 3.7. IOPI Measurements Subject 4.

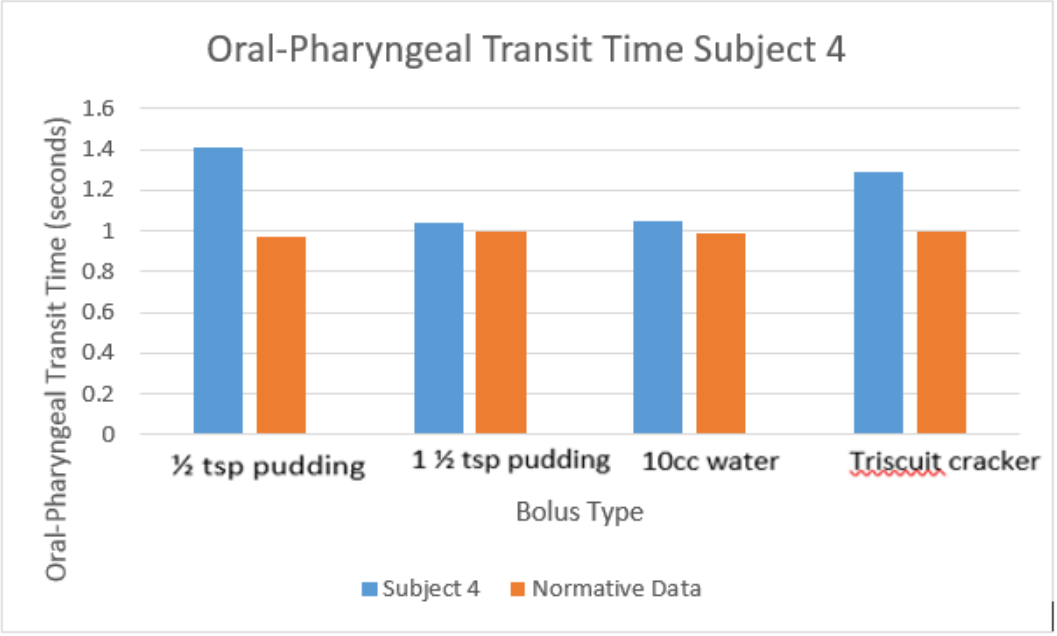

Figure 3.8. Oral-Pharyngeal Transit Time Subject 4.

Subject 5

Subject 5 was a 17-year-old female diagnosed with tongue tie using the LFP. She participated as Group B order of presentation; LFP, EMG masseter strength, EMG swallowing measurements, and IOPI. All measurements were completed in one session.

Table 3.10 contains behavioral and clinical results for Subject 5. She demonstrated difficulty touching the right and left commissura labiorum. Her tongue resting posture was with the tongue protruding between the teeth which is an abnormal resting posture. Examination of the tongue and frenulum exposed a tongue tip that was oblong and the mouth floor was visible from the inferior alveolar crest. Her MOmax=51 mm and MOtts=19 mm. The ratio of MOtts to MOmax was 37% indicting a significant tongue tie. Her score for the general test on the LFP was 4 indicating an altered lingual frenulum.

Table 3.10. Behavioral/Clinical Indicators Subject 5.

Indicators	Results
Ratio of MOmax and MOtts	37%, a ratio less than 50% indicates a tongue-tie
Mouth floor visible from inferior alveolar crest	Present
Tip of the tongue's shape	Oblong
General Test Results (A score equal or greater than 3 means the frenulum may be considered altered)	4/8 indicating the frenulum is altered
Touch the right and left commissura labiorum	Partially successful, tongue twisted
Tongue resting posture	Protrudes between teeth

Data for each objective variable (EMG and IOPI trials) were compared with the Holzer (2011) normative data using z-scores (Table 3.11). As can be seen in this table, IOPI tongue measurements were significantly lower than the norms, while lip strength

was within norm limits. Similarly, all masseter contraction measures except one of the pudding measures were significantly lower than the norms. No oropharyngeal timing measures reached statistical significance. Figure 3.9 presents that IOPI force was noticeably lower for all IOPI measurements compared to the normative data, although lip force did not reach significance. Figure 3.10 reveals that Subject 5 showed a trend toward prolonged oral-pharyngeal transit times during all swallowing trials. In seven out of nine swallowing trials, her tongue protruded forward. Her bolus cohesion was a score of 1 meaning an organized ball and minimal to no residue after the swallow. Overall, the reduced masseter contractions, protruding tongue during swallowing, and reduced labial and tongue strength indicate an OMD. The trend toward prolonged oral-pharyngeal transit time indicates risk for oral-pharyngeal dysphagia.

Table 3.11. Observed Data Subject 5.

Measurement	# 5	Norms		
	Observed Mean	Mean	SD	Probability (p<.05)
Iopitipavg	32	46.06	13.40	0.00
Iopidorsavg	25.33	41.28	13.2	0.00
Iopilipavg	7	32.45	15.61	0.41683 NS
mcbARMSavg	282.93	115.38	98.87	-
mcbBRMSavg	172.65	107.31	96.34	-
mcpud1ARMS	35.25	34.61	35.94	0.42858 NS
mcpud1BRMS	22.38	40.79	47.78	0.00
mcpud2ARMS	64.2	37.28	27.16	-
mcpud2BRMS	29.01	65.93	80.42	0.00
mc10ccARMS	8.37	112.75	307.34	0.00
mc10ccBRMS	9.33	200.28	340.03	0.00
mccrackARMS	50.61	108.13	117.34	0.00
mccrackBRMS	120.90	128.76	171.57	0.14917 NS
stcpud1avg	1.22	.97	.292	0.21186 NS
stcpud2avg	1.11	1.00	.329	0.3707 NS
stc10ccavg	1.24	.99	.298	0.21476 NS
stccrackavg	1.33	1.00	.294	0.14686 NS

Note: Probabilities indicated by dash (-) indicate variables that were significant but in the wrong direction for a one-tailed test. Note: iopitipavg=average IOPI tongue tip strength; iopidorsavg= average IOPI dorsum strength; Iopilipavg= average IOPI lip strength; mcbARMSavg= right masseter contraction baseline average; mcbBRMSavg= left masseter contraction baseline average; mcpud1ARMS=right masseter contraction for ½ tsp. pudding trial; mcpud1BRMS=left masseter contraction for ½ tsp. pudding trials; mcpud2ARMS= right masseter contraction for 1 ½ tsp. pudding trials; mcpud2BRMS= left masseter contractions for 1 ½ tsp pudding trials; mc10ccARMS= right masseter contraction for 10cc water trials; mc10ccBRMS= left masseter contraction for 10cc water trials; mccrackARMS= right masseter contraction for Triscuit cracker trials; mccrackBRMS= left masseter contraction for Triscuit cracker trials; stcpud1avg = average swallowing timing with contraction for ½ tsp pudding trials; stcpud2avg= average swallowing timing with contraction for 1 ½ tsp pudding; stc10ccavg= average swallowing timing with contraction for 10cc water trials; stccrackavg= average swallowing timing with contraction for Triscuit cracker trials.

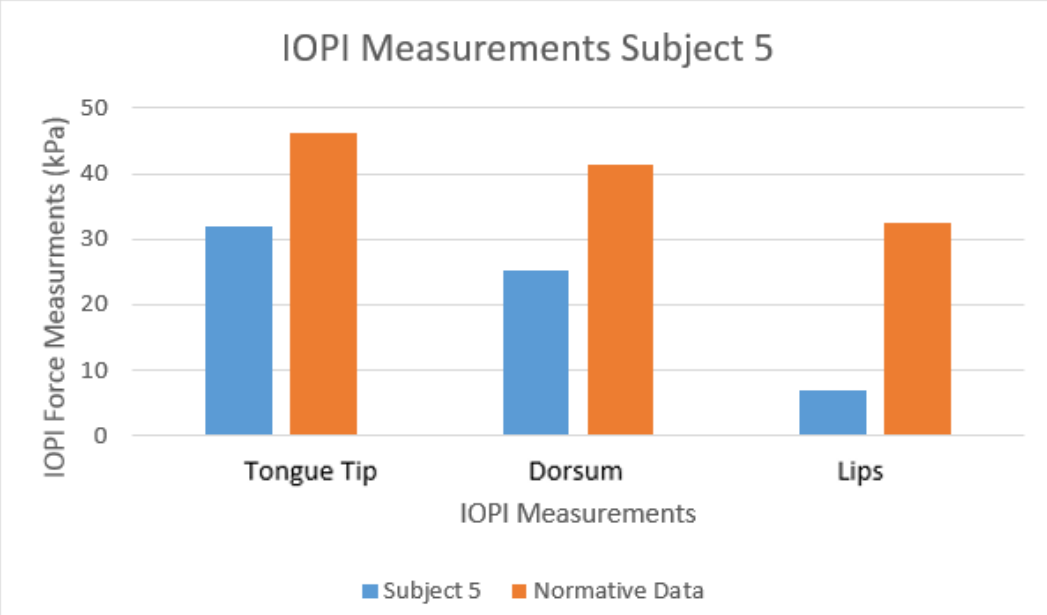

Figure 3.9. IOPI Measurements Subject 5.

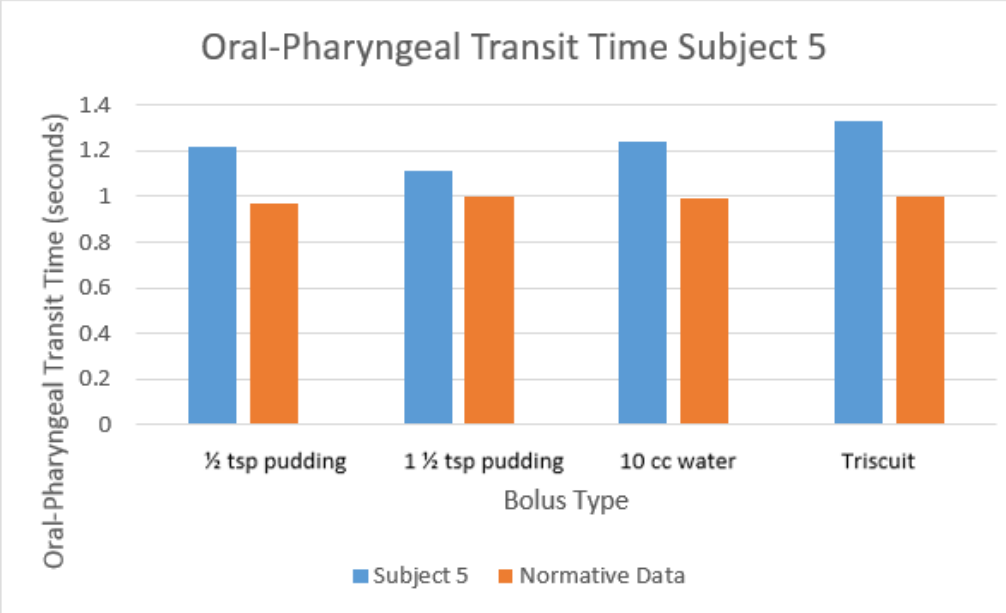

Figure 3.10. Oral-Pharyngeal Transit Time Subject 5.

Subject 6

Subject 6 was a 43-year-old female diagnosed with tongue tie using the LFP. She is diagnosed with Multiple Scleiosis but is in remission. She participated as Group C order of presentation; LFP, EMG swallowing measurements, EMG masseter strength, IOPI measurements. All measurements were completed in one session.

Table 3.12 presents behavioral and clinical results for Subject 6. She demonstrated difficulty touching her superior lip with the apex of her tongue, she had to use her jaw to achieve task. Examination of the tongue and frenulum exposed a tongue tip that was oblong with the frenulum attached sublingually between the middle and the apex of the tongue. Also, the mouth floor was visible from the inferior alveolar crest. Her MOmax=54 mm and MOtts=20mm. The ratio of MOtts and MOmax was 37% which

indicates tongue tie. Overall the result of the general test of the LFP was a score of 5 indicating an altered lingual frenulum.

Table 3.12. Behavioral/Clinical Indicators Subject 6.

Indicators	Results
Ratio of MOmax and MOtts	37%, a ratio less than 50% indicates a tongue-tie
Mouth floor visible from inferior alveolar crest	Present
Sublingal attachment of tongue	Between the middle and apex of the tongue
Tip of the tongue's shape	Oblong
General Test Results (A score equal or greater than 3 means the frenulum may be considered altered)	5/8 indicating the frenulum is altered
Touch the superior lip with the apex of the tongue	Partially successful, used jaw to achieve

Data for each objective variable (EMG and IOPI trials) were compared with the Holzer (2011) normative data using z-scores (Table 3.13). As can be seen in this table, no IOPI measurements were significantly lower than the norms. Similarly, 5 out of 10 masseter contraction measures were significantly lower than the norms, although, interestingly, 5 more (overall mean, two pudding measures and one water measure) were significantly greater than the mean. Because a one-tailed test was conducted these measures were rejected. All oropharyngeal timing measures reached statistical significance except the 10 cc water bolus. Figure 3.11 reveals the trend for IOPI force to be lower for all IOPI measurements compared to the normative data, while Figure 3.12 shows a similar trend for oral-pharyngeal transit times during all swallowing trials. Results of bolus cohesion revealed an average of 2.33 indicating some evidence of cohesion with scattering of the bolus. No tongue protrusion was witnessed during

swallowing. After the swallow, minimal to no residue was seen. Overall, the increased oral-pharyngeal transit time indicates risk for oral-pharyngeal dysphagia.

Table 3.13. Objective Data for Subject 6.

Measurement	#6	Norms		
	Observed Mean	Mean	SD	Probability (p<.05
Iopitipavg	40.67	44.45	14.34	0.08364 NS
Iopidorsavg	38	39.65	16.97	0.6672 NS
Iopilipavg	19.33	20.18	8.99	0.62414 NS
mcbARMSavg	256.39	140.73	144.27	
mcbBRMSavg	187.09	137.13	119.97	-
mcpud1ARMS	36.68	50.36	73.84	0.00578
mcpud1BRMS	80.27	51.35	53.99	
mcpud2ARMS	27.12	51.22	73.69	0.00
mcpud2BRMS	85	42.05	37.33	-
mc10ccARMS	22.55	41.24	70.49	0.00012
mc10ccBRMS	87.133	35.2	33.07	-
mccrackARMS	42.73	153.02	158.22	0.00
mccrackBRMS	148.02	157.41	166.40	0.20766 NS
stcpud1avg	1.81	1.18	.297	0.0455
stcpud2avg	1.64	1.15	.16	0.034
stc10ccavg	1.27	1.09	.14	0.40654 NS
stccrackavg	1.72	1.15	.18	0.0198

Note: Probabilities indicated by dash (-) indicate variables that were significant but in the wrong direction for a one-tailed test. Note: iopitipavg=average IOPI tongue tip strength; iopidorsavg= average IOPI dorsum strength; Iopilipavg= average IOPI lip strength; mcbARMSavg= right masseter contraction baseline average; mcbBRMSavg= left masseter contraction baseline average; mcpud1ARMS=right masseter contraction for ½ tsp. pudding trial; mcpud1BRMS=left masseter contraction for ½ tsp. pudding trials; mcpud2ARMS= right masseter contraction for 1 ½ tsp. pudding trials; mcpud2BRMS= left masseter contractions for 1 ½ tsp pudding trials; mc10ccARMS= right masseter contraction for 10cc water trials; mc10ccBRMS= left masseter contraction for 10cc water trials; mccrackARMS= right masseter contraction for Triscuit cracker trials; mccrackBRMS= left masseter contraction for Triscuit cracker trials; stcpud1avg = average swallowing timing with contraction for ½ tsp pudding trials; stcpud2avg= average swallowing timing with contraction for 1 ½ tsp pudding; stc10ccavg= average swallowing timing with contraction for 10cc water trials; stccrackavg= average swallowing timing with contraction for Triscuit cracker trials.

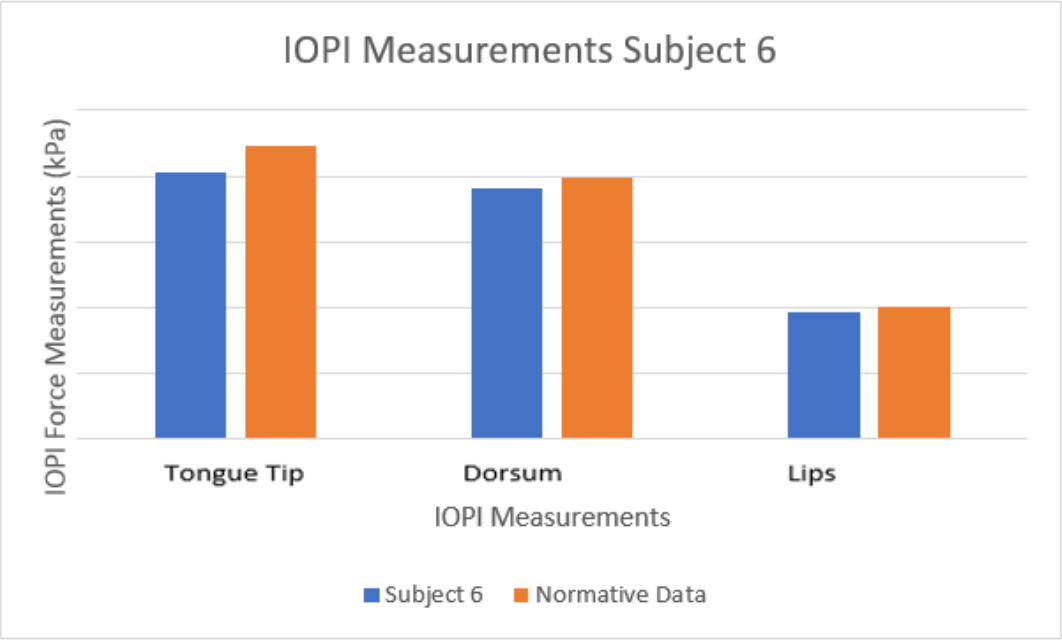

Figure 3.11. IOPI Measurements Subject 6.

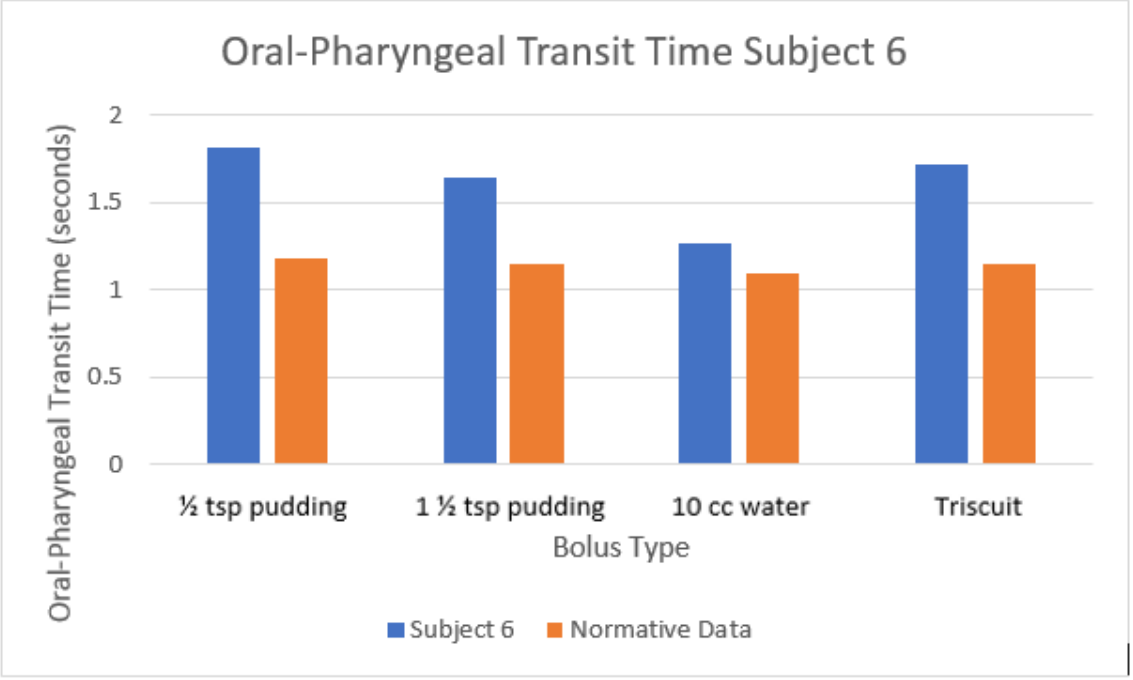

Figure 3.12. Oral-Pharyngeal Transit Time Subject 6.

Subject 7

Subject 7 was a 34-year-old female diagnosed with tongue tie using the LFP. She participated in Group A order of presentation; LFP, IOPI, EMG masseter strength, and EMG swallowing measurements. All measurements were completed in one session.

Table 3.14 presents behavioral and clinical results for Subject 7. She demonstrated difficulty touching the tongue to the right and left commissura labiorum, with her tongue tip twisting. Examination of the tongue and frenulum exposed a tongue tip that was oblong with the frenulum attached sublingually between the middle and the apex of the tongue. Her MOmax=41 mm and MOtts=29mm. The ratio of MOtts and MOmax was 70%, which is within normal limits. Yet, the oblong tongue tip and sublingual attachment between the middle and apex of the tongue resulted in a general score of 3 which indicates tongue tie.

Table 3.14. Behavioral/Clinical Indicators Subject 7.

Indicators	Results
Ratio MOtts and MOmax	70%
Sublingual attachment of tongue	Between the middle and apex of the tongue
Tip of the tongue's shape	Oblong
General Test Results (A score equal or greater than 3 means the frenulum may be considered altered)	3/8 indicating the frenulum is altered
Touch the right and left commissura labiorum	Partially successful

Data for each objective variable (EMG and IOPI trials) were compared with the Holzer (2011) normative data using z-scores (Table 3.15). As can be seen in this table, all IOPI and masseter activity measures were significantly below the norms. No oropharyngeal timing measures reached statistical significance. Figure 3.13 reveals IOPI

force was noticeably lower for all IOPI measurements compared to the normative data. Similarly, Figure 3.14 shows oral-pharyngeal transit times that are predominantly shorter than the normative data. In four out of nine swallowing trials, Subject 7 had her tongue protrude forward. Overall, the reduced masseter contractions, tongue protruding during swallowing, and reduced labial and tongue strength indicate an OMD. Oral-pharyngeal dysphagia is not indicated by the oral-pharyngeal transit times.

Table 3.15. Objective Data Subject 7.

Measurement	#7	Norms		
	Observed Mean	Mean	SD	Probability (p<.05)
Iopitipavg	22.33	40.93	12.77	0.00
Iopidorsavg	15	49.29	11.97	0.00
Iopilipavg	19.67	24.04	12.34	0.03156
mcbARMSavg	172.06	268.25	220.33	0.00
mcbBRMSavg	137.82	291.51	276.32	0.00
mcpud1ARMS	33.23	76.80	86.84	0.00
mcpud1BRMS	32.85	83.51	93.91	0.00
mcpud2ARMS	19.94	91.31	94.19	0.00
mcpud2BRMS	19.27	107.31	132.97	0.00
mc10ccARMS	10.49	34.75	33.54	0.00
mc10ccBRMS	12.75	25.19	38.8	0.00054
mccrackARMS	28.71	168.12	149.93	0.00
mccrackBRMS	29.31	183.53	200.56	0.00
stcpud1avg	1.37	1.41	.48	0.92034 NS
stcpud2avg	.94	1.43	.60	0.30302 NS
stc10ccavg	.78	1.22	.495	0.28014 NS
stccrackavg	.80	1.29	.49	0.22628 NS

Note: iopitipavg=average IOPI tongue tip strength; iopidorsavg= average IOPI dorsum strength; Iopilipavg= average IOPI lip strength; mcbARMSavg= right masseter contraction baseline average; mcbBRMSavg= left masseter contraction baseline average; mcpud1ARMS=right masseter contraction for ½ tsp. pudding trial; mcpud1BRMS=left masseter contraction for ½ tsp. pudding trials; mcpud2ARMS= right masseter contraction for 1 ½ tsp. pudding trials; mcpud2BRMS= left masseter contractions for 1 ½ tsp pudding trials; mc10ccARMS= right masseter contraction for 10cc water trials; mc10ccBRMS= left masseter contraction for 10cc water trials; mccrackARMS= right masseter contraction for Triscuit cracker trials; mccrackBRMS= left masseter contraction for Triscuit cracker trials; stcpud1avg = average swallowing timing with contraction for ½ tsp pudding trials; stcpud2avg= average swallowing timing with contraction for 1 ½

tsp pudding; stc10ccavg= average swallowing timing with contraction for 10cc water trials; stccrackavg= average swallowing timing with contraction for Triscuit cracker trials.

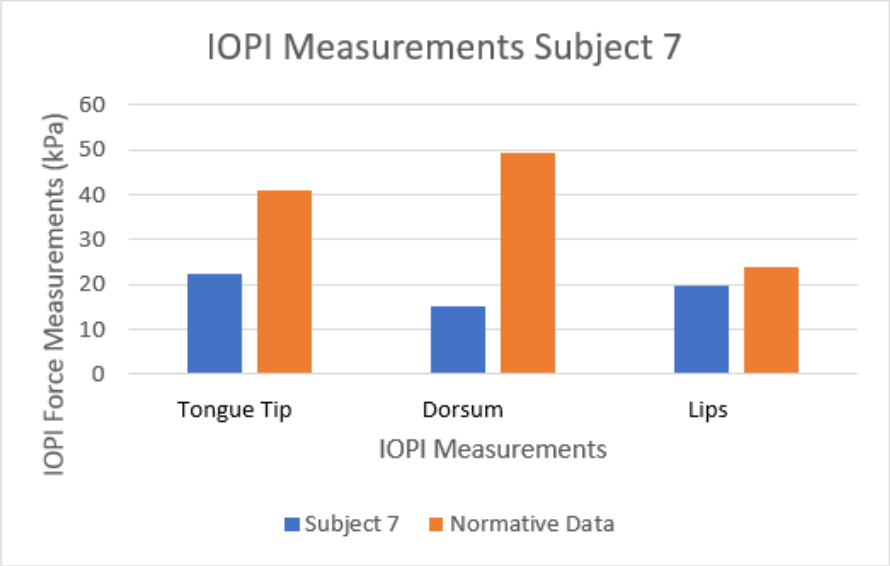

Figure 3.13. IOPI Measurements Subject 7.

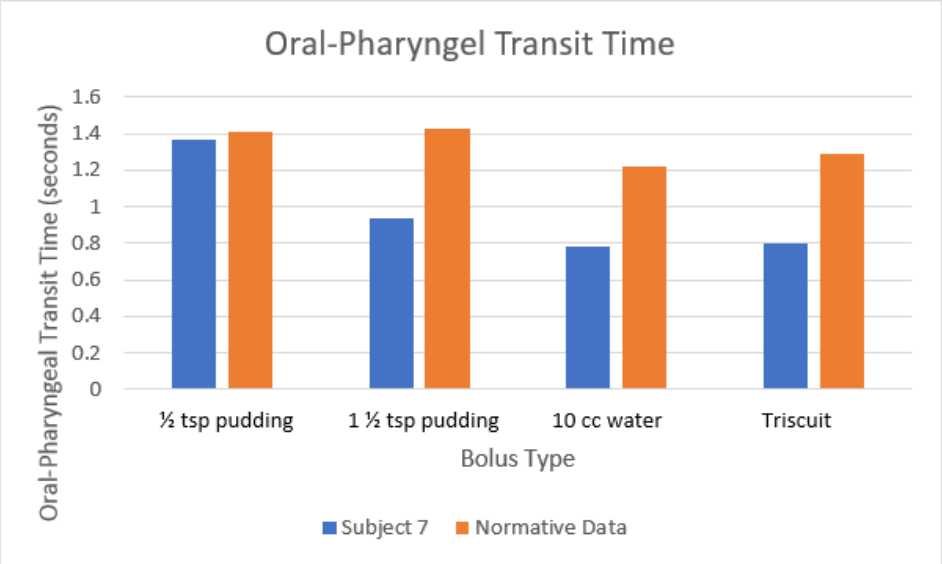

Figure 3.14. Oral-Pharyngeal Transit Time Subject 7.

Subject 8

Subject 8 was a 12-year-old male diagnosed with tongue tie using the LFP. He participated in Group B order of presentation; LFP, EMG masseter measurements, EMG swallowing trials, IOPI measurements. All measurements were completed in one session.

Table 3.16 presents behavioral and clinical results for Subject 8. He demonstrated difficulty touching his superior lip with the apex of the tongue and touching the right and left commissura labiorum. His tongue posture during rest was on the floor of the mouth. During the speech sample he exhibited an initial lateral /s/. Examination of the tongue and frenulum exposed a tongue tip that was oblong and heart shaped with the frenulum attached sublingually between the middle and the apex of the tongue. Also, the mouth floor was visible from the inferior alveolar crest. His MOmax=46 mm and MOtts=21mm. The ratio of MOtts and MOmax was 46% which indicates tongue tie. Overall the result of the general test of the LFP was a score of 7 indicating an altered lingual frenulum.

Table 3.16. Behavioral/Clinical Indicators Subject 8.

Indicators	Results
Ratio of MOmax and MOtts	46%, a ratio less than 50% indicates a tongue-tie
Tip of the tongue's shape	Oblong and heart shape
Mouth floor visible from inferior alveolar crest	Present
Sublingal attachment of tongue	Between the middle and apex of the tongue
General Test Results (A score equal or greater than 3 means the frenulum may be considered altered)	7/8 indicating the frenulum is altered
Touch the right and left commissura labiorum with the tongue	Partially successful
Touch the superior lip with the apex of the tongue	Partially successful

Speech sample	Initial lateral /s/
Tongue position during rest	On floor of mouth

Data for each objective variable (EMG and IOPI trials) were compared with the Holzer (2011) normative data using z-scores (Table 3.17). As can be seen in this table, all IOPI measurements were significantly lower than the norms, with the exception of the lip measure. Notably, this measure was significantly greater than the norms, but because the z-test was one-tailed the results are disregarded. All masseter contraction measures were significantly reduced relative to the norms. No oropharyngeal timing measures reached statistical significance. Figure 3.15 displays the differences in IOPI force measures relative to the norms, while Figure 3.16 shows a trend toward prolonged oral-pharyngeal transit times during swallowing trials. Tongue protrusion during deglutition was exhibited in 9/9 trials. Overall, the reduced masseter contractions, tongue protrusion during swallowing, and reduced labial and tongue strength indicate an OMD. The increased oral-pharyngeal transit time indicates increased risk for oral-pharyngeal dysphagia.

Table 3.17. Objective Data Subject 8.

Measurement	#8	Norms		
	Observed Mean	Mean	SD	Probability (P<.05)
Iopitipavg	21	45.45	14.59	0.00
Iopidorsavg	16.33	42.74	12.74	0.00
Iopilipavg	22.67	17.73	5.63	-
mcbARMSavg	87.56	300.67	179.32	0.00
mcbBRMSavg	126.36	241	144.63	0.00
mcpud1ARMS	23.24	142.84	137.03	0.00
mcpud1BRMS	29.73	123.16	99.49	0.00
mcpud2ARMS	21.63	166.93	187.24	0.00
mcpud2BRMS	33.18	170.48	206.93	0.00
mc10ccARMS	19.22	135.18	117.05	0.00

mc10ccBRMS	24.21	140.72	127.32	0.00
mccrackARMS	14.48	225.39	184.33	0.00
mccrackBRMS	15.51	193.68	175.35	0.00
stcpud1avg	1.03	.96	.12	0.15272 NS
stcpud2avg	.94	.99	.08	0.75656 NS
stc10ccavg	.92	.82	.10	0.58232 NS
stccrackavg	1.00	1.03	.08	0.85716 NS

Note: Probabilities indicated by dash (-) indicate variables that were significant but in the wrong direction for a one-tailed test. Note: iopitipavg=average IOPI tongue tip strength; iopidorsavg= average IOPI dorsum strength; Iopilipavg= average IOPI lip strength; mcbARMSavg= right masseter contraction baseline average; mcbBRMSavg= left masseter contraction baseline average; mcpud1ARMS=right masseter contraction for ½ tsp. pudding trial; mcpud1BRMS=left masseter contraction for ½ tsp. pudding trials; mcpud2ARMS= right masseter contraction for 1 ½ tsp. pudding trials; mcpud2BRMS= left masseter contractions for 1 ½ tsp pudding trials; mc10ccARMS= right masseter contraction for 10cc water trials; mc10ccBRMS= left masseter contraction for 10cc water trials; mccrackARMS= right masseter contraction for Triscuit cracker trials; mccrackBRMS= left masseter contraction for Triscuit cracker trials; stcpud1avg = average swallowing timing with contraction for ½ tsp pudding trials; stcpud2avg= average swallowing timing with contraction for 1 ½ tsp pudding; stc10ccavg= average swallowing timing with contraction for 10cc water trials; stccrackavg= average swallowing timing with contraction for Triscuit cracker trials.

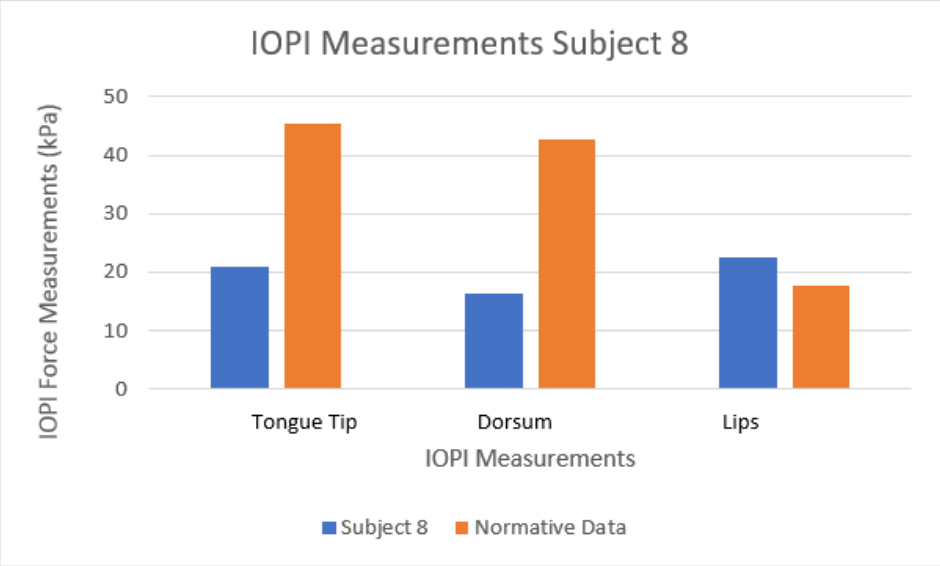

Figure 3.15. IOPI Measurements Subject 8.

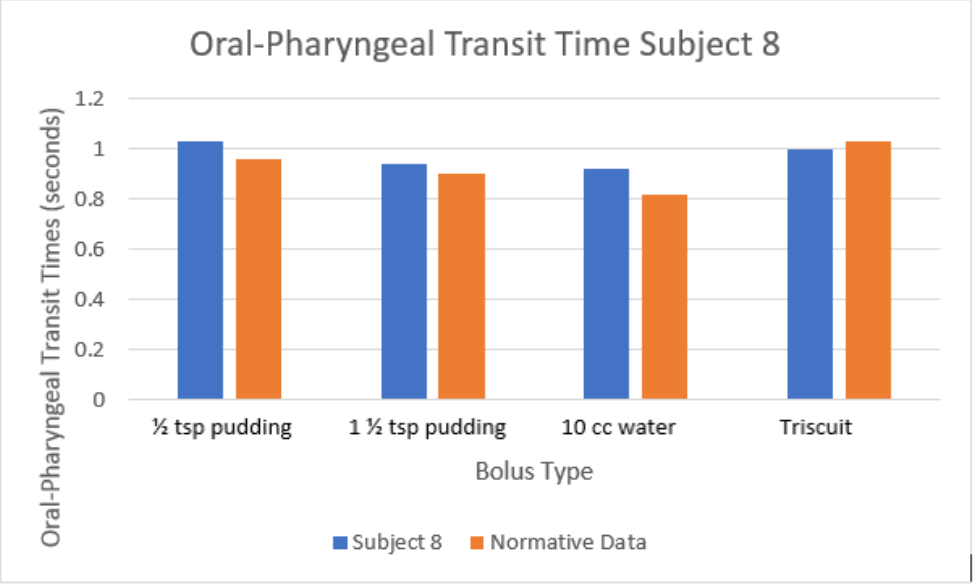

Figure 3.16. Oral-Pharyngeal Transit Time Subject 8.

Group Trends

Group data for IOPI tip, dorsum, and lip measurements are compared to normative data in Figures 3.17, 3.18, and 3.19 respectively, as arrayed by tongue tie coefficient (note that larger coefficients denote more severe tongue tie). With some exceptions, overall, as tongue tie severity increased the ability to generate tongue force decreases when compared to individuals of the same age, without tongue tie.

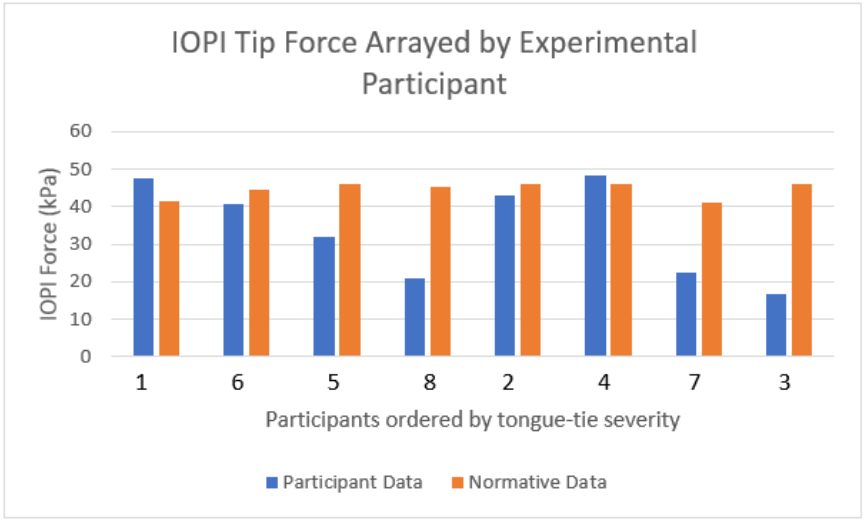

Figure 3.17. IOPI Tongue Tip Comparison by Severity of Tongue Tie to Normative Data.

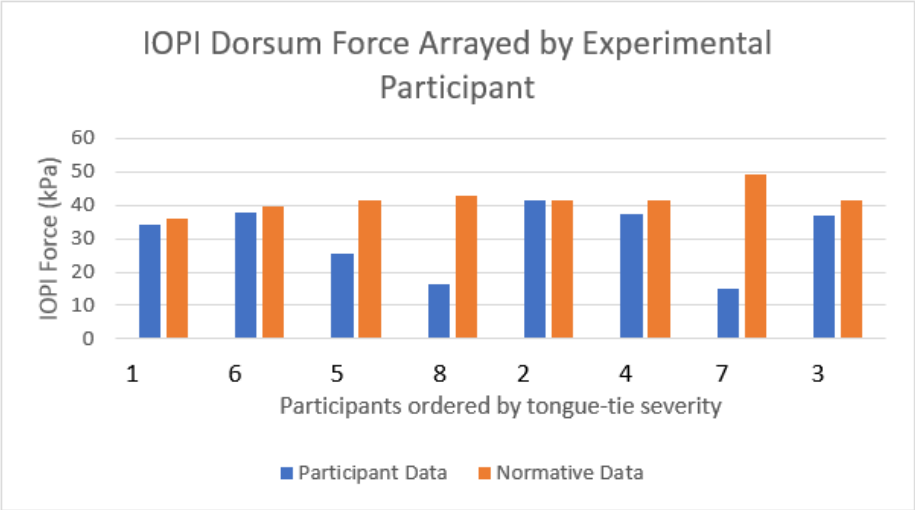

Figure 3.18. IOPI Tongue Dorsum Comparison by Severity of Tongue Tie to Normative Data.

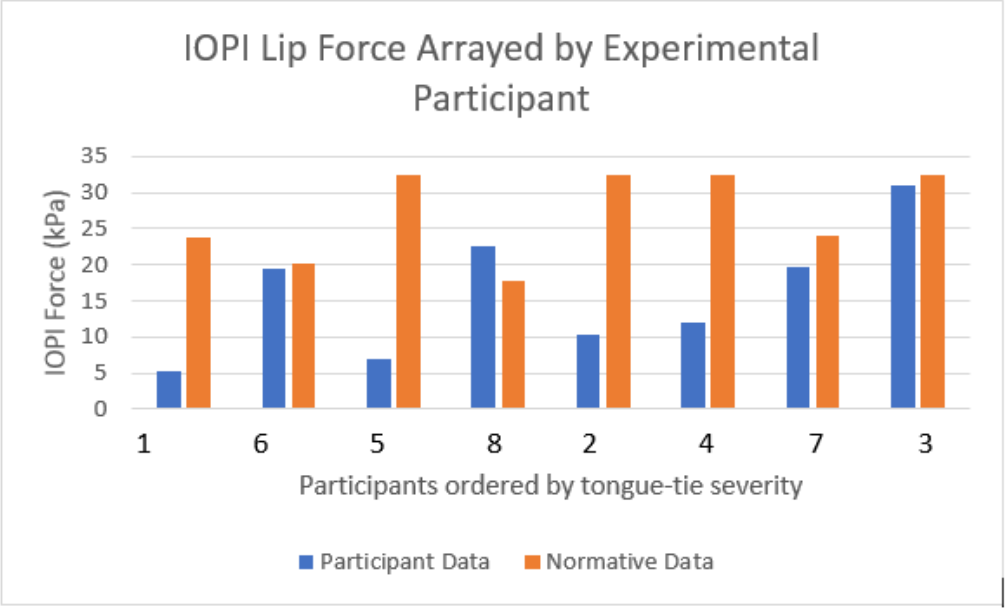

Figure 3.19. IOPI Lips Comparison by Severity of Tongue Tie to Normative Data.

Group comparison of oral-pharyngeal transit times for ½ tsp pudding, 1 ½ tsp pudding, 10 cc water, and Triscuit crackers to normative data are shown in Figures 3.20,

3.21, 3.22, 3.23 respectively arrayed by tongue tie coefficient. For ½ tsp of pudding all but one participant exhibited increased (but non-significant) oral-pharyngeal transit time. For 1 ½ tsp of pudding and 10 cc of water, five out of eight participants demonstrated increased oral-pharyngeal transit time. In the Triscuit cracker trials five out of seven participants had increased oral-pharyngeal transit time (one participant's results did not save correctly).

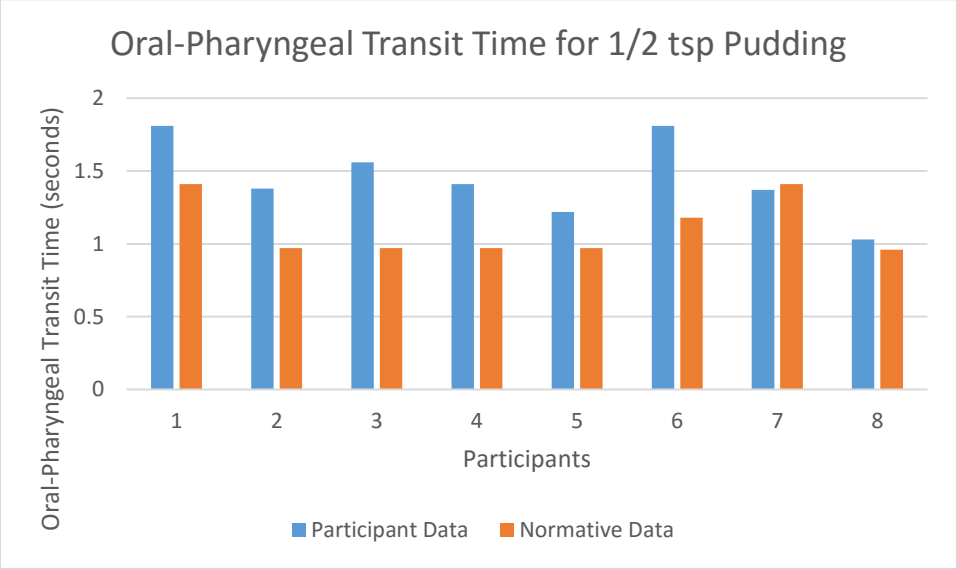

Figure 3.20. Group Oral-Pharyngeal Transit Time for ½ tsp Pudding.

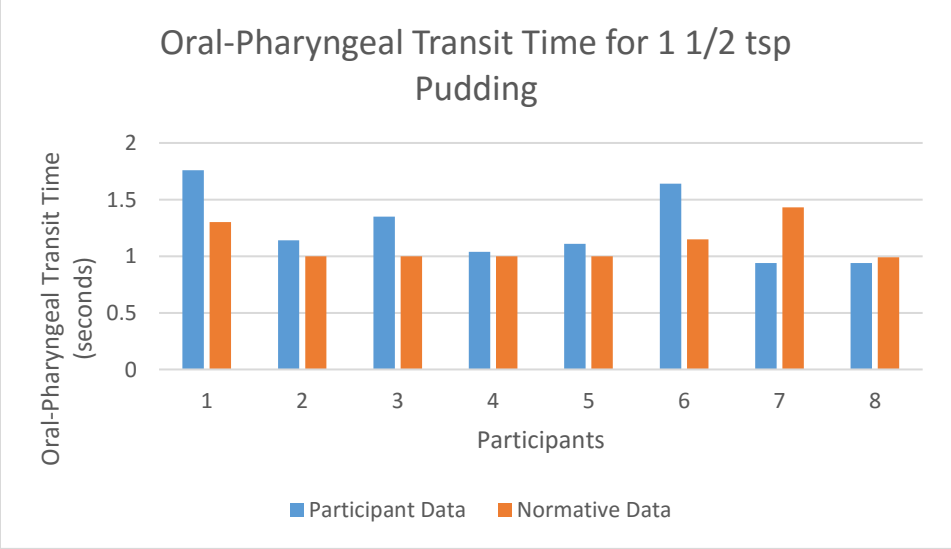

Figure 3.21. Group Oral-Pharyngeal Transit Time for 1 ½ tsp Pudding.

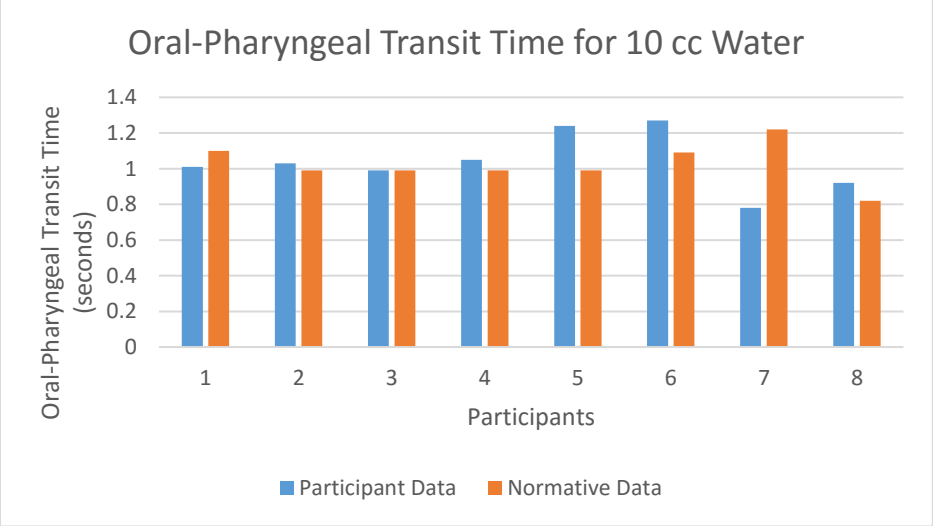

Figure 3.22. Group Oral-Pharyngeal Transit Time for 10 cc water.

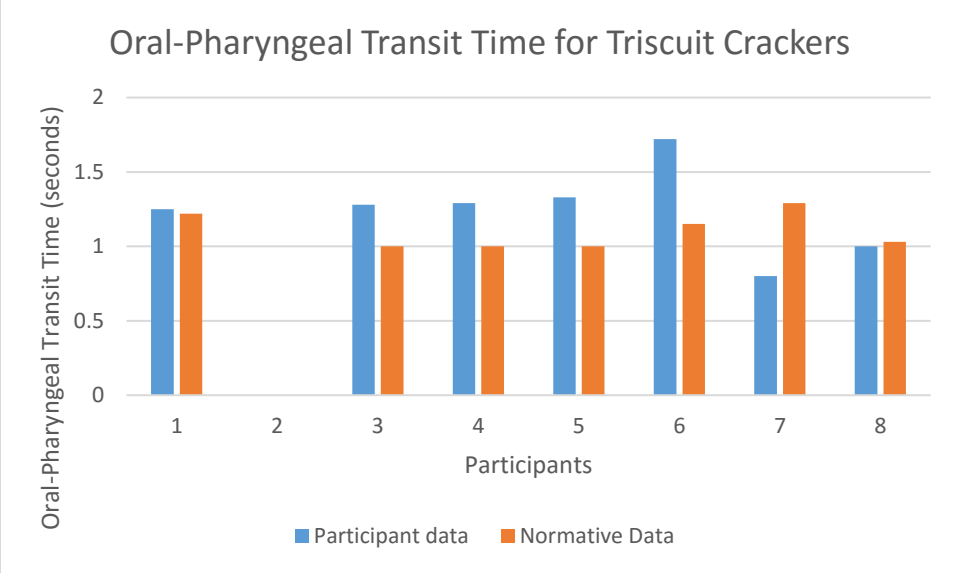

Figure 3.23. Group Oral-Pharyngeal Transit Time for Triscuit Crackers.

Group trends gained from behavioral observations of the tongue indicated that 7/8 participants had oblong or square shaped tips of the tongue and 2/8 had heart shaped tips of tongues. Additionally, 6/8 had the mouth floor visible from the inferior alveolar crest,

6/8 had sublingual attachment between the middle and apex of the tongue, and 1/8 had sublingual attachment at the apex of the tongue. Also, 6/8 had their tongue protrude during swallowing trials which indicates a tongue thrust.

Significant Findings as a Group

Significant findings by variable for each participant were tallied to determine the strength of the phenomenon under study (See Table 3.18). For this analysis, a threshold tally 4 or greater (50% of participants showing significance on a variable) was taken as an indication of a trend in individuals with ankylogolossia.

Table 3.18. Tally of significant findings by subject. An arbitrary criterion of 50% of participants displaying a significant finding was established as the threshold for identifying a variable as demonstrating a strong trend toward presence in individuals with ankyloglossia.

Measurement	Significant Finding by Subject									Meet or Exceed .5 criterion
	1	2	3	4	5	6	7	8	T	
Iopitipavg	0*	0	1	0	1	0	1	1	4	X
Iopidorsavg	0	0	1	1	1	0	1	1	5	X
Iopilipavg	1	1	0	1	0	0	1	0*	4	X
mcbARMSavg	1	-	1	1	0*	0*	1	1	5	X
mcbBRMSavg	1	-	0*	0*	0*	0*	1	1	3	
mcpud1ARMS	0*	1	1	0*	0	1	1	1	5	X
mcpud1BRMS	0*	1	0*	1	1	1	1	1	6	X
mcpud2ARMS	1	1	1	1	0*	0*	1	1	6	X
mcpud2BRMS	1	1	1	1	1	1	1	1	8	X
mc10ccARMS	1	1	1	1	1	1	1	1	8	X
mc10ccBRMS	1	1	1	1	1	0*	1	1	7	X
mccrackARMS	1	1	1	1	1	1	1	1	8	X
mccrackBRMS	1	1	1	0	1	0	1	1	6	X

stcpud1avg	0	0	1	0	0	1	0	0	2	
stcpud2avg	0	0	0	0	0	1	0	0	1	
stc10ccavg	0	0	0	0	0	0	0	0	0	
stccrackavg	0	-	0	0	0	1	0	0	1	

Note that tallies indicated with asterisk (*) were significant but not in the direction predicted through one-tail test, and therefore do not contribute to the tally. Note that scores indicated with dash (-) were not calculated due to anomalies in data.

As can be seen in this table, all IOPI measurements exceeded the criterion, as did all masseter contraction measures with the exception of the right channel average activity. Notably, none of the oropharyngeal timing variables met the criterion. By this metric, individuals with ankyloglossia show consistent reductions in articulator force (tongue tip and dorsum, and lip), as well as masseter activity for all boluses. In contrast, oropharyngeal transit time does not appear to be a consistent indicator related to tongue tie.

Chapter 4: Discussion

The purpose of this study was to obtain data about the possible relationship between tongue tie and oral-pharyngeal dysphagia (OPD). Data were gathered on 8 participants, 5 females and 3 males, with age range of 12 to 43 years. The measurements obtained were tongue tip and dorsum, and lip strength using an IOPI, as well as masseter contraction activity and laryngeal timing using EMG. The measurements of strength and masseter contraction were obtained in order to investigate relationships between tongue-tie and risk factors for OPD. Laryngeal timing was collected as a primary risk factor for OPD. All collected data were compared to normative data and compared through z scores to determine significant differences.

Research Hypothesis:

Research hypotheses for this study are as follows:

Question 1

H_{0a}: No trend exists relating variables associated with oral pharyngeal dysphagia and those associated with ankyloglossia.

H_{1a}: A trend exists relating variables of oral pharyngeal dysphagia and ankyloglossia.

Question 2

H_{0b}: No significant difference exists in masseter contraction based on side and/or bolus type as compared with norms.

H_{1b}: A significant difference exists in masseter contraction based on side and/or bolus type as compared with norms.

Question 3

H_{0c}: No significant difference exists in laryngeal timing based on bolus type and/or measurement type as compared with norms.

H_{1c}: An significant difference exists in laryngeal timing based on bolus type and/or measurement type as compared with norms.

Question 4

H_{0d}: No significant difference exists in force, as measured by IOPI, based on IOPI location as compared with norms.

H_{1d}: A significant difference exists in force, as measured by IOPI, based on IOPI location as compared with norms.

Research Findings

Question 1: Is there a trend relating to variables associated with ankyloglossia and those associated with oral-pharyngeal dysphagia?

In this study the main indicator of ankyloglossia was tongue tie severity determined by tongue tie coefficient, the ratio between MOtts and MOmax. According to

Evers (2013), delayed oral-pharyngeal transit time is the main indicator of oral-pharyngeal dysphagia. Yet, other indicators such as reduced oral musculature strength also exist. Lazarus, et al. (2000) conducted a study which provided evidence that tongue strength plays a role in oropharyngeal swallowing. Thus, decreased tongue strength is linked to oropharyngeal dysphagia. Although the laryngeal timing data of the present study did not differ significantly from the norms, there was nonetheless a clear trend toward longer oropharyngeal transit times for individuals with increased tongue tie severity. The alternative hypothesis must be accepted that a trend exists relating variables of oral-pharyngeal dysphagia and ankyloglossia. Participants demonstrated a trend of decreased tongue tip, dorsum, and lip strength as shown in Table 3.18. Also, consistently reduced masseter activity for all bolus types were confirmed (see Table 3.18). However, as demonstrated by Figures 3.20-3.24 prolonged oral-pharyngeal transit times were noted for some participants but not to an amount considered significant. Figure 4.1 reveals group averages for oral-pharyngeal transit times compared to normative data, revealing a trend toward increased oropharyngeal transit times for the participants relative to the norms. Similarly, individuals with ankyloglossia demonstrate a trend of reduction in articulator force (tongue tip and dorsum, and lips) and reduced masseter activity for all bolus types.

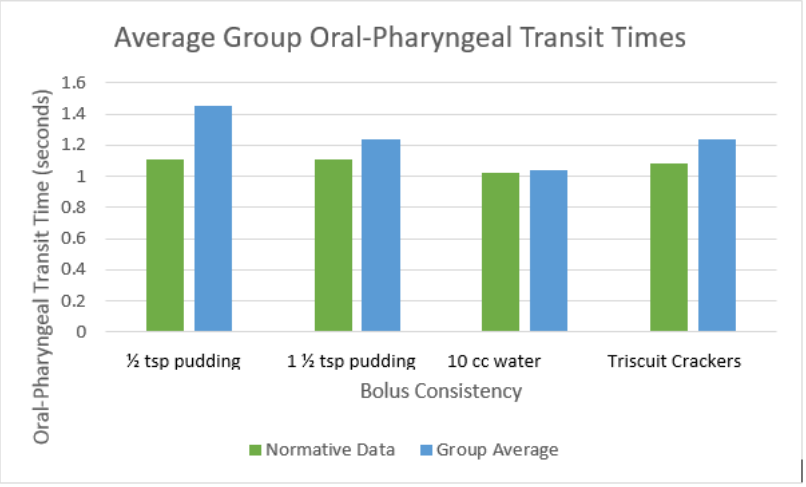

Figure 4.1. Average Group Oral-Pharyngeal Transit Times.

Question 2: Is there a significant difference between masseter contractions based on size or bolus type?

The results for masseter contractions revealed noticeable differences based on both bolus size and bolus type for individuals with tongue tie, as revealed in the group summary in Table 3.18. Reduced masseter contraction activity for individuals with tongue tie could be due to the tongue not contacting the roof of the mouth during the swallow to supply counter pressure. In a typical swallow, during the oral propulsion stage the tongue tip contacts the roof of the mouth, which generates counter-pressure at the tongue base. This activates the masseter stabilization of the tongue base (Olive, 2016). Limited tongue mobility would be expected for individuals with a point of attachment at the inferior alveolar crest, which 6/8 participants had. Also, limited mobility may be seen with individuals with a sublingual attachment between the middle and the apex of the tongue which 7/8 participants possessed. Both of these conditions would lead to reduced masseter activity. Thus, the presence of an oromyofunctional disorder arising from ankyloglossia would be directly linked to oral stage dysphagia.

Question 3: Is there a significant difference in oral-pharyngeal transit time based on bolus type?

A significant difference in oral-pharyngeal transit time was not found for individuals with tongue tie. The null hypothesis must be accepted that no significant difference exists in laryngeal timing based on bolus type and/or measurement type. This having been said, there were clear trends in that direction, which, when coupled with reduced masseter activity and tongue force, may contribute to an oropharyngeal dysphagia.

Question 4: Is there a significant difference that exists in force based on IOPI location?

IOPI measurements of force were taken for tongue tip, dorsum, and lips. Statistical analysis, shown in Tables 3.18, indicates consistent significant difference in force for all locations (tongue tip and dorsum, and lips) for individuals with tongue tie compared to the normative data. The alternative hypothesis must be accepted that a significant difference exists in force based on IOPI location for individuals with tongue tie.

The lower IOPI tongue tip measurements indicate reduced strength in the tongue tip. This may be due to the findings from the LFP that 7/8 participants had an attachment of the frenulum at the apex or between the middle and the apex of the tongue and 6/8 revealed an anterior connection of the frenulum at the inferior alveolar crest. These points of attachment may limit the mobility of the tongue tip which would reduce the use of the tongue tip, causing reduced tongue tip force. The overall trend indicates that tongue tie reduces tongue tip, dorsum, and lips strength. Again, as with the masseter activity

differences and the trend toward longer oropharyngeal transit times, there is strong evidence for risk of oropharyngeal dysphagia in individuals with tongue tie.

Clinical Implications

There is currently no standardized way to identify tongue tie in adults. Tongue tie is usually diagnosed using non-standardized measures such as observation of the frenulum, oral motor assessment, family history, and oral mechanism exam.

This study utilized the *Lingual Frenulum Protocol* (LFP) to identify tongue tie. The LFP includes two sections: first, the general test investigates the autonomy of the frenulum and the tongue, second, the functional test scores the mobility of the tongue. The general test utilized the Quick Tongue-Tie Assessment tool to measure the distance between the superior right incisor to the inferior right incisor with the mouth wide open (MOmax) and with the tongue to spot and the mouth wide open (MOtts). The difference of these measurements was calculated with a result of 50% or lower indicating tongue tie. This section of the protocol also observed the shape of the tongue tip, attachment of the frenulum to the mouth floor and to the tongue. A score of 3 or greater, out of eight was considered as having tongue tie.

The functional test of tongue mobility was not scored due to the researcher's inability to define aspects of this test such as apex vibration. The researcher observed tongue mobility as the participant did tasks such as protruding, retracting, touching superior lip, touching right/left commissura labiorum, etc. This section also included a speech sample, having the client recite the days of the week, months of the year, count to 20, and name common items. One subject exhibited an articulation distortion, a lateral lisp on /s/. Other aspects of the speech section would have required a substantial amount

of time to score. For these reasons the items on the second portion of the LFP were used only as behavioral measures and not for formal scores to indicate tongue tie.

The deeper clinical implications of this study are that individuals with ankyloglossia appear to be at risk for life-threatening oropharyngeal dysphagia. The clear presence of tongue weakness and reduced counterforce by masseter activity speak directly to oral stage dysphagia, including issues related to oral preparation and oral transit. A young individual may be able to compensate for such limitations in oral function. Nicosia, et al. (2000) found that older individuals may be at a greater risk for dysphagia due to age related decreased lingual strength and unchanging swallowing pressure. It is entirely possible that individuals with tongue-tie who begin with decreased lingual strength may continue to experience further muscular weakness associated with aging will result in poor bolus containment and prolonged propulsion which, when coupled with reduced sensory awareness, may result in premature spillage of the bolus into the airway, or other signs of dysphagia.

Limitations of Current Study

Limitations of this study consist of a small sample size, the need for statistical analysis to determine the significance of results, and issues with utilizing the LFP. Without knowing how to perform the second section of the LFP the data could not be scored. All participants were identified with tongue tie using the *Lingual Frenulum Protocol* (LFP), a score of 3 or greater was classified as having tongue tie. However, Guilleminault, Shehlanoor, and Lo (2016) recommended using the difference between the MOmax and MOtt alone to identify tongue tie with a percentage of 50% or less indicating tongue tie. Four of the participants did not have a difference of 50% or below

on this measurement (participants 2, 3, 4, 7). Yet, they received a score of 3 on the LFP due to the appearance and function of the tongue. This may indicate that all participants may not have had a true tongue tie.

Implications for Future Research

Future studies concerning the impact of tongue tie and oral-pharyngeal dysphagia should include a larger sample size and include diadochokinetic rates to measure the coordination of tongue movements. As a majority (6/8) participants exhibited tongue protrusion while swallowing, a study on the relationship between tongue tie and tongue thrust may be beneficial. Additionally, the investigation of the impact of oral motor exercises on tongue strength for individuals with tongue tie would be interesting.

Conclusion

This study analyzed the data of 8 individuals with tongue tie aged 12-43 years compared to age matched norms from Holzer (2011). Statistical significance was found consistently for masseter strength. Measurements of force using IOPI for tongue tip, dorsum, and lips also revealed measures that were statistically significant. Differences in oral-pharyngeal transit time for individuals with tongue tie were not statistically significant, but there were consistent trends in that direction. Based on the results of this study, indicators of oral-pharyngeal dysphagia are present in individuals with ankyloglossia.

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APPENDIX A: Lingual Frenulum Protocol

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Appendix A
LINGUAL FRENULUM PROTOCOL

HISTORY

Name: _____ **Gender**
F ( ) M ( )
Examination date: __ / __ / __ **Age:** ___ **years and** ___ **months** **Birth:** __ / __ / __
Responsible: _____ **Relative:** _____

Studying: ☐ yes ☐ no Grade:
Working: ☐ yes ☐ no Profession:
Worked before ☐ no ☐ yes Professional Area:
Practicing sports: ☐ no ☐ yes Type:

Address: _____
City: _____ **State:** _____ **ZIP:** _____
Phone: Home: (____) _____ Office: (____) _____ Cell: (____) _____
e-mail: _____
Father's name: _____ **Mother's name:** _____
Siblings:
☐ no ☐ yes How many: _____

Who referred patient for evaluation *(Name, specialist, phone)*:
_____
Why?

Main **complaint:**
_____

Other complaints affecting:
(0) no (1) sometimes (2) yes

( ) lips	( ) tongue	( ) sucking	( ) chewing	( ) deglutition
( ) breathing	( ) speech	( ) lingual frenulum	( ) voice	( ) hearing
( ) learning	( ) facial aesthetic	( ) posture	( ) occlusion	( ) headache
( ) TJM clicking	( ) TMJ pain	( ) neck pain	( ) shoulders pain	
( ) mouth opening difficulty	( ) mandible range of motion			( ) Other

Family history – any other relative has frenulum alteration
☐ no ☐ yes Who? Surgery was necessary: ☐ yes ☐ no

Health problems
☐ no ☐ yes What kind:

Breathing problems
☐ no ☐ yes What kind:

International Journal of Orofacial Myology 2012, V38

Suckling

Breast- feeding:	☐ yes	Age: _____	☐ no	The baby had difficult suckling? ☐ no ☐ yes
Bottle:	☐ yes	Age: _____	☐ no	What difficulty: _____

Feeding – chewing difficulties

☐ no ☐ yes What:

Feeding – deglutition difficulties

☐ no ☐ yes What:

Oral habits:

☐ no ☐ yes What:

Speech alterations:

☐ no ☐ yes What:

Any social or professional issues due to speech alteration?

☐ no ☐ yes Social ☐ no ☐ yes Response: _____
Professional ☐ no ☐ yes Response:

Voice alteration:

☐ no ☐ yes What:

Lingual frenulum surgery:

☐ no ☐ yes When: _____ How many: _____
What professional performed surgery: _____
Results: ☐ good ☐ satisfactory ☐ unsatisfactory

Add other important information

_____
_____
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International Journal of Orofacial Myology 2012, V38

LINGUAL FRENULUM PROTOCOL (Continued)

CLINICAL EXAMINATION

I – GENERAL TESTS

Measurements using a caliper. Larger or equal 50,1% (0) – Less or equal 50% (1) FINAL RESULT =

Take measurements from superior right or left incisive to the inferior right or left incisive. Consider the same tooth for all the measurements.	**Value in millimeters**
Open mouth wide	
Open mouth wide with the tongue tip touching the incise papilla	
Difference between the two measurements, in percentage	%

Alterations during tongue elevation (best result = 0 worst result = 2) FINAL RESULT =

Open mouth wide; raise the tongue without touching the palate	NO	YES
1. Tip of the tongue's shape: oblong or square	(0)	(1)
2. Tip of the tongue's shape: like a heart	(0)	(1)

Frenulum fixation. Add A and B (best result = 0 e worst result = 3) Final result =

A – Mouth floor:	
Visible only from the sublingual caruncles	(0)
Visible from inferior alveolar crest	(1)

Fixation in another point:

_____

B – Sublingual:	
In the middle of the tongue	(0)
Between the middle and the apex of the tongue	(1)
At the apex	(2)

Clinical frenulum classification (best result = 0 e worst result = 2) Final result =

Normal (0)	Borderline (1)	Altered (2)

If the frenulum was considered altered it would be because:

The frenulum seems normal but it is attached between the middle and the apex of the tongue	The frenulum is short	The frenulum is short and it is fixed between the middle and the apex of the tongue	
Ankyloglossia (frenulum attached to apex of the tongue)		Another reason	Unsure

General tests evaluation total score: best result = 0 worst result = 8

When the score of the general tests evaluation is equal or greater than 3, the frenulum may be considered altered.

International Journal of Orofacial Myology 2012, V38

II – FUNCTIONAL TESTS

Tongue mobility (best result = 0 worst result = 14). Final result =

	Successful	Partially successful	Unsuccessful
Protrude and retract	(0)	(1)	(2)
Touch the superior lip with the apex	(0)	(1)	(2)
Touch the right commissura labiorum	(0)	(1)	(2)
Touch the left commissura labiorum	(0)	(1)	(2)
Touch U&L molars	(0)	(1)	(2)
Apex vibration	(0)	(1)	(2)
Sucking against the palate	(0)	(1)	(2)

Tongue position during rest (best result = 0 e worst result = 4). Final result =

Not visible	(0)
On the floor of the mouth	(1)
Protrudes between the teeth	(2)
Laterally protrudes between teeth	(2)

Speech (best result = 0 e worst result =12) Final result =

Test 1 – Informal speech
e.g.: What is your name? How old are you? Do you study/work? Tell me about your school/work. Tell me about something interesting.
Test 2 – Ask to count from 1 to 20. Ask to say the days of the week. Ask to say the months of the year.
Test 3 – Ask to name the pictures from the picture table

Speech tests	Omission		Substitution		Distortion	
	No	Yes	No	Yes	No	Yes
1	(0)	(1)	(0)	(1)	(0)	(2)
2	(0)	(1)	(0)	(1)	(0)	(2)
3	(0)	(1)	(0)	(1)	(0)	(2)

Check for which sound there is omission or substitution or distortion

p		t		k		b		d		g		m			
n				f		s		x		v		z			
j		l				r		rr		{S}	{R}	tl			
pr	br	tr	dr	cr	gr	fr	vr	pl	bl	cl	gl	fl	vl		

If the alteration occurs in only one or two tests, identify in which test there was alteration

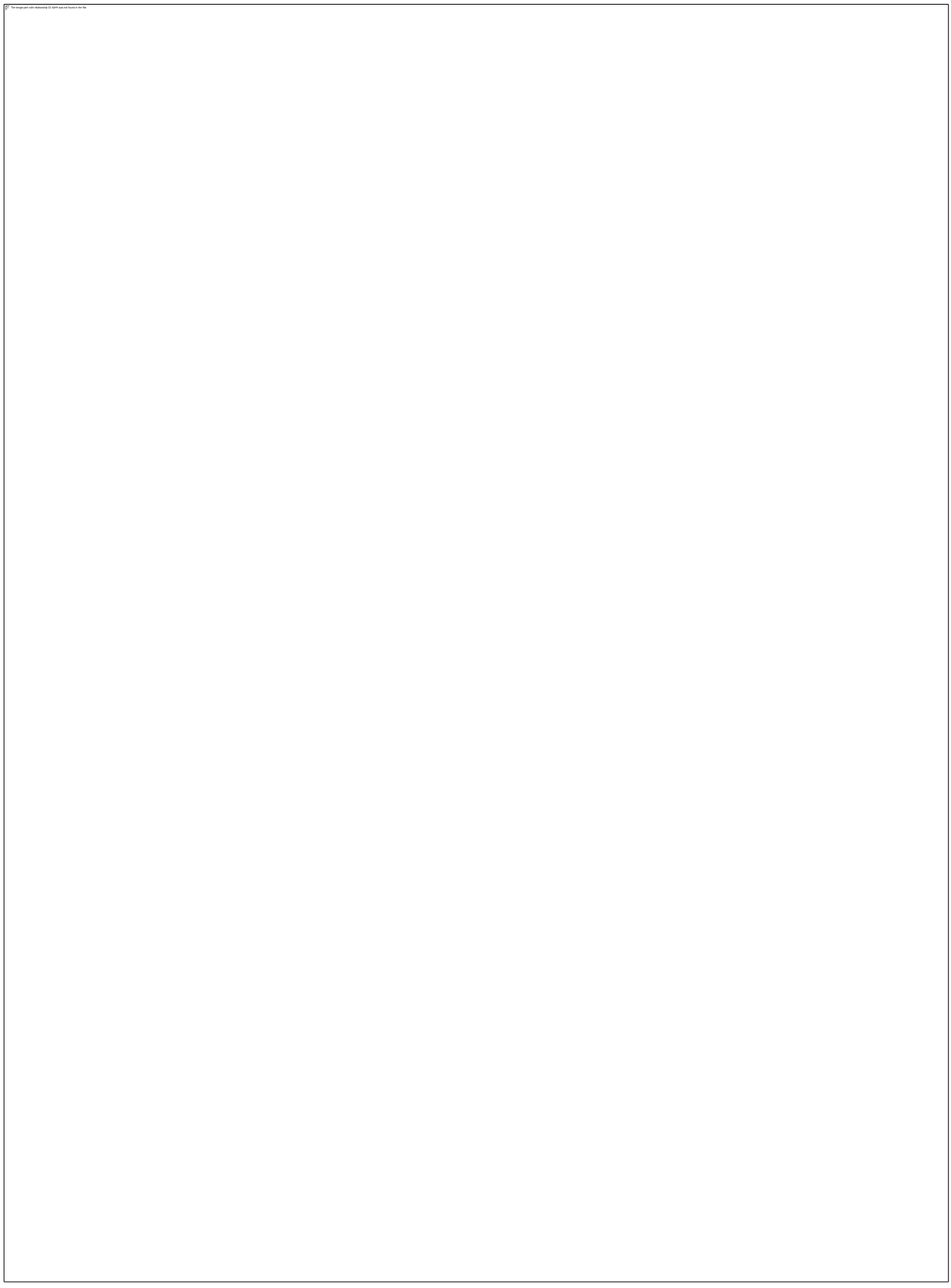
Other aspects to be observed during speech (best result = 0 e worst result =10) Final result =

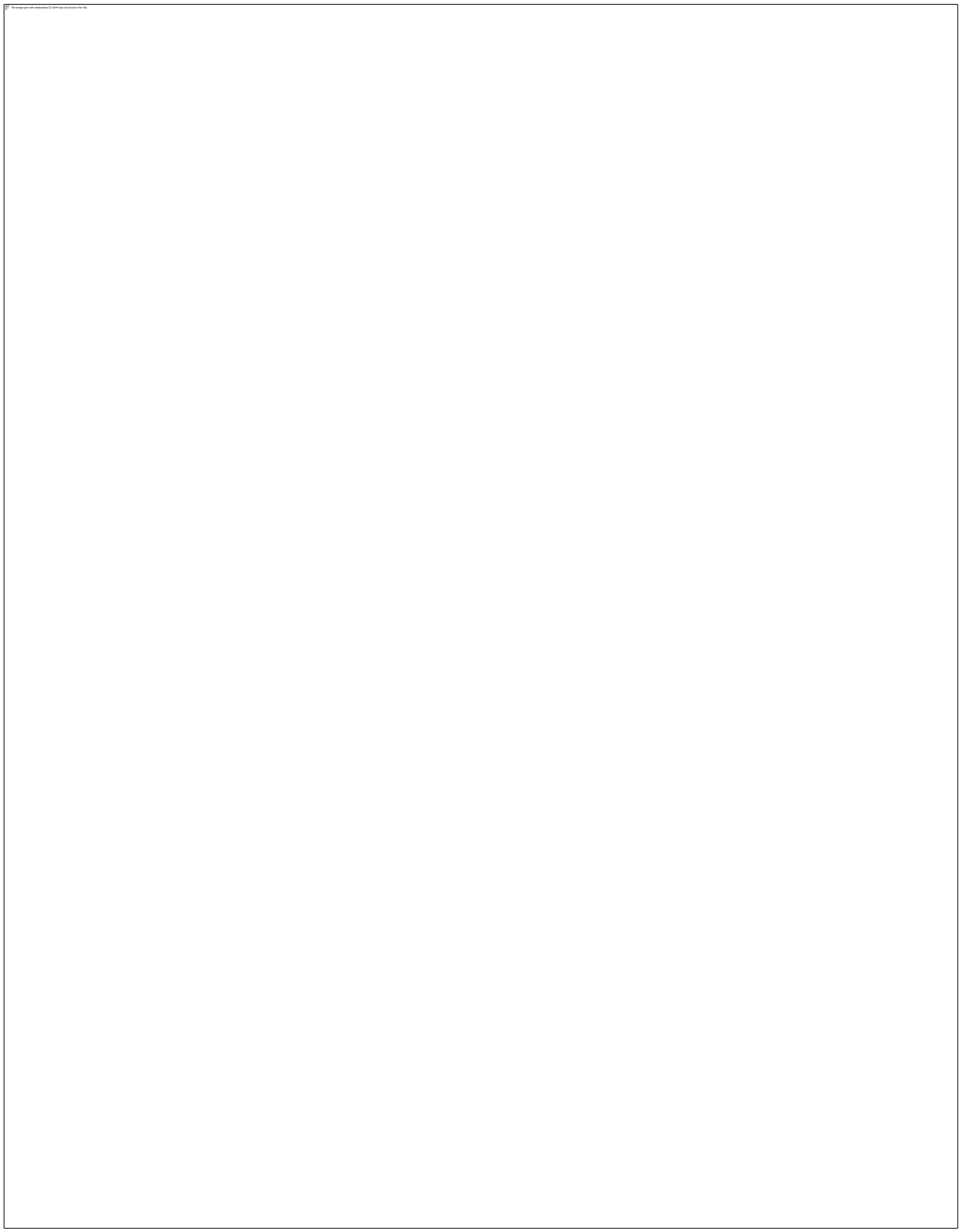
Mouth opening: (0) adequate (1) reduced (1) open wide
Tongue position: (0) adequate (1) on the floor (2) protruded (2) visible sides
Mandible movements: (0) no alteration (1) right displacement (1) left displacement (1) forth displacement
Speed: (0) adequate (1) increased (1) reduced
Speech precision: (0) adequate (1) altered
Voice: (0) no alteration (1) altered

Functional evaluation total score: best result = 0 and worst result = 40

When the score of the functional evaluation is equal or greater than 25, the frenulum can be considered altered.

Documentation:
Photography and video of tongue mobility and speech evaluation





APPENDIX B: Demographic Survey

Subject ID#_____

Demographic Survey

1. Birth Date: _____

2. Circle One: MALE FEMALE

3. Ethnicity (check one):

- ☐ (1) European American (not Hispanic)
- ☐ (2) White Hispanic
- ☐ (3) Latino
- ☐ (4) Asian
- ☐ (5) African American
- ☐ (6) Native American
- ☐ (7) Other / Multi-racial

Health Status

4. Do you have or have you experienced any of the following? (check yes or no)

Neuromedical Risks/Condition

a. Head injury (describe and include point of impact)

_____

☐ Yes ☐ No

b. Loss of consciousness (how long?) _____

☐ Yes ☐ No

c. Seizures

☐Yes ☐ No

d. Stroke/TIA

☐Yes ☐ No

e. Brain Masses (location) _____

☐ Yes ☐ No

f. Multiple Sclerosis (when diagnosed?) _____

☐ Yes ☐ No

g. Cerebral Palsy

☐ Yes ☐ No

h. Dementia /Alzheimer's (when diagnosed?)

_____

☐ Yes ☐ No

i. Brain Surgery (describe) _____

☐ Yes ☐ No

Oromyofunctional Risks/Conditions

aa. Recurrent Pneumonia

☐ Yes ☐ No

bb. Frequent Temperature Spikes

☐ Yes ☐ No

cc. History of Artificial Airway

☐ Yes ☐ No

dd. Mouth Breather

☐ Yes ☐ No

ee. History of Finger Sucking

☐ Yes ☐ No

ff. History of Cheek Biting

☐ Yes ☐ No

gg. Deviated Septum

☐ Yes ☐ No

hh. Enlarged Tonsils/Adenoids

☐ Yes ☐ No

ii. Tonsils/Adenoids Removed

☐ Yes ☐ No

jj. Open Spaced During Mixed Dentition

☐ Yes ☐ No

kk. Current Open Spaces in Dentition

☐ Yes ☐ No

ll. Allergies (explain) _____

☐ Yes ☐ No

mm. TMJ Syndrome

☐ Yes ☐ No

nn. Eating Disorders

☐ Yes ☐ No

oo. Oral Surgery (explain) _____

☐ Yes ☐ No

pp. Neck Surgery (explain) _____

☐ Yes ☐ No

qq. Oral Sores

☐ Yes ☐ No

Other

rr. Other Surgery (explain) _____

☐ Yes ☐ No

5. List and describe any serious accidents that required hospitalization._____

_____

_____

Food Information

7. What are your three favorite foods? _____

8. What are your three least favorite foods? _____

9. Are there any foods that you avoid?

_____

10. How often do you chew gum? _____

11. Do you have any food allergies? If yes, what type of food. (If you are allergic to sugar-free chocolate pudding or Triscuit crackers you will not be able to participate in this study).

_____

12. Have you ever participated in tongue thrust therapy? ☐ Yes ☐ No

APPENDIX C: Clinical Evaluation Protocol
Subject number _____ Group _____
Date_____

1. Obtain informed consent.
2. Set up video camera. Press record.
3. Open Biograph Infiniti Program
4. Select Options and Notch Filters
5. Set them to EMG and 60 Hz and choose okay
6. Select Start Open Display Session
7. Select Add New Client and enter client number under Clinic ID & Name and select OK (see Table of Subjects and Researchers to determine client number)
8. Choose desired client from subjects and Define New session
9. Select Skeletal Muscle Rehab and M1revw- 2 ch Open Display.scr (be sure you have selected MyoTrac Infiniti as encoder type).
10. Make sure the encoder is connected to the computer. Then turn on the encoder. On the encoder, under "New Session" select "Open." A graph should display in Biograph Infiniti Program.
11. Once electrodes are in place, press record and instruct client to do desired task. The spacebar places event markers on the screen (used in swallow timing section/ LE and to mark swallow for masseter activity). Be sure that when you pause the session you press pause and not stop.
12. When you are done with the session, press stop and save it in an uncompressed version with the name being the task you just completed (ex. Masseter activity- 1 tsp pudding).
13. Choose not to review the session.
14. Continue recording with the same client set-up until you have completed the protocol for that client, following step 8-10.
15. Once you've recorded all the necessary sessions for the client and save as instructed in 9, close out the client. See the Biograph Infiniti program information for measuring data.

Group A	Group B	Group C

IOPI	EMG masseter (pg 10)	EMG swallow timing (pg 19)
EMG masseter	EMG swallow timing (pg 19)	IOPI (pg 2)
EMG swallow timing	IOPI (pg 2)	EMG masseter (pg 10)

GROUP A			
Task	Clinician's Instructions to Subject	What Clinician Does	Record Data
1. Human Consent Form			
Human Consent	"Today I will be using different measures and foods to assess your swallow function. I will be placing the IOPI (show them the instrument) on your lips and in your mouth, EMG electrodes (show them instrument) on your throat and jaw, and placing my hands on your face and throat. If at any time you feel uncomfortable please let me know. The IOPI measures how much force		

	your tongue and lips can exert, and the EMG measures electrical activity of your muscles. Neither device should cause you any discomfort."		
2. Medical History Form			
Medical History Form (Appendix D)	"Please answer the following questions to the best of your knowledge. Please make sure to answer all of the questions. If you have any questions, please do not hesitate to ask me. This information will remain confidential. Here is a consent form for you to read as well. You do not need to sign it. It is strictly for your knowledge."	Give subject the medical history form and consent form.	
3. Lingual Frenulum Protocol			
LFP	"I am now going to	Perform oral evaluation	Mark appropriate answers on record form. No names will be written on record form.

	evaluate you using the Lingual Frenulum Protocol. This will allow me to determine the presence or absence of tongue tie."	following LFP protocol (see attached).	Participant will be identified with their assigned number.
4. Oral Peripheral Exam (OPE)	Open your mouth	Look for vaulted palate	Circle for presence or absence of vaulted palate
OPE	Bite down on your teeth and smile	Look for molar classification (See picture on last page for malocclusion type)	Check for presence of each of the following: Crossbite _____ Labioversion _____ Normal malocclusion _____ Malocclusion I _____ Malocclusion II _____ Malocclusion III _____
5. Iowa Oral Performance Instrument (IOPI) Tongue Tip			
IOPI Tongue Tip		Procedures for Clinician 1.Press"Peak" and then press "Reset." 2.Check screen for low battery symbol. Change battery if needed. 3. Attach connecting tube to tongue bulb. IOPI is now ready to use.	

		4. Turn IOPI screen away from subject	
IOPI Tongue Tip		If at any time the bulb moves out of place or directions are not followed, re-administer the directions.	
IOPI Tongue Tip	"I'm going to place this bulb on the tip of your tongue."		
IOPI Tongue Tip	"Open your mouth"		
IOPI Tongue Tip		Clinician places bulb in mouth, making sure bulb is completely behind the front teeth.	
IOPI Tongue Tip		Make sure they are not biting on tubing.	
IOPI Tongue Tip	"Close your lips"		
IOPI Tongue Tip	"When I say go press with the tip of your tongue against the roof of your mouth as hard as you can, hold until you are told to stop."		
IOPI Tongue Tip – Trial 1	"Go"		
IOPI Tongue Tip – Trial 1		Have subject press until	

		IOPI number stabilizes	
IOPI Tongue Tip – Trial 1	"Stop"		
IOPI Tongue Tip – Trial 1			_____Record final number on screen
		Check positioning of bulb and reposition if needed.	
	"We are going to do it again."	Push "reset"	
IOPI Tongue Tip – Trial 2	"Go"		
IOPI Tongue Tip – Trial 2	"Stop"		
IOPI Tongue Tip – Trial 2			_____Record second reading
		Check positioning of bulb and reposition if needed.	
	"We are going to do it again."	Push "reset"	
IOPI Tongue Tip – Trial 3	"Go"		
IOPI Tongue Tip – Trial 3	"Stop"		
IOPI Tongue Tip – Trial 3			_____Record third reading
6. IOPI Dorsum			
IOPI Dorsum	"Now I'm going to place the bulb on a different part of your tongue. Open your mouth and say /a/"	Push "reset"	

IOPI Dorsum		Look for the peak of the tongue dorsum when subject says /a/.	
IOPI Dorsum		Place the tip of the bulb at the peak.	
IOPI Dorsum – Trial 1	"Close your mouth and push as hard as you can against the bulb."	Have subject press until IOPI number stabilizes	
IOPI Dorsum – Trial 1	"Stop"		
IOPI Dorsum – Trial 1			_____Record reading
		Wipe bulb with tissue, reposition bulb & repeat Push "reset"	
IOPI Dorsum – Trial 2	"Go"		
IOPI Dorsum – Trial 2	"Stop"		
IOPI Dorsum – Trial 2			_____Record reading
		Wipe bulb with tissue, reposition bulb & repeat Push "reset"	
IOPI Dorsum – Trial 3	"Go"		
IOPI Dorsum – Trial 3	"Stop"		
IOPI Dorsum – Trial 3		Wipe bulb	_____Record reading
7. IOPI Lip strength		Push "reset"	

IOPI Lip Strength	"Bite down and clench your teeth together. Now I'm going to place this between your lips but be sure not bite the bulb directly"		
IOPI Lip Strength		Place bulb between lips (parallel with lips), but not between teeth.	
IOPI Lip Strength	"When I say go press your lips together"	Have subject press until IOPI number stabalizes	
IOPI Lip Strength – Trial 1	"Go"		
IOPI Lip Strength – Trial 1	"Stop"		
IOPI Lip Strength – Trial 1			_____Record reading
		Reposition bulb between lips parallel with lips & Repeat Push "reset"	
IOPI Lip Strength – Trial 2	"Go"		
IOPI Lip Strength – Trial 2	"Stop"		_____Record reading
		Reposition bulb between lips parallel with lips & Repeat	

		Push “reset”	
IOPI Lip Strength – Trial 3	“Go”		
IOPI Lip Strength – Trial 3	“Stop”		_____Record reading
8. Masseter baseline			
Masseter Baseline		Select “start open display session” on computer. Add new client by number. Define new session and select “skeletal muscle rehab.” Choose screen M1revw-2ch open display screen. Then turn on the encoder.	
Masseter Baseline	“Clench your back teeth”	Palpate the Masseter, Feel for belly of masseter during contraction.	
Masseter Baseline	“Do you have skin allergies?” **(If subject has skin allergies don’t use Nuprep, use alcohol swabs).**	Use Nuprep to exfoliate skin (masseter and clavicle). Rub for 30 seconds on location of electrode placement. Remove excess Nuprep with	

		alcohol. **(If subject has skin allergies don't use Nuprep, use alcohol swabs).**	
Masseter Baseline	"Clench your back teeth"	Palpate masseter again and mark placement for electrodes with marker.	
Masseter Baseline	"Bite down for me while I place these electrodes on your muscle."	**Put conductive gel on electrodes**. Place EMG electrodes bilaterally on masseter belly in a vertical plane, **Channel A is on the subject's right masseter (yellow on superior/blue inferior) & Channel B is on the subject's left masseter (yellow superior/blue inferior). Place the ground electrode (black) on the subject's collar bone.** (Reference Figure 1 for specific	

		placement). Clip electrode cables to subject's sleeve if needed.	
Masseter Baseline		Select record	
Masseter Baseline – Trial 1 (max contraction)	"Clamp down with your back teeth as hard as possible until I say stop and then relax."	Wait 3 seconds	
Masseter Baseline – Trial 1 (max contraction)	"Stop"		_____Check for EMG reading of contraction
Masseter Baseline – Trial 2 (max contraction)	"Clamp down with your back teeth as hard as possible until I say stop and then relax."	Wait 3 seconds	
Masseter Baseline – Trial2 (max contraction)	"Stop"		_____Check for EMG reading of contraction
Masseter Baseline – Trial 3 (max contraction)	"Clamp down with your back teeth as hard as possible until I say stop and then relax."	Wait 3 seconds	
Masseter Baseline – Trial 3 (max contraction)	"Stop"		_____Check for EMG reading of contraction
		Stop recording and save without	

		reviewing in non compressed format and start new session with same client.	
9. Masseter Activity			
Masseter Activity		Electrodes will remain in the same placement. Select record	
Masseter Activity – Trial 1 (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon.	
Masseter Activity – Trial 1 (1/2 tsp pudding)		Have subject place the pudding in their mouth	
Masseter Activity – Trial 1 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 1 (1/2 tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 2 (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon.	

Masseter Activity – Trial 2 (1/2 tsp pudding)		Have subject place the pudding in their mouth	
Masseter Activity – Trial 2 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 2 (1/2 tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 3 (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon.	
Masseter Activity – Trial 3 (1/2 tsp pudding)		Have subject place the pudding in their mouth	
Masseter Activity – Trial 3 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 3 (1/2 tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time

Masseter Activity – Trial 1 (1 ½ tsp pudding)		Stop recording and save without reviewing in non compressed format and start new session with same client.	
Masseter Activity – Trial 1 (1 ½ tsp pudding)		Measure 1 ½ teaspoons of pudding with syringe and place on spoon. Press record.	
		Have subject place the pudding in their mouth	
Masseter Activity – Trial 1 (1 ½ tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 1 (1 ½ tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 2 (1 ½ tsp pudding)		Measure 1 ½ teaspoons of pudding with syringe and place on spoon. Press record.	
		Have subject place the	

		pudding in their mouth	
Masseter Activity – Trial 2 (1 ½ tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 2 (1 ½ tsp pudding)			_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 3 (1 ½ tsp pudding)		Measure 1 ½ teaspoons of pudding with syringe and place on spoon. Press record.	
		Have subject place the pudding in their mouth	
Masseter Activity – Trial 3 (1 ½ tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 3 (1 ½ tsp pudidng)			_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 1 (10 cc water)		Stop recording and save without reviewing in	

		non compressed format and start new session with same client.	
Masseter Activity – Trial 1 (10 cc water)		Measure 10 cc of water, to line marked on the syringe and squirt into cup.	
Masseter Activity – Trial 1 (10 cc water)	"I'm going to give you a small amount of water in a cup."	Press record	
Masseter Activity – Trial 1 (10 cc water)	"Drink the water from the cup but don't swallow until I say swallow."	Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 1 (10 cc water)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 2 (10 cc water)		Measure 10 cc of water, to line marked on the syringe and squirt into cup.	
		Press record	
Masseter Activity – Trial 2 (10 cc water)	"Drink the water from the cup but don't swallow until I say swallow."	Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:

Masseter Activity – Trial 2 (10 cc water)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 3 (10 cc water)		Measure 10 cc of water, to line marked on the syringe and squirt into cup.	
		Press record	
Masseter Activity – Trial 3 (10 cc water)	"Drink the water from the cup but don't swallow until I say swallow."	Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 3 (10 cc water)			_____Check EMG for completion of task _____ Swallow initiation time
		Stop recording and save without reviewing in non compressed format and start new session with same client.	
Masseter Activity – Trial 1 (Triscuit)			
Masseter Activity – Trial 1 (Triscuit)		Give subject whole Triscuit	
Masseter Activity – Trial 1 (Triscuit)	"Take a normal bite, chew it and open your	Press record	

	mouth when you are ready to swallow. Signal to me when you are ready to swallow."		
Masseter Activity – Trial 1 (Triscuit)		Look in mouth & rate bolus	
Masseter Activity – Trial 1 (Triscuit)			1 – organized in ball or tube in middle of tongue 3 – some evidence of cohesion, some scattering 5 – disorganized or scattered on tongue
Masseter Activity – Trial 1 (Triscuit)		Participant signals ready to swallow. Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 1 (Triscuit)	"Open your mouth"	Press pause	_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 1 (Triscuit)		Look for residue on sulci & tongue & rate residue	
Masseter Activity – Trial 1 (Triscuit)			1 - minimal/no residue (few to no parts of residue) 3 – some evidence of residue 5 – significant amount of residue
Masseter Activity – Trial 2 (Triscuit)	"We are going to repeat the process 2 more times"		

Masseter Activity – Trial 2 (Triscuit)	"Take another bite & open your mouth when you are ready to swallow. Signal to me when you are ready to swallow."	Press record.	
Masseter Activity – Trial 2 (Triscuit)		Look in mouth & rate bolus	
Masseter Activity – Trial 2 (Triscuit)			1 - organized in ball or tube in middle of tongue 3- some evidence of cohesion, some scattering 5- disorganized or scattered on tongue | | | | | |
Masseter Activity – Trial 2 (Triscuit)		Participant signals when ready to swallow. Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) ___ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 2 (Triscuit)	"Open your mouth"	Press pause	_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 2 (Triscuit)		Look for residue on sulci with tongue depressor if needed & tongue & rate residue	
Masseter Activity – Trial 2 (Triscuit)			

Masseter Activity – Trial 3 (Triscuit)	"Take another bite & open your mouth when you are ready to swallow. Signal to me when you are ready to swallow."	Press record	
Masseter Activity – Trial 3 (Triscuit)		Look in mouth & rate bolus	
Masseter Activity – Trial 3 (Triscuit)			1- Minimal/No residue (few to no parts of residue 3-some evidence of residue 5- Significant amount of residue
Masseter Activity – Trial 3 (Triscuit)		Participant signals ready to swallow. Watch for swallow initiation and press space bar to mark swallow time.	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
Masseter Activity – Trial 3 (Triscuit)	"Open your mouth"	Press pause	_____Check EMG for completion of task _____ Swallow initiation time
Masseter Activity – Trial 3 (Triscuit)		Look for residue on sulci & tongue & rate residue	
Masseter Activity – Trial 3 (Triscuit)			1 3 5 **Minimal/No residue (few to no parts of residue)** **Some evidence of residue** **Significant amount of residue**

10. Laryngeal elevation (LE)			
LE		Remove channel A & B electrodes	
LE		Prepare skin for electrode placement. **Get new electrodes and place conductive gel on electrodes.** Put Channel **A electrode to geniohyoid**. Measure **2 cm posterior from chin point and place first (yellow) electrode and place second electrode (blue) 2cm posterior** from the first. Place **channel B electrode just off lamina on left side.** Have subject perform dry swallow & feel for thyroid notch. Place electrodes 2cm apart in vertical alignment on left side of thyroid notch	

		with yellow electrode superior and blue electrode inferior. (See Figure 2 for placement)	
LE – <u>Trial 1</u> (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon	
		Press record	
LE – Trial 1 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Have subject place the pudding in their mouth	
LE – Trial 1 (1/2 tsp pudding)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 1 (1/2 tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 1 (1/2 tsp pudding)	"Say ah"		_____ Gurgly voice (+/-)
LE – Trial 2 (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon	
		Press record	
LE – Trial 2	"Place the pudding in	Have subject place the	

(1/2 tsp pudding)	your mouth, cleaning the whole spoon, & swallow when I say swallow"	pudding in their mouth	
LE – Trial 2 (1/2 tsp pudding)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 2 (1/2 tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 2 (1/2 tsp pudding)	"Say ah"		_____ Gurgly voice (+/-)
LE – Trial 2 (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon	
LE – Trial 3 (1/2 tsp pudding)		Press record	
LE – Trial 3 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Have subject place the pudding in their mouth	
LE – Trial 3 (1/2 tsp pudding)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:

LE – Trial 3 (1/2 tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 3 (1/2 tsp pudding)	"Say ah"		_____ Gurgly voice (+/-)
LE – Trial 3 (1/2 tsp pudding)		Stop recording and save without reviewing in non compressed format and start new session with same client.	
LE – protrusion	"I'm going to pull down your lip when you swallow."		
LE/protrusion – Trial 1 (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon	
LE/protrusion – Trial 1 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when ready"	Have subject place the pudding in their mouth Pull down lip while swallowing and watch for protrusion of tongue.	_____ Tongue protrusion (+/-)
LE/protrusion – Trial 2 (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon	
LE/protrusion – Trial 2	"Place the pudding in your mouth,	Have subject place the	_____ Tongue protrusion (+/-)

(1/2 tsp pudding)	cleaning the whole spoon, & swallow when ready"	pudding in their mouth Pull down lip while swallowing and watch for protrusion of tongue.	
LE/protrusion – Trial 3 (1/2 tsp pudding)		Measure 1/2 teaspoon of pudding with syringe and place on spoon	
LE/protrusion – Trial 3 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when ready"	Have subject place the pudding in their mouth Pull down lip while swallowing and watch for protrusion of tongue.	_____ Tongue protrusion (+/-)
LE – Trial 1 (1 ½ tsp pudding)		Measure 1 ½ teaspoons of pudding with syringe and place on spoon	
LE – Trial 1 (1 ½ tsp pudding)		Press record	
LE – Trial 1 (1 ½ tsp pushing)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"		
LE – Trial 1 (1 ½ tsp pushing)	"Swallow"	Feel for swallow initiation and press space	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-)

		bar to mark laryngeal elevation and depression	_____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 1 (1 ½ tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 1 (1 ½ tsp pudding)	"Say ah"		_____ Gurgly voice (+/-)
LE – Trial 2 (1 ½ tsp pudding)		Measure 1 ½ teaspoons of pudding with syringe and place on spoon	
LE – Trial 2 (1 ½ tsp pudding)		Press record	
LE – Trial 2 (1 ½ tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"		
LE – Trial 2 (1 ½ tsp pudding)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 2 (1 ½ tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 2 (1 ½ tsp pudding)	"Say ah"		_____ Gurgly voice (+/-)
LE – Trial 3 (1 ½ tsp pudding)		Measure 1 ½ teaspoons of pudding with syringe and	

		place on spoon	
LE – Trial 3 (1 ½ tsp pudding)		Press record	
LE – Trial 3 (1 ½ tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"		
LE – Trial 3 (1 ½ tsp pudding)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 3 (1 ½ tsp pudding)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 3 (1 ½ tsp pudding)	"Say ah"		_____ Gurgly voice (+/-)
LE		Stop recording and save without reviewing in non compressed format and start new session with same client.	
LE – Trial 1 (10 cc water)		Measure 10 cc of water, to line marked on syringe.	
LE – Trial 1 (10 cc water)		Press record	
LE – Trial 1 (10 cc water)	"I'm going to give you a small amount		

	of water in a cup. Place it all in your mouth but don't swallow until I say swallow"		
LE – Trial 1 (10 cc water)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 1 (10 cc water)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 1 (10 cc water)	"Say ah"		_____ Gurgly voice (+/-)
LE – Trial 2 (10 cc water)		Measure 10 cc of water, to line marked on syringe.	
LE – Trial 2 (10 cc water)		Press record	
LE – Trial 2 (10 cc water)	"I'm going to give you a small amount of water in a cup. Place it all in your mouth but don't swallow until I say swallow"		
LE – Trial 2 (10 cc water)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 2		Press pause	_____Check EMG for completion of task

(10 cc water)			_____ Swallow initiation time
LE – Trial 2 (10 cc water)	"Say ah"		_____ Gurgly voice (+/-)
LE – Trial 3 (10 cc water)		Measure 10 cc of water, to line marked on syringe.	
LE – Trial 3 (10 cc water)		Press record	
LE – Trial 3 (10 cc water)	"I'm going to give you a small amount of water in a cup. Place it all in your mouth but don't swallow until I say swallow"		
LE – Trial 3 (10 cc water)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 3 (10 cc water)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 3 (10 cc water)	"Say ah"		_____ Gurgly voice (+/-)
LE		Stop recording and save without reviewing in non compressed format and start new session with same client.	
LE/protrusion	"I'm going to pull down		

	your lip when you swallow."		
LE/protrusion – Trial 1 (10 cc water)		Measure 10 cc of water, to line marked on syringe.	
LE/protrusion – Trial 1 (10 cc water)	"Open your mouth(place syringe in) close mouth & swallow when ready"	Pull down lip while swallowing and watch for protrusion of tongue.	_____ Tongue protrusion (+/-)
LE/protrusion – Trial 2 (10 cc water)		Measure 10 cc of water, to line marked on syringe.	
LE/protrusion – Trial 2 (10 cc water)	"Open your mouth(place syringe in) close mouth & swallow when ready"	Pull down lip while swallowing and watch for protrusion of tongue.	_____ Tongue protrusion (+/-)
LE/protrusion – Trial 3 (10 cc water)		Measure 10 cc of water, to line marked on syringe.	
LE/protrusion – Trial 3 (10 cc water)	"Open your mouth(place syringe in) close mouth & swallow when ready"	Pull down lip while swallowing and watch for protrusion of tongue.	_____ Tongue protrusion (+/-)
LE – Trial 1 (Triscuit)		Give subject Triscuit	
LE – Trial 1 (Triscuit)	"Take a normal bite of the cracker & signal to me when you are ready to swallow."	Press record	
LE – Trial 1 (Triscuit)		Participant signals ready to swallow. Feel for swallow initiation and	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-)

		press space bar to mark laryngeal elevation and depression	_____ Tongue protrusion (+/-) Additional notes:
LE – Trial 1 (Triscuit)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 1 (Triscuit)	"Say ah"		_____ Gurgly voice (+/-)
LE – Trial 2 (Triscuit)	"Take a normal bite of the cracker & signal to me when you are ready to swallow."	Press record	
LE – Trial 2 (Triscuit)		Participant signals ready to swallow. Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-) _____ Tongue protrusion (+/-) Additional notes:
LE – Trial 2 (Triscuit)			_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 2 (Triscuit)	"Say ah"		_____ Gurgly voice (+/-)
LE – Trial 3 (Triscuit)	"Take a normal bite of the cracker & signal to me when you are ready to swallow."	Press record	
LE – Trial 3 (Triscuit)		Participant signals ready to swallow. Feel for swallow initiation and	_____ Cough (+/-) _____ Clavicle breathing (+/-) _____ Forward posture (+/-) _____ Chin tuck posture (+/-) _____ Neck tension (+/-) _____ Open-mouth posture (+/-)

		press space bar to mark laryngeal elevation and depression	_____ Tongue protrusion (+/-) Additional notes:
LE – Trial 3 (Triscuit)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 3 (Triscuit)	"Say ah"		_____ Gurgly voice (+/-)
LE		Stop recording and save without reviewing in non compressed format.	
LE/protrusion	"I'm going to have you chew the cracker. Let me know when you have finished chewing by raising your hand. Then I will pull your lip down. Then I want you to signal when you are ready to swallow."	Give subject Triscuit	
LE/protrusion – Trial 1 (Triscuit)		Pull lip down and watch for tongue protrusion. Participant signals ready to swallow.	_____ Tongue protrusion (+/-)
LE/protrusion – Trial 2 (Triscuit)	"Take another bite. Let me know when you have finished chewing by		

	raising your hand. Then I will pull your lip down. Then I want you to signal when you are ready to swallow."		
LE/protrusion – Trial 2 (Triscuit)		Pull lip down and watch for tongue protrusion. Participant signals ready to swallow.	_____ Tongue protrusion (+/-)
LE/protrusion – Trial 3 (Triscuit)	"Take another bite. Let me know when you have finished chewing by raising your hand. Then I will pull your lip down . Then I want you to signal when you are ready to swallow.		
LE/protrusion – Trial 3 (Triscuit)		Pull lip down and watch for tongue protrusion. Participant signals ready to swallow.	_____ Tongue protrusion (+/-)
		Stop recording and save without reviewing in non compressed format and start new session with	

		same client. Stop videorecorder .	

***(A),* Normal occlusion; *(B),* Class I malocclusion; *(C),* Class II malocclusion; *(D),* Class III malocclusion. Note the position of the mesial cusp of the maxillary molar relative to the mandibular molar in each type of occlusion.**

http://medical-dictionary.thefreedictionary.com/_/viewer.aspx?path=dorland&name=malocclusion.jpg

General Layout of Protocol – GROUP A

- IOPI - tongue tip = 3 trials
- IOPI - dorsum = 3 trials
- IOPI - lip strength = 3 trials

- Masseter Baseline = 3 trials
- Masseter Activity - ½ tsp pudding = 3 trials
- Masseter Activity - 1 ½ tsp pudding = 3 trials
- Masseter Activity - 10 cc water = 3 trials
- Masseter Activity - bite of Triscuit = 3 trials

- LE - ½ tsp pudding = 3 trials
- LE protrusion - ½ tsp pudding = 3 trials
- LE - 1 ½ tsp pudding = 3 trials
- LE - 10 cc water = 3 trials

- LE protrusion - 10 cc water = 3 trials
- LE - bite of Triscuit = 3 trails
- LE protrusion - bite of Triscuit = 3 trials

APPENDIX D: Consent Forms

Idaho State University

Human Subjects Committee

Informed Consent Form for Non-Medical Research

CONSENT TO PARTICIPATE IN RESEARCH

Examining the Effects of Ankyloglossia on Swallowing Function.

You are asked to participate in a research study conducted by Kliss Moulton, Masters Graduate Student in the department of Communication Sciences & Disorders and Education of the Deaf, Idaho State University, (208-419-9266). The co-investigator for this study is Tony Seikel, Ph.D., of Communication Sciences & Disorders, and Education of the Deaf, Idaho State University (208-282-4196). Data from this study will be reported in this student's Master's thesis. You have been asked to participate in this research because you have not been identified as having had a head injury or neurological or physical disease that could cause swallowing problems. This study is the first of its kind to look at swallowing ability in relation to individuals with tongue tie. 4 subjects will be included in this specific study. Your participation in this research project is voluntary. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

1. **PURPOSE OF THE STUDY**

This study is designed to examine several aspects of how a person swallows, including muscle strength, timing of swallowing, and swallow pattern.

2. **PROCEDURES**

If you volunteer to participate in this study, we would ask you to do the following things:

a. You will be asked to fill out a questionnaire concerning eating and health habits. The form will only have a number on it (not your name) so that your responses won't be identified with your name.

b. You will be given the Lingual Frenulum Protocol (LFP) to assess the presence or absence of Ankyloglossia (tongue tie). The LFP consists of a general case history and a clinical evaluation which consists of two parts. First general aspects of your tongue and frenum will be observed and measured including how wide you can open your mouth and tongue elevation. Second you will perform functional tests of tongue mobility which include the ability of your tongue to protrude and retract, touch your upper lip, move your tongue from side to side, touch your upper and lower molars, and suck your tongue up against the top of your mouth. You will also perform three speech tasks which include having you: discuss something of interest, count from 1 to 20, and name pictures.

c. I will apply electrodes to the side of your face to measure muscle contraction, and then I will ask you to bite down while I make recordings. I will then ask you to chew and swallow pudding and a cracker, as well as take drinks of water while I make these same recordings. I will hold your lips open at one point so I can observe what your tongue is doing during the swallow process. We will ask to look inside your mouth as well.

d. I will apply electrodes under your chin and to the area of your larynx (voice-box) and ask you to chew and swallow liquid, crackers, and pudding.

e. The total time should be approximately 30 minutes for your participation.

f. The study will be performed at the ISU Speech and Hearing Center in Pocatello, the ISU Speech and Language Clinic in Boise, or in your home if you wish.

g. Your session may be videotaped for the purposes of checking how accurately the researcher performed the examination. This video will be viewed by only Kliss Moulton, the researcher, and Tony Seikel, his faculty adviser. The video record will be kept in a secure location and will be destroyed at the end of the study.

3. **POTENTIAL RISKS AND DISCOMFORTS**

The procedures are standard procedures used to examine a person's swallow function. Preparation of your skin will involve cleaning an area using an electrode preparation gel, much like that used in EKG recordings. This may make your skin temporarily red, but that effect will not last long after the period of the study. If you are diabetic we will provide foods with artificial sweetener. If you are allergic to the foods being presented we ask that you not participate in the study. You might feel embarrassment by the attention to your eating habits or by the videotaping process. You could take food or liquid into your lungs (aspiration), which would be a sign of significant swallowing problems. In that case we would end the study and refer you to a physician for attention to this problem. The research procedures may involve risks that are currently unforeseeable. You should know that you are free to discontinue the study at any time.

4. **ANTICIPATED BENEFITS TO SUBJECTS**

This study may identify a swallowing problem that you have, so that you could receive treatment to alleviate the problem.

5. **ANTICIPATED BENEFITS TO SOCIETY**

This study will help researchers understand the relationship among variables related to swallowing, as well as provide some basic information about swallowing measurements

6. **ALTERNATIVES TO PARTICIPATION**

Participation is voluntary, and you may end participation at any time. There are no other alternatives to participation.

7. **PAYMENT FOR PARTICIPATION**

There is no payment offered or available for participation.

8. **FINANCIAL OBLIGATIONS**

You will not be asked to pay for any of these procedures.

9. **PRIVACY AND CONFIDENTIALITY**

The only people who will know that you are a research subject are members of the research team. No information about you, or provided by you during the research, will be disclosed to others without your written permission, except (a) if necessary to protect our rights or welfare (for example, if you are injured), or (b) if required by law.

When the results of the research are published or discussed in conferences, no information will be included that would reveal your identity. If photographs, videos, or audiotape recordings of you will be used for educational purposes, your identity will be protected or disguised. If a video of your participation were to be used you would be informed and have the right to decline its use. Data will be stored in a file cabinet in a locked office, and will be separated from your name so that no one could identify your data individually. Contact data will be destroyed seven years after publication of the research findings.

10. **PARTICIPATION AND WITHDRAWAL**

Your participation in this research is VOLUNTARY. If you choose not to participate, that will not affect your relationship with Idaho State University, or your right to receive services in any clinics or by healthcare providers. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without prejudice to your future at Idaho State University.

11. **WITHDRAWAL OF PARTICIPATION BY THE INVESTIGATOR**

The investigator may withdraw you from participating in the research if circumstances arise which warrant doing so. If you experience any of the following (coughing or hoarse voice after swallowing) you may have to drop out of the research, even if you would like to continue. The investigator (Tony Seikel) will make the decision and let you know if it is not possible for you to continue. The decision may be made either to protect your health and welfare, or because it is part of the research plan that people who develop certain conditions may not continue to participate.

12. **IDENTIFICATION OF INVESTIGATORS**

In the event of a research related injury or if you experience an adverse reaction, please immediately contact one of the investigators listed below. If you have any questions about the research, please feel free to contact Tony Seikel at 208-282-4196 or seikel@isu.edu at any time.

13. **RIGHTS OF RESEARCH SUBJECTS**

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have any questions regarding your rights as a research subject, you may contact the Human Subjects Committee office at 282-2179 or by writing to the Human Subjects Committee at Idaho State University, Mail Stop 8130, Pocatello, ID 83209.

Idaho State University
Human Subjects Committee
Assent Form

Child Assent Form (Ages 4-18)

Presence of Diagnostic Indicators of Oromyofunctional and Oropharyngeal Swallowing Problems.

1. My name is Kliss Moulton.

2. We are asking you to take part in a research study because we are trying to learn more about how people who have tongue tie swallow food and liquid. We are interested in changes that occur in the timing and strength of muscles when a person has tongue tie especially when different foods (pudding and crackers) and liquid are provided to an individual.

3. If you agree to be in this study you will be asked bite down while we measure muscle strength. Then you will be asked to swallow some water, a cracker, and some pudding. You will be asked to push your tongue against a device as hard as you can. As you do some of these tasks we will keep your lips open so we can watch what your mouth and tongue are doing when you swallow.

4. The only real risk is if you were to get food or liquid into your throat which might make you cough. This would tell me that you might be having problems with swallowing, so a speech therapist could test your swallowing more thoroughly. Also, when we put the electrodes on your face it might irritate your skin a little, but that shouldn't bother you for very long.

5. If you have trouble with swallowing or eating we might find this out so someone could help you to correct the problem.

6. This study will help us figure out how people with tongue tie swallow different types of food, and how strong their muscles are when they swallow.

7. We have already received permission from your parent(s) for you to participate in this research. Even though your parent(s) have given permission, you still can decide for yourself if you want to participate.

8. If you don't want to be in this study, you don't have to participate. Remember, being in this study is up to you and no one will be upset if you don't want to participate or even if you change your mind later and want to stop.

9. You can ask any questions that you have about the study. If you have a question later that you didn't think of now, you can ask me later.

Idaho State University

Human Subjects Committee

Parent Consent Form for Non-Medical Research

CONSENT TO PARTICIPATE IN RESEARCH

Examining the Effects of Ankyloglossia on Swallowing Function.

Your child is asked to participate in a research study conducted by Kliss Moulton, Masters Graduate Student in the department of Communication Sciences & Disorders and Education of the Deaf, Idaho State University, (208-419-9266). The co-investigator for this study is Tony Seikel, Ph.D., of Communication Sciences & Disorders, and Education of the Deaf, Idaho State University (208-282-4196). Information from this study will be reported in this student's Master's thesis. Your child has been asked to participate in this research because your child has been identified with having tongue tie. This study will look at swallowing ability in relation to individuals with tongue tie. Eight subjects will be included in this specific study. Your child's participation in this research project is voluntary. You should read the information below, and ask questions about anything you do not understand, before deciding whether to have your child participate. Deciding not to participate in this study will have no impact on your relationship with the researcher.

1. **PURPOSE OF THE STUDY**

This study is designed to examine several aspects of how a person swallows, including muscle strength, timing of swallowing, and swallow pattern.

2. **PROCEDURES**

If your child volunteers to participate in this study, he/she will participate in a one hour evaluation session. We would ask your child to do the following things:

a. Your child will be asked to fill out a questionnaire concerning eating and health habits. The form will only have a number on it (not your child's name) so that your child's responses won't be identified with your child's name.

b. Your child will be given the Lingual Frenulum Protocol (LFP) to assess the presence or absence of Ankyloglossia (tongue tie). The LFP consists of a general case history and a clinical evaluation which consists of two parts. First general aspects of your child's tongue and frenulum will be observed and measured including how wide your child can open his/her mouth and tongue elevation. Second your child will perform functional tests of tongue mobility which include the ability of his/her tongue to protrude and retract, touch his/her upper lip, move his/her tongue from side to side, touch his/her upper and lower molars, and suck his/her tongue up against the top of his/her mouth. Your child will also perform three speech tasks which include having his/her: discuss something of interest, count from 1 to 20, and name pictures.

c. I will apply electrodes to the side of your child's face to measure muscle contraction, and then I will ask him/her to bite down while I make recordings. I will then ask your child to chew and swallow pudding and a cracker, as well as take drinks of water while I make these same recordings. I will hold his/her lips open at one point so I can observe what the tongue is doing during the swallow process. We will ask to look inside your child's mouth as well.

d. I will apply electrodes under your child's chin and to the area of his/her larynx (voice-box) and ask him/her to chew and swallow liquid, crackers, and pudding.

e. The total time should be approximately 60 minutes for your child's participation.

f. The study will be performed at the ISU Speech and Hearing Center in Pocatello, or in your home if you wish.

g. Your child's session may be videotaped for the purposes of checking how accurately the researcher performed the examination. This video will be viewed by only Kliss Moulton, the researcher, and Tony Seikel, his faculty adviser. The video record will be kept in a secure location and will be destroyed at the end of the study.

3. **POTENTIAL RISKS AND DISCOMFORTS**

The procedures are standard procedures used to examine a person's swallow function. Preparation of your child's skin will involve cleaning an area using an electrode preparation gel, much like that used in EKG recordings. This may make your child's skin temporarily red, but that effect will not last long after the period of the study. If your child is diabetic we will provide foods with artificial sweetener. If your child is allergic to the foods being presented we ask that your child not participate in the study. Your child might feel embarrassment by the attention to his/her eating habits or by the videotaping process. Your child could take food or liquid into your lungs (aspiration), which would be a sign of significant swallowing problems. In that case we would end the study and refer your child to a physician for attention to this problem. The research procedures may involve risks that are currently unforeseeable. You should know that you or your child are free to discontinue the study at any time.

4. **ANTICIPATED BENEFITS TO SUBJECTS**

This study may identify a swallowing problem that your child has, so that your child could receive treatment to alleviate the problem.

5. **ANTICIPATED BENEFITS TO SOCIETY**

This study will help researchers understand the relationship among variables related to swallowing, as well as provide some basic information about swallowing measurements.

6. **ALTERNATIVES TO PARTICIPATION**

Participation is voluntary, and you or your child may end participation at any time. There are no other alternatives to participation.

7. **PAYMENT FOR PARTICIPATION**

There is no payment offered or available for participation.

8. **FINANCIAL OBLIGATIONS**

You will not be asked to pay for any of these procedures.

9. **PRIVACY AND CONFIDENTIALITY**

The only people who will know that your child is a research subject are members of the research team. No information about your child, or provided by you or your child during the research, will be disclosed to others without your written permission, except (a) if necessary to protect our rights or welfare (for example, if your child is injured), or (b) if required by law.

When the results of the research are published or discussed in conferences, no information will be included that would reveal your child's identity. If photographs, videos, or audiotape recordings of your child will be used for educational purposes, your child's identity will be protected or disguised. If a video of your child's participation were to be used you would be informed and have the right to decline its use. Data will be stored in a file cabinet in a locked office, and will be separated from your child's name so that no one could identify your child's data individually. Contact data will be destroyed five years after publication of the research findings.

10. **PARTICIPATION AND WITHDRAWAL**

Your child's participation in this research is VOLUNTARY. If you choose not to you're your child participate, that will not affect your or your child's relationship with Idaho State University, or your or your child's right to receive services in any clinics or by healthcare providers. If you decide to have your child participate, you are free to withdraw your consent and discontinue participation at any time without prejudice to your or your child's future at Idaho State University.

11. **WITHDRAWAL OF PARTICIPATION BY THE INVESTIGATOR**

The investigator may withdraw your child from participating in the research if circumstances arise which warrant doing so. If your child experiences any of the following (coughing or hoarse voice after swallowing) your child may have to drop out of the research, even if your child would like to continue. The investigator (Tony Seikel) will make the decision and let you and your child know if it is not possible for your child to continue. The decision may be made either to protect your child's health and welfare, or because it is part of the research plan that people who develop certain conditions may not continue to participate.

12. **IDENTIFICATION OF INVESTIGATORS**

In the event of a research related injury or if your child experiences an adverse reaction, please immediately contact one of the investigators listed below. If you have any questions about the research, please feel free to contact Tony Seikel at 208-282-4196 or seikel@isu.edu at any time.

13. **RIGHTS OF RESEARCH SUBJECTS**

You may withdraw your consent at any time and discontinue your child's participation without penalty. You are not waiving any legal claims, rights or remedies because of your child's participation in this research study. If you have any questions regarding your and your child's rights as a research subject, you may contact the Human Subjects Committee office at 282-2179 or by writing to the Human Subjects Committee at Idaho State University, Mail Stop 8130, Pocatello, ID 83209.

☐ **I have read the above terms and wish for my child to participate in this study.**

☐ **I have read the above terms and do not wish for my child to participate in this study.**

Participant's Parent's Signature **Date**

APPENDIX E: Raw Data for Subjects

SE 1				
	Trial 1	Trial 2	Trail 3	Average
M-Baseline A	52.99	30.2	32.84	38.67667
M-Baseline B	112.86	67.69	76.54	85.69667
M-pud .5 A max	90.6	70.83	46.86	69.43
M-pud .5 A avg	66.44	57.74	35.84	53.34
M-pud .5 B max	181.43	103.33	127.36	137.3733
M-pud .5 B avg	110.26	81.03	76.13	89.14
M-pud 1.5 A max	37.2	49.39	26.75	37.78
M-pud 1.5 A avg	21.8	36.14	18.56	25.5
M-pud 1.5 B max	42.48	49.39	51.87	47.91333
M-pud 1.5 B avg	27.6	59.2	33.68	40.16
M-water A max	33.21	17.35	22.94	24.5
M-water A avg	20.87	12.49	12.81	15.39
M-water B max	29.11	43.93	22.02	31.68667
M-water B avg	20.87	18.95	12.6	17.47333
M-tris A max	98.05	106.53	122.88	109.1533
M-tris A avg	68.95	57.95	56.89	61.26333
M-tris B max	183.85	132.25	131.6	149.2333
M-tris B avg	121.96	74.61	93.93	96.83333
LE pudding .5	2.14	1.72	1.58	1.813333
LE pudding 1.5	1.39	1.97	1.91	1.756667
LE water	1.12	0.9	1.01	1.01
LE triscuit	1.12	0.9	1.01	1.01
Iopitip	55	44	44	47.66667
Iopidor	37	32	34	34.33333
Iopitong	4	6	6	5.333333

SE 2				
	Trial 1	Trial 2	Trail 3	Average
M-Baseline A	558.05	701.7	711.75	657.1667
M-Baseline B	633.13	614.51	709.73	652.4567
M-pud .5 A max	64.4	23.77	35.56	41.24333
M-pud .5 A avg	27.07	12.4	12.99	17.48667

M-pud .5 B max	51.61	23.39	26.73	33.91
M-pud .5 B avg	27.06	13.69	16.5	19.08333
M-pud 1.5 A max	42.29	47.54	15.01	34.94667
M-pud 1.5 A avg	18.7	18.93	11	16.21
M-pud 1.5 B max	59.94	47.3	31.57	46.27
M-pud 1.5 B avg	27.57	22.73	15.55	21.95
M-water A max	41.39	48.22	42.88	44.16333
M-water A avg	16.01	16.71	17.56	16.76
M-water B max	53.68	37.88	33.87	41.81
M-water B avg	23.46	17.51	20.45	20.47333
M-tris A max	26.98	68.66	90	61.88
M-tris A avg	15.24	25.14	39.96	26.78
M-tris B max	42.05	62.7	82.32	62.35667
M-tris B avg	20.68	23.68	41.88	28.74667
LE pudding .5	1.24	1.56	1.34	1.38
LE pudding 1.5	1.01	1.29	1.13	1.143333
LE water	1.15	0.99	0.96	1.033333
LE triscuit				
IOPItip	54	40	35	43
IOPIdor	44	42	38	41.33333
IOPIton	8	13	10	10.33333

SE 3				
	Trial 1	Trial 2	Trail 3	Average
M-Baseline A	96.85	127.71	83.14	102.5667
M-Baseline B	105.51	140.42	114.94	120.29
M-pud .5 A max	31.26	42.76	49.98	41.33333
M-pud .5 A avg	21.7	22.82	34.98	26.5
M-pud .5 B max	99.42	96.73	99.2	98.45
M-pud .5 B avg	50.29	54.37	51.01	51.89
M-pud 1.5 A max	43.15	42.5	81.23	55.62667
M-pud 1.5 A avg	27.94	25.64	38.24	30.60667
M-pud 1.5 B max	98.93	76.67	75.98	83.86

M-pud 1.5 B avg	48.75	50.41	43.19	47.45
M-water A max	60.43	88.78	78.9	76.03667
M-water A avg	27.72	33.62	34.14	31.82667
M-water B max	116.69	120.98	105.95	114.54
M-water B avg	44.36	49.65	47.34	47.11667
M-tris A max	43.45	202.12	52.76	99.44333
M-tris A avg	29.15	77.21	35.71	47.35667
M-tris B max	186.96	314.44	157.48	219.6267
M-tris B avg	68.17	154.96	79.06	100.73
LE pudding .5	1.4	1.97	1.3	1.556667
LE pudding 1.5	1.4	1.23	1.43	1.353333
LE water	0.87	0.97	1.12	0.986667
LE triscuit	1.4	1.45	0.99	1.28
IOPITip	21	17	12	16.66667
IOPIdor	42	38	30	36.66667
IOPIlip	32	31	30	31

SE 4				
	Trial 1	Trial 2	Trail 3	Average
M-Baseline A	107.65	150.76	122.3	126.9033
M-Baseline B	216.04	229.48	210	218.5067
M-pud .5 A max	15.91	13.21	20.66	16.59333
M-pud .5 A avg	7.47	9.12	9.57	8.72
M-pud .5 B max	10.26	9.84	16.09	12.06333
M-pud .5 B avg	6.89	7.45	9.82	8.053333
M-pud 1.5 A max	15.26	38.75	13.81	22.60667
M-pud 1.5 A avg	11.47	15.78	7.14	11.46333
M-pud 1.5 B max	64.4	23.71	27.9	38.67
M-pud 1.5 B avg	19.12	13.77	11.68	14.85667
M-water A max	9.31	11.63	19.39	13.44333
M-water A avg	6.41	6.93	11.77	8.37
M-water B max	7.95	10	27.22	15.05667
M-water B avg	6.06	6.87	15.07	9.333333
M-tris A max	276.55	109.75	29.5	138.6

M-tris A avg	103.91	32.67	15.26	50.61333
M-tris B max	833.86	369.91	92.34	432.0367
M-tris B avg	240.99	97.79	23.91	120.8967
LE pudding .5	1.44	1.7	1.1	1.413333
LE pudding 1.5	0.76	1.26	1.09	1.036667
LE water	0.85	0.99	1.3	1.046667
LE triscuit	1.2	1.21	1.47	1.293333
IOPItip	50	46	49	48.33333
IOPIdor	48	36	28	37.33333
IOPIlip	11	11	14	12

SE 5				
	Trial 1	Trial 2	Trail 3	Average
M-Baseline A	230.13	263.07	355.58	282.9267
M-Baseline B	152.35	176.22	189.37	172.6467
M-pud .5 A max	117.8	144.11	92.28	118.0633
M-pud .5 A avg	33.59	42.41	29.75	35.25
M-pud .5 B max	28.62	55.21	71.56	51.79667
M-pud .5 B avg	18.3	18.74	30.1	22.38
M-pud 1.5 A max	182.28	212.33	196.62	197.0767
M-pud 1.5 A avg	56.16	76.6	59.84	64.2
M-pud 1.5 B max	38.08	80.28	101.59	73.31667
M-pud 1.5 B avg	23.11	31.73	32.2	29.01333
M-water A max	9.31	11.63	19.39	13.44333
M-water A avg	6.41	6.93	11.77	8.37
M-water B max	7.95	10	27.22	15.05667
M-water B avg	6.06	6.87	15.07	9.333333
M-tris A max	276.55	109.75	29.5	138.6
M-tris A avg	103.91	32.67	15.26	50.61333
M-tris B max	833.86	369.91	92.34	432.0367
M-tris B avg	240.99	97.79	23.91	120.8967
LE pudding .5	1.15	1.16	1.35	1.22
LE pudding 1.5	1.1	1.1	1.13	1.11
LE water	1.25	1.18	1.29	1.24
LE triscuit	1.64	1.22	1.14	1.333333

IOPItip	38	28	30	32
IOPIdor	30	18	28	25.33333
IOPIlip	10	6	5	7

SE 6				
	Trial 1	Trial 2	Trail 3	Average
M-Baseline A	239.23	279.06	250.88	256.39
M-Baseline B	198.48	166.97	195.83	187.0933
M-pud .5 A max	176.22	95.56	44.15	105.31
M-pud .5 A avg	56.89	30.66	22.49	36.68
M-pud .5 B max	165.21	180.23	182.68	176.04
M-pud .5 B avg	88.81	93.19	58.82	80.27333
M-pud 1.5 A max	59.87	38.93	47.96	48.92
M-pud 1.5 A avg	28.99	25.71	26.67	27.12333
M-pud 1.5 B max	204.51	173.99	170.33	182.9433
M-pud 1.5 B avg	89.83	71.83	93.35	85.00333
M-water A max	37.03	39.81	31.04	35.96
M-water A avg	25.08	23.98	18.58	22.54667
M-water B max	221.09	176.05	139.66	178.9333
M-water B avg	107.49	90.92	62.99	87.13333
M-tris A max	55.03	97.09	127.25	93.12333
M-tris A avg	31.48	38.24	58.48	42.73333
M-tris B max	307.99	218.63	276.39	267.67
M-tris B avg	144.97	109.07	190.01	148.0167
LE pudding .5	1.5	1.75	2.18	1.81
LE pudding 1.5	1.4	2.23	1.29	1.64
LE water	1.09	1.36	1.36	1.27
LE triscuit	1.72	1.45	1.99	1.72
IOPItip	48	41	33	40.66667
IOPIdor	37	41	36	38
IOPIlip	14	21	23	19.33333

SE 7				

	Trial 1	Trial 2	Trail 3	Average
M-Baseline A	184.87	169.69	161.61	172.0567
M-Baseline B	141.35	147.23	124.87	137.8167
M-pud .5 A max	99.49	16.43	86.3	67.40667
M-pud .5 A avg	37.35	10.9	51.44	33.23
M-pud .5 B max	93.69	25.56	70.23	63.16
M-pud .5 B avg	41.26	12.97	44.32	32.85
M-pud 1.5 A max	22.77	48.34	31.06	34.05667
M-pud 1.5 A avg	16.82	19.65	23.34	19.93667
M-pud 1.5 B max	27.88	42.19	29.28	33.11667
M-pud 1.5 B avg	17.24	16.44	24.14	19.27333
M-water A max	14.71	17.82	17.22	16.58333
M-water A avg	9.69	10.4	11.39	10.49333
M-water B max	21.84	20.93	19.16	20.64333
M-water B avg	11.95	14.13	12.17	12.75
M-tris A max	21.6	20.35	142.59	61.51333
M-tris A avg	15.69	13.46	56.97	28.70667
M-tris B max	28.11	28.19	128.71	61.67
M-tris B avg	17.7	18.79	51.45	29.31333
LE pudding .5	1.35	1.45	1.31	1.37
LE pudding 1.5	1	0.99	0.84	0.943333
LE water	0.66	0.87	0.82	0.783333
LE triscuit	0.81	0.8	0.8	0.803333
IOPItip	22	22	23	22.33333
IOPIdor	13	18	14	15
IOPIlip	20	21	18	19.66667

SE 8				
	Trial 1	Trial 2	Trail 3	Average
M-Baseline A	122.26	53.99	86.44	87.56333
M-Baseline B	202.24	16.54	160.3	126.36
M-pud .5 A max	51.26	30.23	37.46	39.65
M-pud .5 A avg	30.42	16.5	22.8	23.24
M-pud .5 B max	89.32	41.56	42.51	57.79667
M-pud .5 B avg	41.27	20.37	27.54	29.72667

M-pud 1.5 A max	23.34	31.29	33.5	29.37667
M-pud 1.5 A avg	17.64	23.42	23.84	21.63333
M-pud 1.5 B max	28.71	41.18	56.19	42.02667
M-pud 1.5 B avg	18.04	26.67	33.18	33.18
M-water A max	35.78	41.21	32.9	36.63
M-water A avg	18.72	19.14	19.79	19.21667
M-water B max	42.81	57.71	43.85	48.12333
M-water B avg	24.06	27.3	21.26	24.20667
M-tris A max	30.05	23.11	25.55	26.23667
M-tris A avg	18.81	14.45	10.17	14.47667
M-tris B max	30.47	30.45	26.15	29.02333
M-tris B avg	20.67	15.67	10.18	15.50667
LE pudding .5	1.12	1.09	0.88	1.03
LE pudding 1.5	1.17	0.74	0.91	0.94
LE water	0.86	0.79	1.12	0.923333
LE triscuit	0.88	1.14	0.99	1.003333
IOPITip	21	23	19	21
IOPIdor	12	18	19	16.33333
IOPIlip	20	23	25	22.66667