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Instrumental Investigation of the Effects of Tongue Thrust on Swallow Function

Lyndsey M. Evans

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in the Department of
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Committee Approval

To the Graduate Faculty:

The members of the committee appointed to examine the thesis of Sydni Arnold find it satisfactory and recommend that it be accepted.

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December 23, 2014

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RE: Your application dated 12/23/2014 regarding study number 4178: Instrumental Investigation of the Effects of Tongue Thrust on Swallow Function

Dear Ms. Evans:

Thank you for your response to requests from a prior review of your application for the new study listed above. Your response is eligible for expedited review under FDA and DHHS (OHRP) designation.

This is to confirm that your application is now fully approved. The protocol is approved through 12/23/2015.

You are granted permission to conduct your study as most recently described effective immediately. The study is subject to continuing review on or before 6/23/2015, unless closed before that date.

Please note that any changes to the study as approved must be promptly reported and approved. Some changes may be approved by expedited review; others require full board review. Contact Tom Bailey (208-282-2179; fax 208-282-4723; email: humsubj@isu.edu) if you have any questions or require further information.

Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

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Abstract

Although tongue thrust and oropharyngeal dysphagia (OPD) share many characteristics, they are treated separately without evidence of a relationship in the field of speech-language pathology. The present study included six subjects, ranging from 11-40 years of age, with behavioral and clinical indicators of oromyofacial disorders (OMD). The purpose of the study was to replicate a study that found significant differences in masseter contraction and swallow timing in individuals with tongue thrust when compared to normative data (Evers, 2013). The study evaluated tongue tip strength, tongue dorsum strength, lip strength, masseter contraction, and oropharyngeal transit time in the subjects, who were all found to have tongue thrust. Results were then compared to normative data, which were gathered from a previous study (Holzer, 2011) to determine if significant differences exist.

Results revealed significant differences that suggest possible OPD signs in the subjects diagnosed with OMD. Specifically, the subjects were found to have significantly decreased lip strength and significantly increased oropharyngeal transit time. Increased oropharyngeal transit time, which was found across all subjects, is one risk factor associated with OPD. Thus, it appears that tongue thrust is related functionally and etiologically to OPD, implying that presence of this OMD may be predictive of OPD in later life.

Chapter 1: Review of Literature

Introduction

To sustain appropriate levels of nutrition and hydration, it is imperative that individuals safely consume foods and liquids that will later be digested in the body. Two major processes that make this possible are mastication and deglutition, otherwise knowing as chewing and swallowing, respectively (Seikel, King, & Drumright, 2015). The act of swallowing is carried out by several facial muscles, mandibular muscles, lingual muscles, velar muscles, pharyngeal muscles, laryngeal muscles, and cranial nerves (Seikel et al., 2015), proving to be quite a complex task, though often done with little to no thought.

Although swallowing typically occurs naturally and effortlessly in most individuals, deficits can occur during any of the four stages of the swallow. Deficits that may be observed prior to and during the swallowing process include, but are not limited to the following: muscle weakness, reduced sensation, dysfunction of anatomical structures, failure to protect the airway, premature spillage of foods and liquids, delayed or absent initiation of the swallow, gastroesophageal reflux disease (GERD), pain, choking, poor control of salivary secretions, or lack of salivary secretions (Groher, 1997; Logemann & Larsen, 2012; Seikel et al., 2015).

When an individual demonstrates impairments that hinder the transportation of foods or liquids from the mouth to the stomach, they are said to have dysphagia (Arvedson & Brodsky; Logemann, 1998). According to a statistic reported by Smith-Hammond and Goldstein (2006), aspiration pneumonia, a life-

threatening consequence of dysphagia, “occurs in 4 to 8 of every 1,000 patients who are admitted to hospitals in the United States (p. 156S). Because dysphagia has several negative implications, it is critical that individuals are appropriately assessed and treated to ensure optimal safety when consuming foods and liquids orally (Logemann, 1998). This literature review will discuss the stages of the swallow, development of the swallow, oromoyfunctional disorders (OMD), and oropharyngeal dysphagia (OPD). Additionally, instrumental evaluation of swallow function and bedside evaluation of swallow function will also be discussed.

Stages of the Swallow

The act of swallowing has been broken into four distinct, agreed upon stages: 1) oral preparatory stage, 2) oral stage, 3) pharyngeal stage, and 4) esophageal stage, all of which commonly occur without thought or effort (Logemann, 1998; Seikel et al., 2015). The oral preparatory stage occurs when an individual anticipates food or liquid as it approaches and enters the oral cavity (Logemann, 1998). Foods and liquids can be presented into the mouth by a variety of modalities, including eating utensils, fingers, cups, or straws. It is imperative that an individual maintains appropriate labial seal during this stage to prevent food or liquid spillage (Logemann, 1998). During this stage, the airway remains open and the individual breathes through his or her nose (Logemann, 1998). Once the food or liquid enters the mouth, various muscles of mastication form the food/liquid into a cohesive ball commonly referred to as the bolus. Specifically, the masseter, temporalis, medial pterygoid, and lateral pterygoid are

critical muscles that are used during mastication. Several lingual muscles also play a vital role during this stage as the tongue moves the bolus within the oral cavity and forms a cohesive, appropriate-to-swallow bolus. As the individual masticates, the parotid, submandibular, and sublingual glands secrete saliva, making the bolus a more appropriate consistency to swallow.

The oral stage of the swallow is initiated once the consistency of the bolus is appropriate for the individual to swallow. According to Seikel et al. (2015), the following six tongue muscles are involved in this stage of the swallow: mylohyoid, superior longitudinal, vertical, genioglossus, styloglossus, and palatoglossus. As the tongue tip makes contact with the hard palate and the tongue base bunches in the posterior region of the oral cavity, the bolus is essentially squeezed posteriorly towards the faucial pillars. The mature swallow depends on the contraction of all of the following muscles: masseter, temporalis, and medial pterygoid. According to Fletcher, Casteel, and Bradley (1961), individuals with deviant swallow patterns typically present with decreased contraction of mastication muscles, which can often be felt during palpation. The duration of the oral stage is approximately 1-1.5 seconds, but may take longer with more viscous consistencies of boluses (Logemann, 1998). The pharyngeal stage is triggered once the bolus comes into contact with one of the following structures: the faucial pillars, the soft palate which is commonly referred to as the velum, or the base of the tongue (Logemann, 1998).

During the pharyngeal stage, which typically lasts 1 second or less (Logemann & Larsen, 2012), several anatomical structures work together to carry

out involuntary yet complex responses (Seikel et al., 2015). To prevent nasal regurgitation of material, the once-depressed velum elevates (Matsuo & Palmer, 2008). Velopharyngeal closure also increases pressure of the pharynx, which drives the bolus towards the esophagus (Seikel et al., 2015). Elevation and protraction of the hyoid and larynx is also observed during this stage, which typically occurs at the same time as velopharyngeal closure (Logemann, 1998). Following elevation of the larynx, a sequence of movements begins that is protective in nature. Once the larynx elevates, adduction of the vocal folds and inversion of the epiglottis occur in order to prevent the bolus from entering the esophagus (Logemann, 1998; Seikel et al., 2015). Next, the tonically-contracted upper esophageal sphincter (UES) relaxes and is pulled open as a result of the elevation and protraction movements of the hyoid and larynx (Logemann, 1998; Seikel el al., 2015). Opening of the UES makes it possible for the bolus to pass through the pharynx and to enter the esophagus (Logemann, 1998).

Finally, the esophageal stage occurs as the bolus travels from the upper esophageal sphincter (UES) to the stomach (Logemann, 1998). A critical point made by Seikel et al. (2015) is that this stage of the swallow is “purely reflexive and is not within voluntary control” (p. 464). As the bolus passes through the UES of the esophagus, it travels to the lower esophageal sphincter (LES) via peristalsis waves (Logemann, 1998; Seikel et al., 2015). This typically lasts 8-20 seconds (Logemann, 1998; Seikel et al., 2015). Because the LES is typically contracted at rest, it must relax in order to open (Matsuo & Palmer, 2008). Once the LES opens, the bolus enters the stomach, which concludes the four stages of

the swallow (Logemann, 1998).

Development of the Swallow

Several anatomical structures and motor movements that are directly and indirectly involved in swallowing first appear *in utero* and undergo significant changes as the newborn infant develops (Arvedson & Brodsky, 2002; Seikel et al., 2015). The pharyngeal swallow first appears in the 10th week of gestation (Arvedson & Brodsky, 2002) and non-nutritive sucking is evident in the 15th week of gestation (Seikel et al., 2015). A suckling response emerges between the 18th and 24th week of gestation (Arvedson & Brodsky, 2002; Delaney & Arvedson, 2008). Suckling and swallowing responses are typically mature enough to sustain appropriate nutrition by the 34th week of gestation, which is critical for pre-term infants (Arvedson, & Brodysky, 2002).

The newborn infant demonstrates the rooting reflex, in which he or she turns their head with their mouth open towards the cheek in which tactile stimulation was applied (Seikel et al., 2015). Breathing and swallowing at the same time is observed in newborn infants, a skill that diminishes with development (Smith-Hammond & Goldstein, 2006). From birth to infancy, the pumping action of the tongue, which is exhibited by the newborn, undergoes changes. Specifically, from birth to 6 months of age, infants demonstrate an in-out suckling pattern (Seikel et al., 2015) and by the second 6 months of life, infants begin demonstrating an up-down sucking pattern (Avedson & Brodsky, 2002).

In regard to the various structures of the oropharynx in infants, the size of

the mouth is smaller, the larynx and hyoid are located higher in the oropharynx, and the size of the velum is larger than observed in adults (Seikel et al., 2015). As the infant develops, the size of the mouth increases and the larynx and hyoid descend into the oropharynx. According to Vorperian et. al (2009), the vocal tract "increases…from approximately 7 to 8 cm in infants to 15 to 18 cm in adult females and males, respectively" (Vorperian et. al, 2009, p. 1666).

Eruption of dentition occurs at approximately 6 months of age, prompting introduction of chewable foods (Seikel et al., 2015). The once observed anterior thrust of the tongue during the swallow becomes obstructed by the presence of teeth (Seikel et al., 2015). According to Arvedson and Brodsky (2002), the once "munching" chewing pattern exhibited at 6 months of age diminishes and the infant begins using a "rotary jaw action" for chewing at 7 months of age, which is later mastered between 19 and 24 months of age (p. 71).

During the last 6 months of the first year of life, the infant begins to gain more control over his or her posture, which prepares the infant to self-feed (Arvedson & Brodsky, 2002). All babies between 13-18 months of age are expected to be able to drink from a straw and to be able to accept foods of all textures (Arvedson & Brodsky, 2002). As the baby continues to grow and develop, total self-feeding, including drinking from a cup, is expected between 24 and 36 months of age (Arvedson & Brodsky, 2002).

Orofacial Myofunctional Disorders

The International Association of Orofacial Myology (IAOM) has defined orofacial myofunctional disorders (OMDs) as "behaviors and patterns created by

inappropriate muscle function and incorrect habits involving the tongue, lips, jaw and face" (International Association of Orofacial Myology, n.d.). OMDs can be caused by one or more of the following commonly agreed upon etiologies: noxious oral habits (e.g. thumb sucking, lip/nail/cheek biting, clenching/grinding of the teeth), allergies, enlarged tonsils and/or adenoids, ankyloglossia, or heredity for anatomical and/or physiological deviations (American Speech-Language-Hearing Association, n.d.; International Association of Orofacial Myology, n.d.). The four OMDs include: noxious oral habits, abnormal tongue rest posture, abnormal lip rest posture, and tongue thrust (Mason, 2009). According to Mason, the one aspect that is shared among all OMDs is that all OMDs "result in change in the vertical dimension, or free way space" (Mason, 2009).

Tongue thrust, the specific OMD to be examined in the present study, is the most prevalent OMD (International Association of Orofacial Myology, n.d.). According to the American Speech-Language-Hearing Association (ASHA) (American Speech-Language-Hearing Association, n.d.) the presence of tongue thrust is not atypical in infants, but should be eliminated as children develop. However, acquired tongue thrust observed in adults is often associated with neurologic injury (Logemann, 1998).

Individuals with signs of tongue thrust demonstrate distinctive characteristics that differ from individuals without signs of tongue thrust, many of which are visually apparent. According to Hanson and Mason (2003), individuals with tongue thrust typically demonstrate excessive vertical freeway space

between upper and lower dental arches, and therefore demonstrate open mouth breathing; on the other hand, individuals with normal resting posture breathe through the nose with closed lips. During abnormal tongue rest posture, the tongue rests forward or on the floor of the oral cavity, against the lower or upper teeth (Hanson & Mason, 2003). However, during normal tongue rest posture, the tongue tip makes contact against the upper alveolar ridge, as the rest of the tongue rests in the oral cavity (Hanson & Mason, 2003).

It is known among OMD professionals that tongue thrust is a sign that something else is occurring, such as a residual habit or issues with the individual's upper airway (Mason, 2009). It is critical to acknowledge the numerous negative implications of OMDs. OMDs can negatively affect an individual's facial structure, management of salivary secretions, and eating and drinking habits (American Speech-Language-Hearing Association, n.d.; Hanson & Mason 2003; International Association of Orofacial Myology, n.d.). It is also expected that disruptions of the vertical freeway space will lead to dental issues (Mason, 2009). OMDs can negatively impact the eruption and growth of teeth, potentially leading to dental malocclusions (Mason, 2008).

Individuals can demonstrate tongue thrust during speech and/or swallowing (Mason, 2009). According to the IAOM (n.d.), 38% of individuals have OMD, with 81% of individuals with OMD being children who demonstrate speech sound disorders. Speech may also be affected by the presence of tongue thrust. The following speech sounds are commonly misarticulated by individuals with tongue thrust: /r, l, s, t, d, n/ (Hanson & Mason, 2008).

Several terms have been used to describe the swallow pattern observed in individuals with tongue thrust, including the following: *deviate swallow*, *deviant swallow*, *reversed swallow*, *perverted swallow*, *infantile swallow*, and *abnormal swallow* (Mason, 1988; Pierce, 1978). When referring to the swallow pattern exhibited by individuals with tongue thrust, Mason (2009) encourages using the term "tongue thrust swallow." During a "tongue thrust swallow," instead of elevating the tongue tip as expected, the individual's tongue tip moves forward, protruding between the teeth (Mason, 2009). This atypical swallow pattern sometimes results in foods and/or liquids being forced out of the individual's mouth (Logemann, 1998). Additionally, due to the lack of use of facial muscles and decreased muscle strength, individuals with tongue thrust generally do not form cohesive boluses (Hanson & Mason, 2008).

According to Pierce (1978), a challenge regarding identification of tongue thrust, which is still relevant today, is the lack of a universal criterion to evaluate and diagnose individuals as having tongue thrust. According to Hanson and Mason (2008), clinicians must carefully inspect the appearance and function of the following structures when evaluating individuals for tongue thrust: symmetry of the face, overall presence of the face, dentition, presence or absence of malocclusions, deviations of the hard and soft palate, appearance of the uvula, presence or absence of tonsils, pharyngeal wall constriction during phonation, presence or absence of gag reflex, tongue strength, tongue mobility, and tongue coordination.

The *Stone Tongue Thrust Protocol* (STTP) (Stone, 2010) (see Appendix

A) is one measure used in clinical diagnosis and treatment of tongue thrust in Idaho. There are two portions to the STTP: *Oral Evaluation* and *Treatment Protocol* (Stone, 2010). The *Oral Evaluation* portion of the STTP includes the following main sections: *History*, *Oral/Motor Exam*, *Clinical Swallowing Evaluation Oral Prep Phase*, *Comments/Impressions*, and *Recommendations* (Stone, 2010). The *History* section of the STTP includes questions relating to the individual's eating and drinking habits, difficulty swallowing certain foods, and history of thumb sucking and/or pacifier use (Stone, 2010). In the *Oral/Motor Exam* section, the clinician evaluates the appearance and function of the various structures: dentition, tongue, palate, and lips (Stone, 2010). Also included in the *Oral/Motor Exam* is evaluation of the patient's breathing patterns and production of speech sounds (Stone, 2010). In the next section, the *Clinical Swallow Evaluation Oral Prep Phase*, the clinician evaluates various characteristics of the oral preparatory stage, oral phase, and pharyngeal stage (Stone, 2010). Stone explained the *Oral Evaluation* portion to be very similar to a bedside evaluation (C. Stone, personal communication, September 26, 2014). Some observations made during this portion of the protocol include chewing pattern, poor lip seal, burping post-swallow, or pursing of the lips (Stone, 2010). Additional observations and/or recommendations are to be recorded in the *Comments/Impressions* portion of the protocol form (Stone, 2010).

According to Stone, "If an individual has a 'reverse swallow,' they have tongue thrust" (C. Stone, personal communication, September 26, 2014). Stone (2010) has defined the "reverse swallow" as "a forward thrusting of the tongue

where the tip of the tongue moves the bolus posteriorly." It is important to note that the term "reverse swallow" is considered outdated amongst OMD professionals.

Although the importance of treating OMDs is still not fully recognized by some professionals, it is the goal of the IAOM that OMD professionals continue to educate the public and other professionals on the importance of identifying and treating OMDs. Identification and treatment of OMDs involves the collaboration of several professionals from various fields. According to Hanson and Mason (2003), the following professionals are vital to the field of orofacial myology: speech-language pathologists, dentists, orthodontists, oral and maxillofacial surgeons, peridontists, pediatricians, family physicians, allergists, and orolaryngologstis (ENTS).

Oropharyngeal Dysphagia

When an individual demonstrates swallowing deficits that interfere with the transportation of foods and liquids from the mouth to the stomach, the individual is said to have dysphagia (Logemann 1998). According to Groves-Wright and Kelchner (1999), an individual with OPD may present with the following signs: a delayed or absent trigger of the pharyngeal swallow, aspiration of foods and liquids, unintentional escape of foods and liquids into the nasopharynx, or the presence of residue post-swallow in the pharynx. According to Logemann (1998), aspiration occurs when foods and liquids escape beyond the point of the true vocal folds. Individuals with OPD may also experience penetration, which occurs when foods and liquids pass to, but not beyond, the point of the true vocal

folds (Logemann, 1998).

Dysphagia can negatively impact the overall well-being of an individual. Specifically, dysphagia can lead to lack of proper nutritional intake, insufficient water intake, or the development of pneumonia, all of which are potentially life-threatening (Logemann, 1998; Matsuo & Palmer, 2008). Dysphagia can also negatively impact an individual's social and emotional health. In a study conducted by Leow et al. (2010) the *Swallowing Quality of Life* (SWAL-QOL) questionnaire was administered to typically aging individuals in good health and individuals with Parkinson's Disease, a population with a high incidence of dysphagia, to determine the impact of swallowing disorders on quality of life. Results at the conclusion of the study revealed that the individuals with Parkinson's Disease rated themselves as having a significantly reduced quality of life due to the following: trouble choosing textures of foods that were safe to consume, trouble choosing foods they both enjoyed and could safely consume, and the burden of having a swallowing disorder (Leow, Huckabee, Anderson, & Beckert, 2010).

Achieving a safe swallow on all regular diet food textures and liquid consistencies is not always attainable. Therefore, some individuals must either modify their diets by altering consistencies of allowable foods and liquids, utilizing eating techniques and strategies, or receiving nutrients via feeding tubes to ensure optimal safety (Groves-Wright, Boyce, & Kelchner, 2010; Vesey, 2013). However, many patients receive nutrition both orally and from a feeding tube, which ensures nutritional needs are met while still allowing the patient to enjoy

and take pleasure in eating (Vesey, 2013).

OPD has several etiologies. Commonly known disorders that are present at birth that are associated with dysphagia include cerebral palsy, cleft palate, and muscular dystrophy (Logemann & Larsen, 2012). Osteophytes in the cervical vertebrae region, webs, strictures, scar tissue, or cricopharyngeal bars are all examples of structural abnormalities than can compromise the swallow (Logemann & Larsen, 2012; Matsuo & Palmer, 2008). Stroke, traumatic brain injury (TBI), injury to the cervical spinal cord, and Guillain-Barré are neurological conditions that can cause dysphagia (Logemann, 1998). Alzheimer's disease, Amyotrophic Lateral Sclerosis (ALS), Werdnig-Hoffmann disease, Parkinson's Disease, and myasthenia gravis are degenerative diseases that are associated with impaired swallow function (Logemann, 1998). Radiation can cause dysphagia due to fibrosis of the muscles and surgery of the head and neck can also impair the swallow to some extent (Logemann & Larsen, 2012). Medications can also negatively affect the swallow by weakening muscles or drying out the oral cavity (Logemann & Larsen, 2012).

Bedside Evaluation of Swallow Function

When working with patients who are suspected to be at risk for aspiration, a beside examination, which is also known as a clinical evaluation, is conducted to determine if an in-depth diagnostic instrumental evaluation is warranted (Logemann, 1998; Logemann & Larsen, 2012; Speyer, 2013). For the sake of consistency, the term bedside evaluation will be used in this literature review. One weakness of the bedside evaluation, as supported by results from a study

conducted by Leder and Espinosa (2002), is that the bedside evaluation of swallow function does not always correctly identify patients with and without aspiration risks. Another disadvantage of the bedside evaluation, as explained by Logemann (1998), is that clinicians neglect to recognize the occurrence of aspiration 40% of the time. Another disadvantage of the bedside evaluation of swallow function is that the perceived assessment measures can be rather subjective (Yoshida, Kikutani, Tsuga, Utanohara, Hayashi, & Akagawa, 2006). These statistics suggest that, unless an instrumental evaluation of swallow function is conducted, appropriate treatment may unintentionally be withheld from patients (Leder & Espinosa, 2002).

According to Logemann (1998) the speech-language pathologist should conduct a thorough chart review prior to meeting the patient to identify the following information: the patient's health history, the patient's current health status, medications currently and formerly taken, previous complaints or diagnoses indicating a swallowing problem, if the patient relies on some type of airway device, and if the patient receives nutrition orally or non-orally. Upon meeting the patient, the clinician should observe the patient's positioning, attentiveness, respiratory behaviors, management of secretions, and level of cognitive ability (Logemann, 1998). Observation of the patient's general appearance can also indicate whether or not the patient is well nourished and hydrated (Miller, 1997).

It is imperative for the clinician to interview the patient, the patient's caregivers, or a health care professional regarding the patient's presenting

problems (Miller, 1997). Questions that can provide useful information include the onset and progression of symptoms, what worsens and relieves the symptoms, if/where food feels like it is getting lodged, if the patient ever coughs, and if the patient chokes (Logemann, 1998; Miller, 1997). Information obtained from both the chart review and the interview can help the clinician narrow the stages of the swallow in which the patient is experiencing difficulty, what food and liquid textures and consistencies are easiest for the patient to consume, and possible causes of the swallowing disorder (Logemann, 1998).

The next step of the bedside evaluation is to thoroughly inspect the general appearance of the oral mechanism, making note of the presence of asymmetry and other atypical deviations (Logemann, 1998). Once the structures have been observed at rest, the clinician will conduct an oral-motor control examination to evaluate the function of the structures of the oral mechanism (Logemann, 1998). Tasks that include prolonged vowels and rate of diadochokinetic production are two ways the clinician can evaluate the patient's vocal quality and speech (Miller, 1997). Additionally, the clinician will instruct the patient to perform various oral-motor tasks to evaluate the function of the following structures of the oral mechanism: lips, tongue, hard palate, soft palate, larynx, and various muscles of mastication (Logemann, 1998; Miller, 1997).

Depending on the current health status of the patient, the clinician will proceed to conduct swallow trials (Logemann, 1998). The consistencies and textures of foods and liquids typically administered during a bedside evaluation include thin liquids, thick liquids, puree, and solids (McCullough et al., 2005).

According to Logemann (1998), selection of the food texture and liquid consistency to be administered to the patient will be contingent on the "information collected in the history, data on oral control, and information on pharyngeal and laryngeal control" (p. 162). During each swallow trial, the clinician should observe for overt signs and symptoms of aspiration, buildup of food in the oral cavity, and whether or not certain postural adjustments improve the swallow (Miller, 1997).

During swallow trials, palpation of the neck is crucial when determining whether or not elevation and protraction of the larynx occurs during the swallow (Miller, 1997) and to estimate the duration of the swallow (Logemann, 1998). The five-finger palpation method, as described by Logemann (1998), includes gently placing "the index…behind the mandible anteriorly, 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" (p. 165). Because the five-finger palpation method only provides the clinician with an approximated duration of oral transit time and pharyngeal time (Logemann, 1998) the method can be subjective.

It is not uncommon for the clinician to ask the patient to sustain *ah* in between swallow trials, in which a gurgly vocal quality may suggest the presence of residue on the vocal folds (Logemann, 1998). Coughing is a protective response and does not always imply the patient is aspirating (Miller, 1997). However, when the patient appears to be choking or is demonstrating difficulty breathing that is not alleviated by coughing, aspiration has likely occurred (Miller, 1997).

Instrumental Evaluation of Swallow Function

Silent aspiration occurs when an individual aspirates without any overt response, such as coughing (Smith-Hammond & Goldstein, 2006). An alarming statistic reported by Logemann (1998) is that fewer than 50% of patients who aspirate cough. This statistic implies that the presence of a cough is not enough to determine whether or not the patient experiences penetration or aspiration of foods or liquids; this signifies that further assessment must be done. A longstanding belief that has been implemented in the practices of several speech-language pathologists in regards to the evaluation of swallowing disorders, which has been supported by several studies in the past, is that there is a relationship between the presence of wet vocal quality post-swallow ("gurgly voice") and the entry of food and/or liquid into the larynx (Groves-Wright, Boyce, & Kelchner, 2010). However, at the conclusion of their study, Groves-Wright et al. (2010) gathered evidence suggesting that speech-language pathologists are inconsistent when perceiving the presence or absence of wet vocal quality when assessing patients with penetration or aspiration risks**.** A suggested reason for this is the ambiguity that surrounds what constitutes as wet vocal quality, because the term "wet vocal quality" is essentially undefinable (Groves-Wright et al., 2010). The findings of the study suggest that other evaluation tools must be implemented when evaluating swallow function.

One of the most commonly utilized tools to evaluate swallow function is the videofluoroscopy (VFSS), also known as modified barium swallow study (MBSS) (Seikel et al., 2015). During VFSS, patients are asked to consume

various textures and consistencies of foods and liquids that are mixed with barium (American Speech-Language-Hearing Association, n.d.). Each bolus trial is recorded videoradiographically (Seikel et al., 2015) and therefore requires the presence of a radiologist during the evaluation (American Speech-Language-Hearing Association, n.d.). VFSS allows the speech-language pathologist to determine the presence or absence of aspiration, dysfunction of anatomical structures, food textures and liquid consistencies that are safest to swallow, and the effectiveness of postural maneuvers or techniques (American Speech-Language-Hearing Association, n.d.). VFSS can be conducted with either a lateral or anterior view of the patient (Seikel et al., 2015).

Another tool used to investigate swallow function is fiberoptic endoscopic evaluation of swallowing (FEES) (Seikel et al., 2015). During FEES, the clinician inserts a flexible laryngoscope through the nasal cavity and rests the scope above the epiglottis (Leder & Murray, 2008). Thus, the clinician can clearly visualize the laryngeal and pharyngeal anatomical structures to determine if food or liquid secretions are left-over after the individual has swallowed (Leder, Sasaki, & Burrell, 1998). The clinician can also determine if premature spillage is occurring prior to the initiation of the swallow (Leder, Sasaki, & Burrell, 1998). Leder and Espinosa (2002) conducted a study which compared results from a bedside examination to FEES. At the conclusion of their study, it was found that FEES more accurately estimated aspiration risks and no aspiration risks in individuals compared to a bedside examination (Leder & Espinosa, 2002).

In their 1998 study, Leder, Sasaki, and Burrell examined 400 patients to

determine the effectiveness of identifying silent aspiration in patients using FEES and compare it to VFSS. The 400 subjects were divided into 2 groups, 56 subjects in the first group and 344 subjects in the second group (Leder, Sasaki, & Burrell, 1998). Group 1 subjects were evaluated via VFSS and FEES and group 2 subjects were evaluated via FEES only (Leder et al., 1998). At the conclusion of the study, Leder, Sasaki, and Burrell (1998) found that 38% of the subjects silently aspirated when evaluating using VFSS and FEES and that 26% of the subjects silent aspirated when evaluating using FEES only. Based on results from a study with an extremely large sample size, there is strong evidence suggesting FEES is an appropriate and very reliable measure when identifying possible silent aspiration (Leder, Sasaki, & Burrell, 1998).

Kelly et al. (2007) conducted a study which compared how severity ratings of penetration and aspiration, via the *Penetration-Aspiration Scale*, differed when using FEES and when using VFSS. At the conclusion of the study, results revealed that severity of aspiration and penetration was rated higher when evaluating patients via FEES rather than VFSS, which suggests that the two methods do not yield identical results (Kelly, Drinnan, & Leslie, 2007). As explained by Kelly et al., (2007), these results suggest that by using different assessment tools, clinicians may misinterpret a patient's swallow based on the differences between the two instrumental evaluation methods.

Surface electromyography (sEMG) is another instrumental tool used in the evaluation of swallow function. When implemented, sEMG electrodes are placed onto the surface of the skin that overlays the muscles intended for evaluation

(Logemann, 1998). According to Stepp (2013), sEMG detects and measures motor unit action potentials (MUAP) from muscles, which measures muscle activation. Specifically relating to speech-language pathology, sEMG is implemented to measure electrical activity of muscles used during swallowing to evaluate the initiation of the swallow (Logemann, 1998). Removing the top layer of dead skin and oils of the skin helps improve the conductivity and improves signal detection (Stepp, 2013). Muscles used in the process of mastication and deglutition that are easy to locate and measure via sEMG electrodes include the following: masseter, sternohyoid, and omohyoid (Stepp, 2013).

The Iowa Oral Performance Instrument (IOPI) is an objective clinical instrument used to evaluate tongue strength, lip strength, and tongue endurance (IOPI Medical, 2013). The IOPI "measures tongue pressure pneumatically using a nickel-sized, air-filled polymer balloon called a tongue bulb" (Hewitt, Hind, Kays, Nicosia, Doyle, Tompkins, Gangnon, & Robbins, 2008) which is connected to a pressure transmitter (Crow & Ship, 1996). Pressures obtained from the IOPI are measured in kilopascals (kPa) (Hewitt et al., 2008).

A study conducted by Stierwalt and Youmans (2007) examined tongue strength and tongue endurance in individuals with and without dysphagia via the IOPI. For individuals without histories of dysphagia or oral motor deficits, significant differences were found relating to age and gender. Specifically, Stierwalt and Youmans (2007) found that tongue strength decreased with age and that men had greater tongue strength than women. For individuals with signs and symptoms of dysphagia, statistically significant results were once

again found in which men had greater tongue strength than women (Stierwalt & Youman, 2007). When comparing age-matched and gender-matched control group subjects and experimental subjects, significant differences were found. Stierwalt and Youman (2007) found that the control subjects had significantly greater tongue strength but no differences in tongue endurance. Stierwalt's and Youman's (2007) study supports the hypothesis that tongue strength decreases with age and that individuals with dysphagia will demonstrate reduce tongue strength when compared to individuals without dysphagia.

Crow and Ship (1996) also conducted a study measuring hand strength, hand endurance, tongue strength, and tongue endurance in 52 healthy males and 47 healthy females, who ranged from 19 to 96 years of age. Significant differences were found in hand strength and tongue strength relating to age and gender (Crow & Ship, 1996). Specifically, hand strength and tongue strength was lower in the older subjects of the study and in the female subjects of the study (Crow & Ship, 1996). This suggests there is a decrease in strength, specifically hand strength and tongue strength, due to gender and age trends, but observable differences between hand and tongue strength are not evident (Crow & Ship, 1996). It appears that tongue function, specifically strength, declines as a part of the aging process (Crow & Ship, 1996).

A similar study conducted by Stierwalt and Youmans (2007) measured tongue strength and tongue endurance, using the IOPI, in subjects with and without oral phase dysphagia. In the control group of individuals without oral phase dysphagia, gender and age differences were observed for tongue strength

but not for tongue endurance (Stierwalt & Youmans, 2007). Of the individuals with oral phase dysphagia differences were only observed in tongue strength, in which men once again demonstrated greater strength as opposed to women. Finally, when comparing individuals that grouped based on age and gender matching, individuals from the control group demonstrated greater tongue pressure than the individuals from the experimental group. Results from the study (Stierwalt & Youmans, 2007) yielded similar results as Crow and Ship (1996) that there is an observable tongue strength decline with age and that there are observable differences in males and females, but that there are no observable differences in age or gender in regards to tongue endurance.

Conclusion

The proposed question of the presented study was *Do individuals with tongue thrust, an OMD, differ from the norms of individuals without tongue thrust in the following measures: tongue strength, lip strength, masseter contraction, and oropharyngeal transit time?* The purpose of the study was to replicate a study that found significant differences in masseter contraction and oropharyngeal transit time in individuals with tongue thrust when compared to normative data (Evers, 2013). The present study included six subjects, ranging from 11-40 years of age, who were all diagnosed with tongue thrust.

Chapter 2: Methodology

The present study replicated a previous study (Evers, 2013), with the purpose to add more evidence to the field of speech-language pathology, indicating whether or not individuals with tongue thrust differ from individuals without tongue thrust on various OPD measures. Specifically, the researcher evaluated the following measures: tongue tip strength, tongue dorsum strength, lip strength, masseter contraction, and oropharyngeal transit time. Results from this study on the aforementioned measures were compared to normative data of age and gender matched individuals without signs of tongue thrust, which were gathered from a previous study (Holzer et al., 2011), to determine if significant differences exist. The current study included six subjects, ranging from 11-40 years of age. Significant differences were found in IOPI lip strength, EMG oropharyngeal transit time, and subjective variable measurements. This study is part of a larger study, examining tongue strength, lip strength, masseter contraction, and oropharyngeal transit time across the lifespan. Results from the present study were compared to previous findings (Evers, 2013; Holzer et al., 2011) to see if individuals with tongue thrust differ from the normative data of individuals without tongue thrust.

Research Hypotheses

H_{0a}: No significant difference exists in masseter contraction as measured by EMG between individuals diagnosed with tongue thrust and normative data.

H_{1a}: A significant difference exists in masseter contraction as measured by EMG

between individuals diagnosed with tongue thrust and normative data.

H_{0b}: No significant difference exists in force, as measured by IOPI, based on location or between individuals diagnosed with tongue thrust and normative data.

H_{1b}: A significant difference exists in force, as measured by IOPI, based on location or between individuals diagnosed with tongue thrust and data.

H_{0c}: No significant difference exists in oropharyngeal transit time based on bolus type, and/or measurement type between individuals in the experimental and normative data.

H_{1c}: A significant difference exists in oropharyngeal transit time based on bolus type, and/or measurement type between individuals diagnosed with tongue thrust and normative data.

Subjects

The study included six subjects, ranging from 11-40 years of age, who were identified as having tongue thrust. The study included two males (ages 11 and 11) with a mean age of 11.34 years of age and four females (ages 23, 40, 17, and 23) with the mean age of 26.36 years of age. The mean age of all six subjects was 21.36 years of age. Specific demographic information for each subject is reported in Chapter 3. Recruitment letters (see Appendix B) outlining the objectives of the study were sent to individuals known through personal contacts. Recruitment letters were also sent to local dentists and local orthodontists, inviting patients with tongue thrust to participate in the study.

The STTP (see Appendix A) confirmed the presence or absence of tongue

thrust in all subjects and also provided the researcher with pertinent case history information. By using the same protocol for every subject, the researcher ensured that all of the subjects were diagnosed with tongue thrust based on the same criteria. A medical history form (see Appendix C) was also given to each subject at the beginning of the evaluation. Information obtained from the medical history form included the following: date of birth, sex, ethnicity, medical conditions and/or disorders, OMD risks and/or conditions, surgeries, medications, alcohol consumption, tobacco use, food preferences, and food avoidances. The researcher recorded any additional information reported by subjects or caregivers during the study.

Exclusion criteria included a history of neurogenic or structural impairments of the head or neck with no association with tongue thrust; this information was obtained through the medical history form. If subjects indicated that they had sustained a concussion and were unconscious for less than 5 minutes, but reported no motor or cognitive deficits as a consequence of the concussion, they were not withdrawn from the study.

Variables

The independent variables for the study were subject age, sex, bolus characteristics, and protocol group assignment. The following foods and liquids were used during trials of the study protocol: ½ tsp of pudding, 1 ½ tsp of pudding, a “typical” bite of Triscuit cracker, and 10 cc water delivered from a cup.

Subjective variables were measured via clinical observation and clinical judgment of the researcher. The following subjective variables were recorded for

each subject: presence/absence of a vaulted palate, dental occlusions/malocclusions, open/closed mouth posture at rest, presence/absence of residue on the tongue and in the sulci following the swallow, and a gurgly voice post-swallow. Tongue protrusion was observed as subjects consumed ½ tsp pudding, 10 cc water, and Triscuit cracker; during these trials, as outlined on the study protocol, the researcher pulled down the lower lip, instructing the subject to swallow when they were ready. During Triscuit cracker trials, the researcher rated pre-swallow bolus cohesion based on a "1-3-5" rating scale (1= *organized ball or tube in middle of tongue*, 3= *some evidence of cohesion/some scattering*, 5= *disorganized or scattered on tongue*) and post-swallow residue on a "1-3-5" rating scale (1= *minimal/no residue*, 3= *some evidence of residue*, 5= *significant amount of residue*). Finally, the following characteristics, which were recorded as either present or absent, were also observed during swallow trials: open mouth posture, coughing, clavicular breathing, forward posture, chin-tuck, neck tension, and tongue protrusion. Any additional observations made by the researcher were noted on the study protocol.

Instruments and Materials

Upon the arrival of each subject, the researcher set up a video recorder and videotaped all sessions from start to finish. Upon arrival, all subjects, and guardians in cases in which the subjects were minors, were asked to sign consent forms to participate in the research study and were asked to complete the medical history form (see Appendix C). The STTP was the chosen protocol used to determine the presence or absence of tongue thrust in all of the subjects.

As outlined on the STTP protocol, the researcher observed the subjects as they consumed water, diced peaches, chocolate pudding, and Triscuit crackers. Observations made during the swallows across the various consistencies and textures were noted on the STTP protocol. Additionally, the researcher asked all subjects to perform “smile swallows,” in which the subjects were asked to take a small sip of water and to swallow with the lips open in a smiling manner. The “smile swallow” is common practice amongst OMD professionals when assessing for tongue thrust, in that it allows the professional to observe forward movement of the tongue during the swallow. The researcher determined that the results from the STTP swallow trials and the “smile swallows” were in agreement with each other in regards to confirming the presence for tongue protrusion during the swallow, indicating tongue thrust.

Once subjects were diagnosed as having tongue thrust, the researcher proceeded to follow the study protocol (see Appendix D). The Iowa Oral Performance Instrument (IOPI) (Model 2.2) was used to measure tongue tip, tongue dorsum, and lip strength. A two channel Myotrac Infiniti EMG was used to measure masseter contraction and oropharyngeal transit time, using surface electrodes. EMG data were recorded on a Toshiba Model PSAG8U-04001W laptop. Foods and liquids that were administered to each subject during the study protocol included Snack Pack Sugar Free chocolate pudding, water, and Triscuit crackers. A syringe calibrated for volume measured in cubic centimeters was used to measure amounts of pudding and water. Water was presented to subjects in a cup, pudding was presented on a spoon, and subjects were

instructed to take a “typical” bite of Trisucit cracker. Other clinical materials to be used by the researcher included the following: gloves, tongue depressors, straws, cups, spoons, paper towels, a flashlight, alcohol swabs, gauze pads, hand sanitizer, skin prepping gel, and conductive gel.

Procedures

The study included six individuals who were either previously diagnosed with tongue thrust, have a history of signs of tongue thrust, or were believed to have tongue thrust. The researcher recorded all sessions with a video recorder. All subjects, and guardians in cases in which the subjects were minors, were asked to sign consent forms to participate in medical research. Next, the researcher evaluated all subjects using the STTP (see Appendix A) to evaluate and diagnose each subject as either having tongue thrust or not having tongue thrust. No subjects were dismissed from the study because all subjects were diagnosed as having tongue thrust.

All subjects were consecutively assigned to one of three different protocol groups, based on subject number assignments. The researcher rotated subjects through protocols A, B, and C. Based on the group assignments, the researcher measured IOPI tongue and lip strength, EMG masseter contraction, and EMG oropharyngeal transit time in different sequences. Table 2.1 outlines the three protocol groups of the study and the sequence of measurements for each group:

Table 2.1. Protocol Groups.

Group A	Group B	Group C
IOPI force	EMG masseter contraction	EMG swallow timing
EMG masseter contraction	EMG swallow timing	IOPI force
EMG swallow timing	IOPI force	EMG masseter contraction

Five subjects were tested at the Idaho State University Speech-Language-Hearing Clinic and one subject was tested in her home. All subjects were seated comfortably in upright positions. Subjects were first asked to read and sign the consent forms and then asked to complete the medical history forms. Caregivers were present for evaluations that included minors; the caregivers assisted the subjects in completing the medical history forms and answering questions related to their case histories. Upon completion of the aforementioned paperwork, all subjects were informed that an IOPI bulb would be placed between their lips and in their mouth, as well as electrodes on their throat and jaw. Subjects were told they should not experience any pain or discomfort and that they could end their participation during the study at any time.

Oral peripheral examination. The researcher performed an oral peripheral examination, as outlined in the STTP, to evaluate the structures and functions of each subject's oral mechanism. Any structural or functional deviations observed by the researcher were noted on the STTP protocol form. Specifically, the researcher observed the following structures: teeth, tongue, lips, tonsils, and palate. The researcher noted either the presence or absence of a vaulted palate. Additionally, the researcher observed and noted the presence of

the following: crossbite, labioverted teeth, normal occlusion, class I malocclusion, class II malocclusion, or class III malocclusion.

Tongue tip, tongue dorsum, and lip strength. The IOPI was utilized to measure tongue tip, tongue dorsum, and lip strength. The IOPI bulb was first placed on the tongue tip. Subjects were instructed to occlude their teeth and lips and to compress the bulb against the alveolar ridge with their tongue as hard as they could for approximately two seconds, without biting on the tubing. This was completed three times, with the researcher repositioning the bulb after each attempt. The researcher recorded the force exerted after each of the three attempts.

Next, the subjects were asked to sustain phonation of the vowel /a/, to facilitate in the placement of the IOPI bulb on the tongue dorsum. The researcher placed the bulb 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/. Subjects were instructed to occlude their teeth and lips while pushing against the bulb against the hard palate with as much force as they could, without biting on the tubing. This was completed three times for approximately two second trials, with the bulb being dried off and repositioned after each attempt. The researcher recorded the readings of the IOPI after each trial.

Finally, the bulb was placed parallel with the lips. Before placing the bulb, the researcher instructed all subjects to dry their lips with a tissue, wiping away any saliva or chapstick that could potentially cause the IOPI bulb to move. Subjects were instructed to clench their back teeth and to press their lips

together against the bulb as hard as they could, without biting down on the tube with their teeth. Instructions to clench the back teeth during this task were given to ensure subjects were not relying on their teeth. When subjects unclenched their teeth and were unable to hold the bulb between the lips, the readings were scored as “0.” Measuring lip strength via the IOPI bulb was completed for three two second trials, with the bulb being dried off and repositioned in between attempts. The IOPI readings were recorded on the protocol by the researcher after each attempt.

EMG masseter contraction. EMG measurements recording master contraction were collected with EMG electrodes being placed along the masseter belly in a vertical plane. All subjects were asked about skin allergies or sensitivities prior to skin preparation. If no skin allergies or sensitivities were reported, the researcher proceeded to prepare the skin for electrode placement by applying NuPrep skin prepping gel with a gauze pad for approximately 30 seconds. NuPrep gel residue was wiped away with alcohol swabs. One subject reported skin sensitivities that resulted in forgoing the application of the NuPrep gel; the researcher only used alcohol swabs to prepare the subject’s skin for electrode placement.

Subjects were instructed to clench their back teeth, as the researcher palpated the masseter belly and made marks for appropriate electrode placement. The EMG electrodes were placed bilaterally on the masseter belly in a vertical plane. Channel A was assigned to the right masseter and Channel B was assigned to the left masseter. The ground electrodes for both channels were

placed on the left clavicle.

A masseter baseline was first recorded. Subjects were instructed to bite down with their back teeth as hard as possible for approximately three seconds and then to relax. This was repeated for a total of three trials. The researcher confirmed that the EMG reading was recorded for each trial. Subjects were then instructed to consume ½ tsp pudding, 1 ½ tsp pudding, 10 cc water, and a bite of Triscuit cracker, as the electrodes measured masseter contraction. Each presentation occurred in a series of three trials. Subjects were given each stimulus and instructed to hold the bolus in their mouth until instructed to swallow. The researcher palpated the lateral neck and submental region, using the five-finger method of Logemann (1998), and depressed the spacebar of the laptop computer at the initiation and termination of the swallow; depression of the spacebar placed markers on the EMG readings, which were displayed on the laptop screen. The only exception to the instructions given to participants regarding when to swallow was for the Triscuit cracker trials. During these trials, subjects were instructed to chew, signal just before they were ready to swallow, and then to do so on their own timing. It was felt this would be minimally disruptive to the swallow timing itself.

Bolus cohesion and post-swallow reside were examined for the Triscuit cracker trials. Subjects were instructed to chew the bites of cracker and then to open their mouths so the researcher could examine the boluses. The researcher rated pre-swallow bolus cohesion based on a “1-3-5” rating scale (1= *minimal/no residue*, 3= *some evidence of reside*, 5= *significant amount of residue*) and post-

swallow residue based on a “1-3-5” rating scale (1= *organize ball or tube in middle of tongue*, 3= *some evidence of cohesion/ some scattering*, 5 = *disorganized or scattered on tongue*).

The researcher experienced some difficulty while marking initiation and termination of the swallow when subjects demonstrated false pumps and/or weak musculature in the submental region upon palpation. Consequently, clinical judgment was utilized to determine the initiation of the swallow when examining EMG results. The following observational measures were also noted during the swallow trials: cough, clavicle breathing, forward posture, chin tuck posture, neck tension, open-mouth posture, tongue protrusion, and any additional observations. Because the researcher was engaged in several tasks at once, any obvious signs were noted in real-time. The researcher later watched all recordings of each evaluation for all subjects to note any observations that were not noted during the evaluation itself. Due to variety and the amount of extraneous movements and simultaneous tracking of the swallow, the researcher marked as many variables as possibly observed.

EMG and behavioral swallow timing. Oropharyngeal transit time was measured both instrumentally and behaviorally. Initiation of the swallow was defined as upward movement of the larynx and was instrumentally measured by recording the EMG of the submental region. Termination of the swallow was defined as the depression of the larynx, which was felt upon palpation by the researcher.

The same skin preparation procedure was implemented for oropharyngeal

transit time as previously discussed for masseter contraction. Channel A was placed on the submental region, approximating the mylohyoid muscle. One electrode was placed two centimeters posterior from the chin point, and the second electrode was placed two centimeters posterior to the first. Channel B electrodes were vertically placed just off the thyroid lamina on the left side. The ground electrodes remained on the collarbone.

Subjects were once again given ½ tsp pudding, 1 ½ tsp pudding, 10 cc water, and a bite of Triscuit. Each stimulus was presented three times. With the exception of the bite of Triscuit, subjects were instructed to hold the bolus in the oral cavity until being instructed by the researcher to swallow. For the Triscuit cracker, subjects were instructed to chew, signal just before they were ready to swallow, and to swallow on their own timing. The researcher depressed the spacebar on the laptop at initiation and termination of the swallow, as felt upon palpation of the swallow, which placed marks on the EMG recordings, which were displayed on the laptop screen. The researcher experienced some difficulty in marking initiation and termination of swallow when subjects demonstrated false tongue pumps and/or weak musculature in the throat region upon palpation. Consequently, clinical judgment was utilized to determine the initiation of the swallow when examining EMG results.

The researcher subjectively recorded the presence/absence of a gurgly voice post-swallow. The researcher also recorded the presence/absence of tongue protrusion utilizing the lip pull down method for all stimuli presentations except 1 ½ tsp pudding. The following subjective measures were also noted

during the swallow trials: cough, clavicle breathing, forward posture, chin tuck posture, neck tension, open-mouth posture, tongue protrusion, and any additional observations. Because the researcher was engaged in several tasks at once, any obvious signs were noted in real-time, and the researcher later watched the recordings to note any measures that were not noted during the evaluation itself. Due to variety and the amount of extraneous movements and simultaneous tracking of the swallow, the researcher marked as many variables as possibly observed.

Reliability

Inter-judge reliability. To ensure inter-judge reliability, consensus coding was conducted between two researchers for all six subjects on oropharyngeal transit time. All EMG oropharyngeal transit time graphs were examined by the researchers at the same time. Both researchers came to a consensus for each trial for each food/liquid presentation for oropharyngeal transit time.

Intra-judge reliability. To examine intra-judge reliability, all EMG oropharyngeal transit time graphs for 16% of trials were re-measured by the researcher and cast into a Pearson Product Moment Correlation with a value of .947795323.

Data Analysis

All raw scores obtained during the study were converted into *t*-scores and *p*-values to determine if significant differences exist between the subjects of the present study and the normative sample. For measures in which the *p*-value was .05 or smaller, when compared to the normative data, the data were considered

statistically significant. Significant differences were found on IOPI lip strength, IOPI tongue dorsum strength, EMG oropharyngeal transit time, and subjective variable measurements.

Chapter 3: Results

The purpose of the present study was to determine whether or not individuals with tongue thrust differ from individuals without tongue thrust on various OPD measures, which may be predictive of oropharyngeal dysphagia later in life. Specifically, the researcher evaluated the following OPD measures: tongue tip strength, tongue dorsum strength, lip strength, masseter contraction, and oropharyngeal transit time. The study included six subjects, who were confirmed to have tongue thrust, based on findings from the STTP and clinical observation. Measurements were obtained via the IOPI and EMG and were compared to normative data of individuals without tongue thrust. All raw scores obtained during the study were converted into *t*-scores and *p*-values to determine if significant differences exist between the subjects of the present study and the normative data, which were gathered from a previous study (Holzer et al., 2011). For measures in which the *p*-value was .05 or smaller, when compared to the norms, the data was considered to be statistically significant. Significant differences were found on IOPI lip strength, EMG oropharyngeal transit time, and subjective variable measurements.

Medical History Form

The study included six subjects, two males and four females. The subjects ranged from 11-40 years of age. The mean age of the subjects was 21.36 years (26.36 years for females, 11.34 for males). Five subjects were European American and one subject was White Hispanic. Four subjects reported themselves to be mouth breathers, three subjects reported enlarged

tonsils and adenoids, and one subject reported removal of tonsils and adenoids.

One subject reported a history of finger sucking and three subjects reported a history of cheek biting. No subjects answered “Yes” to having a deviated septum, although two subjects wrote “Maybe” next to the question. Four subjects reported allergies, including the following: seasonal allergies, mold, cats, “strange chemicals,” and band aids. Four subjects reported open spaces during mixed dentition and two subjects reported current open spaces in dentition. One subject reported on the medical history form that she underwent oral surgery, although it was later indicated that three subjects had undergone surgery for wisdom teeth removal. Three subjects reported oral sores, which included cold sores and canker sores.

One subject’s caregiver wrote “Maybe” in response to a question regarding history of bleeding GI (stomach, throat, intestines); the caregiver indicated on the form that the subject swallowed 13 magnets and thus, received an endoscopy at 26 months of age. The same subject was also reported to have been hospitalized for one night after drinking an entire bottle of Children’s Tylenol at approximately 2 ½ years of age; the subject spent one night in the hospital, receiving medications to clear his kidney and liver function. Another subject indicated a history of hospitalizations for asthma attacks and for recurrent pneumonia.

Three subjects indicated they had taken medication the day of the evaluation. One subject reported a history with the following: heart and blood problems (including chest pain due to heart problems, irregular heartbeat, high

blood pressure (hypertension), blood clots, anemia, blood transfusion, high cholesterol, heart failure, or heart bypass surgery), recurrent pneumonia, and infrequent alcohol consumption. One subject reported a history including a loss of consciousness for less than one minute and TMJ Syndrome. Results from the medical history form are summarized in Table 3.1. All other areas listed in the demographic survey (see Appendix C) were not indicated as present in any of the participants.

Table 3.1. Medical history form results.

	Males	**Females**	**Total**
European American	2	3	5
White Hispanic	0	1	1
Heart & Blood Problems (including chest pain due to heart problems, irregular heartbeat, high blood pressure, blood clots, anemia, hypertension, blood transfusion, high cholesterol, heart failure, or heart bypass surgery)	0	1	1
Bleeding GI (stomach, throat, intestines)	1	0	1
Loss of consciousness	0	1	1
Recurrent pneumonia	0	1	1
Mouth breather	1	3	4
History of finger sucking	1	0	1
History of cheek biting	1	2	3
Enlarged tonsils/adenoids	0	3	3
Tonsils/adenoids removed	0	1	1
Open spaces during mixed dentition	2	2	4
Current open spaces in dentition	1	1	2
Allergies	0	4	4
TMJ syndrome	0	1	1
Oral sores	1	2	3
Medications	0	3	3
Alcohol consumption	0	1	1

Oropharyngeal Transit Time Trends

A consistent observation, which was also noted by Evers (2013), is that

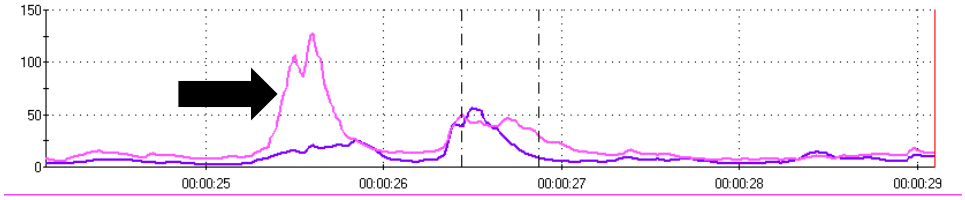
some subjects from the present study required multiple swallows across bolus consistencies. The researcher also noted extraneous movements leading up to the perceived swallow, which was felt upon palpation. The extraneous movements that the subjects demonstrated, such as pumping or false starts, posed a challenge to the researcher when attempting to palpate a clearly defined swallow. Therefore, the researcher used clinical judgment and recorded the perceived "true swallow" for the following stimuli: ½ tsp pudding, 1 ½ tsp pudding, and 10 cc water. During Triscuit cracker trials, multiple swallows were more easily felt upon palpation due to the longer gaps in time between swallows. Therefore, the researcher noted as many additional swallows as possible during these trials. However, the data obtained for multiple swallows on Triscuit cracker trials could not be compared to the normative data because the normative data only included results for single swallows (Holzer, 2011).

When analyzing the EMG graphs for oropharyngeal transit time, the researcher determined that the onset and offset of each swallow were not always defined by a distinct EMG peak. This posed a challenge while measuring EMG oropharyngeal transit time graphs. Onset of the swallow was defined by palpable elevation of the larynx; offset of the swallow was defined by palpable depression of the larynx. Both onset and offset were indicated by event markers, which were placed on the EMG graphs as the researcher depressed the space bar on the laptop.

Based on the analysis criteria of Holzer (2011) and Evers (2013), onset of the swallow was indicated by the first perturbation in the EMG before the space

bar was initially hit on the laptop; offset of the swallow was indicated by the second marker, which was placed upon depression of the space bar. Figure 3.1 illustrates an example of atypical "pre-swallow activity" occurring before the palpable onset of the swallow. The figure illustrates "pre-swallow activity" for subject 522 on the third trial of 1 ½ tsp pudding. The "pre-swallow activity" has been indicated by the arrow:

Figure 3.1."Pre-Swallow Activity" for Subject 522 on third trial of 1 ½ tsp pudding.

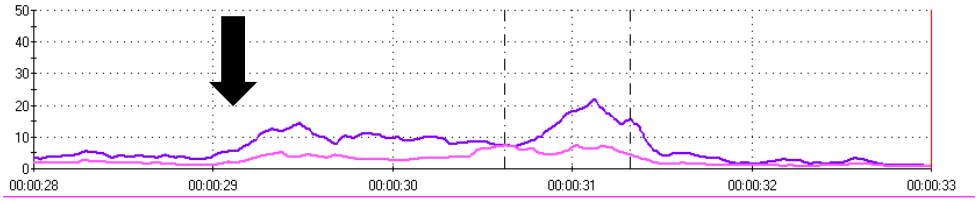


As indicated in Figure 3.1, onset of the swallow, as indicated by the first event marker (approximately 26.5 seconds), occurs after a distinct perturbation (approximately 25.35 seconds). Because Channel A and Channel B do not appear to fully return to baseline, the researcher deemed the muscle activity at approximately 25.35 seconds to be related to the swallow and therefore included the "pre-swallow activity" in the subject's oropharyngeal transit time. In other words, the researcher determined that the distinct peak of the muscle activity occurring before the palpable onset of the swallow was too significant not to be related to the swallow itself.

Figure 3.2 illustrates another atypical swallow pattern demonstrated by a different subject included in the study. The EMG graph for Figure 3.2 illustrates

the swallow activity for subject 524 during the third trial of 10 cc water:

Figure 3.2.“Pre-Swallow Activity” for Subject 524 on third trial of 10 cc water.



As illustrated by the arrow in figure 3.2, a rise in EMG activity begins at approximately 29.15 seconds. Based on the readings, there is approximately 1.50 seconds of “pre-swallow activity” leading up to the first event marker, indicating the onset of the swallow (approximately 30.60 seconds). Because the EMG channel readings of the “pre-swallow activity” do not reach baseline, the activity was considered to be related to the swallow and was therefore included in the subject’s oropharyngeal transit time for this trial.

The following pages provide summaries of each of the six subjects, outlining information obtained through the medical history forms, the STTP, and additional interview questions asked by the researcher. Tables outlining OMD indicators for each subject are also included. Finally, tables indicating objective and subjective data results obtained via the IOPI, EMG, and behavioral and observational data have been included, as well as all subjects' raw scores derived *t*-scores and *p*-values. In cases in which the *p*-value was .05 or smaller, it was determined that significant differences were present, when compared to the normative data. Table 3.2 lists the abbreviations used in the results tables for observed data in all subjects:

Table 3.2. Abbreviations used in results.

Abbreviation	**Description**
iopitipavg	average force for IOPI tongue tip measure
iopidorsavg	average force for IOPI tongue dorsum measure
iopilipsavg	average force for IOPI lips measurement
mcbARMSav	right masseter contraction baseline average
mcbBRMSav	left masseter contraction baseline average
mcpud1ARMS	right masseter contraction for ½ tsp pudding trials
mcpud1BRMS	left masseter contraction for ½ tsp pudding trials
mcpud2ARMS	right masseter contraction for 1 ½ tsp pudding trials
mcpud2BRMS	left masseter contraction for 1 ½ tsp pudding trials
mc10ccARMS	right masseter contraction for 10 cc water trials
mc10ccBRMS	left masseter contraction for 10 cc 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 trials
stc10ccavg	average swallowing timing with contraction for 10cc water trials
stccrackavg	average swallowing timing with contraction for Triscuit cracker trials
tppud1	tongue protrusion for ½ tsp pudding trials
tp10cc	tongue protrusion for 10 cc water trials
tpcrack	tongue protrusion for Triscuit cracker trials
boluscoh	bolus cohesion during Triscuit cracker trials
bolusres	bolus residue following Triscuit cracker trials
ope_p	oral peripheral exam of palate (1= presence of high vaulted palate, 0= absence of high vaulted palate)
ope_d	oral peripheral exam of teeth (0 = normal, 1 = type 1, 2 = type 2, 3 = type 3, 4= open bite, 5= other)
cough	any cough during bolus trials
CB	indicates clavicular breathing during bolus trials
FP	forward posture during bolus trials
CTP	chin tuck position
NT	neck tension during bolus trials
OMP	open mouth posture during bolus trials
TP	tongue protrusion during bolus trials

Subject 520

Subject 520 was a 23 year old female whose participation included two sessions at the Idaho State University Speech, Language, and Hearing Clinic. During the first session, the subject completed the medical history form and was assessed for tongue thrust via the STTP. Additionally, IOPI measurements for tongue tip, tongue dorsum, and lip strength were collected. Although the researcher intended to collect EMG masseter and EMG swallowing timing measurements during the first session, the EMG electrodes did not record any muscle activity, and therefore the researcher ended the session. Because the subject reported skin sensitivities, the researcher did not use skin prepping gel and only used alcohol swabs to prepare the skin for electrode placement. A second session was scheduled once the previously used electrodes were replaced. The researcher was successful in obtaining EMG masseter and EMG swallowing timing data the second session.

Table 3.3 indicates that subject 520 had tongue thrust secondary to behavioral and clinical indicators of an oromyofacial disorder. The subject self-diagnosed herself with tongue thrust, based on her case history and current signs and symptoms of tongue thrust. The subject reported that she always has and still, especially when she is stressed, sucks her tongue. The subject also indicated on the medical history form that she has a history of cheek biting. The subject did not report any other noxious oral habits.

The subject reported she underwent two years of orthodontic treatment. Oral examination revealed a central open bite, a class II malocclusion, and

labioverted teeth. Habitual tongue rest posture was reported to be pressed against the upper teeth, although when sporadically asked where her tongue was resting throughout the evaluation, the subject reported that her tongue was resting against her lower teeth. Habitual lip rest posture was reported to be lip closed. However, the researcher noted the subject's lips were apart for more than half of the evaluation. Lip movements were noted to be asymmetrical. The researcher also observed the subject's gag reflex to be significantly reduced.

The subject is a self-reported mouth breather, especially when she is not paying attention, and reported she frequently experiences chapped lips, which suggests open mouth rest posture. It was indicated on the medical history form that the subject has TMJ Syndrome. The subject reported several environmental allergies, seasonal allergies, and skin sensitivities. The subject underwent a tonsillectomy on December 23, 2014 and reported she was experiencing some soreness the day of the evaluation. In conversation, no audible frontal lisping or interdental productions of speech sounds were observed. However, the researcher noted the tongue was visibly forward during speech, which is suggestive of forward tongue rest posture.

The subject reported she avoids eating sandwiches that aren't cut up because they are difficult to chew with her open bite. During the STTP, the subject was observed to protrude her tongue during saliva swallows and food and liquid trials. Additionally, tongue protrusion to presentation of foods, liquids, cup, and straw was observed. During food and liquid trials during the STTP, the subject reported her back teeth were apart across all food and liquid trials.

Pursing of the lips was observed across food and liquid trials and an audible swallow was observed on liquid trials.

During the food and liquid trials of the study protocol, the subject was observed to clean her teeth and lips post-swallow. The subject's nares flared during the swallow on five occasions. Finally, the researcher noted a rotational chew, during which the subject's tongue protruded.

Table 3.3. Indicators of OMD for Subject 520, a 23 year old female.

OMD Indicators	Results
Use liquid to wash foods down	Yes, especially when swallowing "huge bites of bread." Subject also reported self to be a "ripper" when biting foods.
Food avoidances	Sandwiches that aren't cut up because of difficulty chewing due to her open bite.
Noxious oral habits	Reported to have always sucked her tongue. Reported a history of cheek biting.
Open bite	Yes, central.
Malocclusion	Class II.
Labioverted teeth	Yes.
Tongue rest posture	Reported to be pressed against upper teeth. When asked during evaluation where her tongue was, subject reported on more than one occasion that it was resting against her lower teeth.
Gag reflex	Significantly reduced.
Gargling	Experiences difficulty.
Orthodontic treatment	Two years of braces.
Lip rest posture	Reported to be lips closed. Researcher noted lips were apart for more than half of the evaluation.
Lip movements	Movements were not symmetrical.
Mouth breather	Yes. Also reported frequent chapped lips.
TMJ Syndrome	Yes.
Allergies	Allergic to pollen, mold, juniper, and cats. Also reported skin sensitivities, which resulted in not using skin prepping gel during evaluation.
Tonsils	Removed December 23, 2014. Reported some soreness day of the evaluation.
Speech	No audible frontal lisping or interdental

	productions of speech sounds noted. Researcher did note the tongue was visibly forward during speech.
Tongue protrusion	Noted across saliva swallows and food and liquid trials.
Tongue protrudes to presentations of foods and liquids	Noted across all liquid and food presentations.
Back teeth apart	Reported back teeth were apart across trials.
Pursing lips	Was noted across food and liquid trials.
Audible swallow	Was noted on liquid trials.
Post-swallow behaviors	Subject was note to clean her teeth and lips.
Flared nares	Observed five times during food and liquid trials of study protocol.
Rotational chew	Observed during food and liquid trials of study protocol; tongue protruded while subject was chewing.

Table 3.4. Instrumental and observational data for Subject 520, a 23 year old female.

	Normative Mean	**Std Dev**	**Std Err**	**Observed Score**	***t*-score**	***p*-value**
iopitipavg	37.44	15.13	3.9	29.33	0.54	0.595
iopidorsavg	34.21	9.43	2.16	24.67	1.01	0.318
iopilipsavg	24.33	12.67	2.91	0.00	1.92	0.062
mcbARMSav	153.15	110.23	25.29	87.30	0.60	0.554
mcbBRMSav	159.43	104.11	23.89	179.57	0.19	0.848
mcpud1ARMS	27.7	14.92	3.42	18.32	0.63	0.533
mcpud1BRMS	48.88	72.52	16.64	23.49	0.35	0.728
mcpud2ARMS	39.67	29.39	6.74	28.06	0.40	0.695
mcpud2BRMS	49.62	82.78	19	59.23	0.12	0.908
mc10ccARMS	22.04	8.79	2.02	25.21	0.36	0.720
mc10ccBRMS	26.2	22.8	5.23	36.1	0.43	0.667
mccrackARMS	108.9	79.56	18.25	26.23	1.04	0.305
mccrackBRMS	152	140.6	32.3	57.61	0.67	0.506
stcpud1avg	1.34	0.33	0.08	0.99	1.06	0.295
stcpud2avg	1.29	0.27	0.06	0.98	1.15	0.258
stc10ccavg	1.03	0.16	.04	0.77	1.63	0.112
stccrackavg	1.2	0.22	0.05	1.66	2.09	0.043*

tppud1	0.21	0.71	0.16	3	3.93	0.000***
tp10cc	1.05	1.31	0.3	3	1.49	0.145
tpcrack	0.37	0.83	0.19	3	3.17	0.003**
bolusres	1.28	0.56	0.13	3	3.07	0.004**
ope_p	0.21	0.42	0.1	0	6.64	0.000***
ope_d	0.58	1.46	0.34	2	0.40	0.693
cough	0	0	0	0	[1]	[1]
CB	0	0	0	1	[1]	[1]
FP	0	0	0	2	[1]	[1]
CTP	0.05	0.23	0.05	12	8.48	0.000***
NT	0	0	0	2	[1]	[1]
OMP	0	0	0	22	[1]	[1]
TP	0	0	0	8	[1]	[1]

***** $p \leq .05$. ****** $p \leq .01$. ******* $p \leq .001$. [1] no data available from normative sample

Table 3.4 reveals objective data obtained via the IOPI and EMG, as well as behavioral and observational data obtained during the evaluation. EMG data results indicate a statistically significant longer swallow during cracker trials (stccrackavg), when compared to the normative data. During trials in which the researcher utilized the lip pull down method, noting the presence/absence of tongue protrusion, the subject's tongue protruded more frequently than the norming population. Specifically, the subject's tongue was noted to protrude during all three trials of ½ tsp pudding and all three trials of Triscuit cracker.

The subject's data also indicate a significant amount of residue post-swallow, when compared to the normative data. Increased incidence of clavicular breathing, forward posture, chin tuck position, neck tension, open mouth posture, and tongue protrusion were also observed more frequently when compared to the norming population. Increased frequency of tongue protrusions and significant amounts of residue post-swallow are indicators of OMD, while

increased swallow timing is potentially a sign of OPD.

Subject 521

Subject 521 was a 40 year old female, whose participation included three separate sessions, all conducted at the Idaho State University Speech, Language, and Hearing Clinic. The first session included the subject completing the medical history form and being assessed for tongue thrust via administration of the STTP. During the second session, the researcher attempted to collect EMG data for masseter contraction and laryngeal elevation. However, the subject reported the electrodes were causing her discomfort and felt as though they were shocking her. The session was immediately ended and a third session was scheduled after replacing the electrodes. The final session was successful in obtaining EMG and IOPI measurements. The subject did not report any discomfort with the EMG electrodes.

Table 3.5 reveals results for subject 521 with tongue thrust secondary to behavioral and clinical indicators of an oromyofacial disorder. The subject was self-diagnosed with tongue thrust, based on her case history and current signs and symptoms of tongue thrust. The subject revealed that she requires liquid to wash down almost all foods and that she drinks approximately two full glasses of water during meals. Food avoidances that were reported include steak, dry meats, gum, and hard candy. The subject also recalled a choking incident when she was 19 years old; she reported that it took her a few years to get over the incident. When asked if she would consider herself to be a messy eater, the subjected said “Yes” due to dribbles of liquids and crumbs.

The subject reported it is very difficult for her to swallow pills because her

gag reflex is very sensitive. When asked to gargle during the evaluation, the subject triggered her gag reflex and she coughed. When the gag reflex was elicited by the researcher using a tongue depressor, the researcher determined the gag reflex was hypersensitive. The subject reported a history of sucking habits and oral noxious habits. Specifically, the subject reported she sucked a blanket until she was 6-7 years of age. She also reported she chewed on the sides of Tupperware lids until she was 8-9 years of age, which led to fingernail biting. The subject reported she still bites her nails.

Upon observation of the subject's teeth, the researcher noted a class II malocclusion and a central open bite that extended more to the left side. The subject reported she used to be able to stick her tongue through her open bite. The subject has never received orthodontic treatment but reported that her teeth have shifted throughout the years. The subject reported her tongue rest posture to be on the floor of her mouth, touching the sides of her bottom teeth.

When asked if her tongue felt large in her mouth, the subjected reported "Yes." However, the researcher found the tongue size to be within normal limits. During tongue-tip elevation exercises, the researcher observed a heart shape appearance of the tongue. After further examination, the researcher diagnosed the subject with ankyloglossia and provided appropriate referral information. During the third session, the subject reported that she spoke with her mother and found out she had previously had her frenum surgically released when she was a baby. It is the belief of the researcher that not enough of the frenum was clipped which would explain the subject's current presentation of ankyloglossia.

Lip movements appeared smooth, symmetrical, and coordinated upon observation. However, when asked to seal lips to hold air in the oral cavity, the subject reported the task to be difficult. The researcher observed the subject's lip quivering when asked to keep her lips together.

The subject was a self-reported mouth breather and that although she can breathe through her nose, her nasal passages were reported to often be obstructed. The subject's medical history includes a broken nose from a diving board incident; she suspected she may have a deviated septum as a result. The subject reported a history of frequent sinus infections. Additionally, the subject reported she experiences seasonal allergies, which sometimes result in allergy attacks. Upon examination, the subject's tonsils were enlarged. Because the subject had a history of recurrent tonsillitis when she was younger, removal of the tonsils was previously discussed. Since the subject stopped getting tonsillitis, surgery was no longer discussed.

During conversation, no audible speech sound errors were noted. However, the tongue was visually present and was forward during speech. During the food and liquid trials on the STTP, the researcher observed the subject's tongue protruding to presentation of the straw and spoon. Across all food and liquid trials, the subject reported her back teeth were apart during the swallow. The researcher noted the subject sucking in her lips across all food and liquid trials, to keep the boluses from escaping the mouth. The swallow was judged to be audible during liquid trials. The subject consistently took multiple swallows. When asked to take bits of the Triscuit cracker during the STTP, the

subject reported she could feel residue and reported that the chewing hurt her teeth. Finally, the subject reported a history of GERD, but when she eliminated foods and drinks containing red dye, her symptoms were alleviated.

During the food and liquid trials of the study protocol, the researcher noted that the subject tilted her head back during swallow trials on five occasions. Her tongue greeted the spoon, which is consistent with observations during the STTP trials. Finally, the subject was noted to protrude her tongue during saliva swallows.

Table 3.5. Indicators of OMD for Subject 521, a 40 year old female.

OMD Indicators	Results
Use liquid to wash food down/difficulty swallowing dry foods	Requires liquids to wash down almost all foods. Drinks approximately two glasses of water during meals.
Food avoidances	Steak, dry meats, gum, berries with seeds, and hard candy. Reported a choking incident when eating steak at 19 years of age. Took several years to get over the incident.
Difficulty swallowing pills	Yes. Often triggers gag reflex.
Messy eater	Yes. Notices wiping away liquids and crumbs.
Noxious oral habits	Sucked blanket until 6-7 years of age. Chewed on the sides of Tupperware lids until 8-9 years of age, which led to fingernail biting. Reported she still bites nails.
Open bite	Yes. Central but extends slightly more to the left side.
Malocclusion	Class II.
Tongue size	Perceived tongue size as large. No evident signs of macroglossia.
Tongue elevation	Relied on mandible to move the tongue. Researcher noted a heart shaped tongue during tongue-tip elevation task.
Tongue weakness	Yes. Noted on the back of tongue.
Tongue rest posture	Floor of mouth, touching sides of lower back teeth.

Ankyloglossia	Yes.
Gag reflex	Hypersensitive.
Difficulty gargling	Yes. Sometimes chokes or gags while trying to gargle. Coughed when asked to gargle during evaluation.
Lip rest posture	Lips apart.
Lip seal	Reported difficulty holding air in oral cavity while resisting pressure applied by the researcher. Lips quivered when asked to keep lips together.
Mouth breather	Yes.
Allergies	Allergies include hay, dust, and other unknown environmental allergens. Experiences allergy attacks.
Sinus and upper airway issues	Can breathe through nose although airflow is often obstructed. Broke nose during childhood during a diving board incident. Subject suspected a possibly deviated septum. Subject reported she has a history of frequent sinus infections.
Tonsils	Appeared enlarged. Discussed removal during childhood due to recurrent tonsillitis.
Speech	No audible frontal lisping or interdental productions of speech sounds noted. Researcher did note the tongue was visibly forward during speech.
Tongue protrusion	Noted to presentation of straw and spoon during STTP and study protocol. Tongue protrusion was observed during completion of study protocol.
Back teeth apart	Yes. Reported back teeth were apart during the swallow across food and liquid trials.
Pursing lips	Noted across all food and liquid trials.
Audible swallow	Yes. Observed during liquid trials.
Multiple swallows	Yes. Subject did report she could feel cracker residue post-swallow.
History of GERD	Yes. Subject reported eliminating foods containing red dye have alleviated her symptoms.
Head tilt back	Observed five times during food and liquid trials of the study protocol.

Table 3.6. Instrumental and observational data for Subject 521, a 40 year old female.

	Normative Mean	**Std Dev**	**Std Err**	**Observed Score**	***t*-score**	***p*-value**
iopitipavg	34.79	12.92	2.5	35.67	0.07	0.946
iopidorsavg	48.42	10.78	1.88	NA	NA	NA
iopilipsavg	25.43	9.3	1.62	0.00	2.73	0.008**
mcbARMSav	94.6	105.63	18.39	3.13	.87	.39
mcbBRMSav	151.84	207.74	36.16	2.40	.72	.48
mcpud1ARMS	71.98	146.08	25.43	.9	.49	.63
mcpud1BRMS	229.36	407.94	71.01	.94	.56	.58
mcpud2ARMS	75.54	131.47	22.89	1.07	.57	.57
mcpud2BRMS	189.78	306.97	53.43	1.23	.61	.54
mc10ccARMS	92.62	175.37	30.53	.61	.52	.60
mc10ccBRMS	160.9	248.88	43.32	.95	.64	.52
mccrackARMS	143.88	242.78	42.26	1.14	.59	.56
mccrackBRMS	194.51	286.9	49.94	1.87	.67	.51
stcpud1avg	1.33	0.69	0.12	0.91	0.61	0.545
stcpud2avg	1.04	0.21	0.04	1.05	0.05	0.962
stc10ccavg	0.87	0.36	0.063	0.68	0.53	0.600
stccrackavg	1.24	0.41	0.07	1.07	0.41	0.680
tppud1	0.16	0.45	0.08	3	6.31	0.000***
tp10cc	0.19	0.6	0.1	3	4.68	0.000***
tpcrack	0.23	0.56	0.1	3	4.95	0.000***
bolusres	1.51	0.89	0.15	3	1.67	0.100
ope_p	0	0	0	0	[1]	[1]
ope_d	0.3	0.59	0.1	2	2.88	.006**
cough	0	0	0	1	[1]	[1]
CB	0	0	0	1	[1]	[1]
FP	0.06	0.24	0.04	4	16.42	0.000***
CTP	0	0	0	7	[1]	[1]
NT	0	0	0	0	[1]	[1]
OMP	0	0	0	14	[1]	[1]
TP	0.06	0.35	0.06	10	28.40	0.000***

***** $p \leq .05$. ****** $p \leq .01$. ******* $p \leq .001$. [1] no data available from normative sample

Table 3.6 reveals objective data obtained via the IOPI and EMG, as well as behavioral and observational data obtained during the evaluation. IOPI

data results for tongue dorsum strength (iopidorsavg) were not attainable, due to continual elicitation of the subject's gag reflex during placement of the IOPI bulb; therefore, no data results were reported. When obtaining measurements for IOPI lip strength (iopilipsavg), the subject relied on unclenching her jaw in order to exert force against the IOPI bulb; therefore, the subject received a score of 0, which indicates decreased strength when compared to the means of the normative data.

Upon palpation, the researcher judged the subject to have a very weak masseter. However, no significant differences were found between the subject and the norming population in regards to masseter contraction.

Data results indicate that, during the lip pull down method trials, tongue protrusion was observed across all trials for ½ tsp pudding (tppud1), 10 cc water (tp10cc), and Triscuit cracker (tpcrack); therefore, the incidence of tongue protrusion is significantly higher in the subject than the incidence reflected in the normative data results column. Data also indicate an increased incidence of the following subjective variables during swallow trials: clavicular breathing, forward posture, neck tension, open mouth posture, and tongue protrusion. The subject was also observed to cough once during the evaluation which is greater than the normative sample, who did not exhibit any coughing.

A higher occurrence of tongue protrusions, potentially decreased tongue dorsum strength, and decreased lip strength are indicators of OMD. The incidence of coughing post-swallow is a possible indicator of a compromised swallow, which may suggest potential OPD.

Subject 522

Subject 522 was an 11 year old male, whose participation included one session at the Idaho State University Speech, Language, and Hearing Clinic. His mother attended the entire session and assisted him in completing paperwork and answering case history questions.

Table 3.7 indicates that subject 520 has tongue thrust secondary to behavioral and clinical indicators of an oromyofacial disorder. His mother, who is a dental hygienist, was the one who recognized that he had tongue thrust; his mother also reported his grandfather and older brother also have tongue thrust. Based on case history information and observations made during the session, the researcher deemed the severity of the subject's tongue thrust as one of the less severe cases in comparison to the other subjects who participated in the study.

Upon inspection, the subject had normal occlusion. The subject and his mother reported previous orthodontic treatment including the following: palatal expander for approximately six months, orthodontic braces for one year, and a tongue positioning appliance for nine months. The medical history form revealed that the subject had open spaces during mixed dentition, but did not have any current open spaces in dentition. The subject reported that, at rest, his tongue rests against his upper teeth and that his lips are closed at rest. The subject and his mother reported no past history of noxious oral habits.

During tongue-tip elevation tasks, the subject was noted to rely on his lips and mandible to move his tongue. He also demonstrated slight weakness in the

lateral borders of the tongue when the researcher pushed against his tongue with a tongue depressor. Although no audible speech sound errors were noted during conversation with the researcher, the researcher noted that the subject's tongue was forward and visible during speech.

The subject demonstrated a normal gag reflex. The subject retracted and protruded his lips and did so with smooth, coordinated, and symmetrical movements. However, when asked to hold air in the oral cavity and resist the researcher pushing against his cheeks, the subject demonstrated difficulty. Neither the subject nor his mother considered him to be a mouth breather. The medical history form revealed no reports of restricted nasal airflow, except when sick, no reports of upper airway issues, and no reports of allergies. Upon observation, the subject's tonsils did not look enlarged.

The subject did not report any food avoidances, based on difficulty chewing and swallowing. He did report that he experiences difficulty swallowing dry foods such as pretzels and chips. In regards to swallowing pills, the subject reported difficulty. He reported he chews gum as often as possible. When asked if he prefers to chew on one side of his mouth, the subject reported his left side. During food and liquid trials, the subject was noted to protrude his tongue upon presentations, took large bites, and had an audible swallow. On every trial that included presentation of food via a spoon, the researcher noted the client turned the spoon upside down and slid the spoon down his tongue as he presented the food into his mouth.

During food trials of the study protocol, the subject was noted to turn his

spoon upside down, sliding the food on his tongue, across all food trials, which was consistent with observations during the STTP. He was observed to tilt his head back during swallows on nine occasions. Pursing of lips was observed three times and two of his swallows were audible.

Table 3.7. Indicators of OMD for Subject 522, an 11 year old male.

OMD Indicators	Results
Difficulty swallowing foods	Subject reported “just dry foods,” including pretzels and chips.
Difficulty swallowing pills	Yes.
Orthodontic treatment	Reported a palatal expander for approximately six months, braces for one year, and a tongue positioning appliance for nine months.
Tongue-tip elevation	Relied on lips and mandible to move tongue.
Tongue weakness	Slight weakness noted on the lateral edges of tongue.
Lip seal	Demonstrated difficulty when clinician applied light pressure to cheeks.
Speech	No audible speech sound errors. No audible frontal lisping or interdental productions of speech sounds noted. Researcher did note the tongue was visibly forward during speech.
Tongue protrudes to presentation	Yes, noted across food and liquid trials.
Large presentations	Yes.
Tongue protrusion during swallow	Yes, noted across food and liquid trials.
Audible swallow	Yes, noted on the STTP and during protocol.
Food presentation	Subject was observed to turn spoon upside down and slide food onto his tongue during all food trials of the STTP and study protocol.
Head tilt back	Observed nine times during study protocol.
Pursing lips	Noted three times during study protocol.

Table 3.8 reveals objective data obtained via the IOPI and EMG, as well

as behavioral and observational data obtained during the evaluation. IOPI data reveal significantly reduced lip strength (iopilipsavg), when compared to the means of the norming population; the subject received a score of 0 due to his inability to perform the task without unclenching his back teeth while pushing the IOPI bulb between his lips. EMG data results indicate significantly increased swallow timing for the following: ½ tsp pudding (stcpud1avg), 1 ½ tsp pudding (stcpud2avg), 10 cc water (stc10ccavg), and Triscuit cracker (stccrackavg).

Table 3.8. Instrumental and observational data for Subject 522, an 11 year old male.

	Normative Data	**Std Dev**	**Std Err**	**Observed Score**	***t*-score**	***p*-value**
iopitipavg	48.25	14.35	3.59	43.67	0.32	0.752
iopidorsavg	46.56	12.06	3.01	53.67	0.59	0.560
iopilipsavg	18.21	5.46	1.37	0.00	3.34	0.002**
mcbARMSav	336.1	168.73	42.18	15.19	1.90	0.066
mcbBRMSav	252.89	133.24	33.31	192.86	0.45	0.655
mcpud1ARMS	165.03	170.11	42.53	2.63	0.95	0.347
mcpud1BRMS	139.09	117.6	29.4	18.2	1.03	0.311
mcpud2ARMS	178.04	150.31	37.58	3.05	1.16	0.253
mcpud2BRMS	179.95	164.11	41.03	20.47	0.97	0.338
mc10ccARMS	148.57	125.58	31.4	4.06	1.15	0.258
mc10ccBRMS	155.61	131.32	32.83	20.63	1.03	0.311
mccrackARMS	281.38	232.31	58.1	5.94	1.19	0.244
mccrackBRMS	261.18	222.8	55.7	29.37	1.04	0.306
stcpud1avg	0.94	0.06	0.01	2.10	19.33	0.000***
stcpud2avg	0.98	0.05	0.01	1.90	18.40	0.000***
stc10ccavg	0.81	0.08	0.02	1.45	8.00	0.000***
stccrackavg	1.02	0.03	0.01	0.78	8.00	0.000***
tppud1	0.25	0.68	0.17	3.00	4.04	0.000***
tp10cc	0.38	0.72	0.18	3	3.64	0.001***
tpcrack	0.5	1	0.24	3	2.50	0.018*
boluscoh	1.75	0.87	0.22	5	3.74	0.001***
bolusres	1.75	0.87	0.22	2.33	0.67	0.510

ope_p	0.19	0.4	0.1	0	0.48	0.638
ope_d	0.69	0.79	0.2	0	0.87	0.389
cough	0	0	0	0	[1]	[1]
CB	0	0	0	2	[1]	[1]
FP	0	0	0	1	[1]	[1]
CTP	0	0	0	1	[1]	[1]
NT	0	0	0	0	[1]	[1]
OMP	0	0	0	5	[1]	[1]
TP	0	0	0	0	[1]	[1]

***** $p \leq .05$. ****** $p \leq .01$. ******* $p \leq .001$. [1] no data available from normative sample

Results from Triscuit cracker trials reveal significant differences in bolus cohesion (boluscoh) and bolus residue (bolusres) between the subject and the normative sample. When compared to the norms, the subject's bolus cohesion was judged to be more disorganized and the subject's bolus residue was judged to be significantly different than the normative sample. Additionally, increased occurrence of tongue protrusion, as observed during the lip pull down method, was noted for all trials for the following: ½ tsp pudding (tppud1), 10 cc water (tp10cc), and Triscuit cracker (tpcrack). The incidences of clavicular breathing, forward posture, chin tuck position, and open mouth posture were higher than the incidence of the norming population. Decreased lip strength, high occurrence of tongue protrusion, poor bolus cohesion, and significant bolus residue are indicators of OMD. Increased swallow timing may be potentially indicative of OPD.

Subject 523

Subject 523 was an 11 year old male, whose participation included one session at the Idaho State University Speech, Language, and Hearing Clinic. His mother attended more than half of the session, assisting him in completing the medical history form and answering case history questions.

Table 3.9 indicates that subject 520 has tongue thrust secondary to behavioral and clinical indicators of an oromyofacial disorder. The subject's mother was the one who diagnosed him with tongue thrust; the subject's mother also reported that his orthodontist did not think he had tongue thrust. The subject reported to bite his nails for as long as he could remember and sucked his thumb in the first grade. Additionally, the subject used a pacifier until 3 years of age and off-and-on until 5 years of age. On the medical history form, a history of cheek biting was also indicated.

Table 3.9. Indicators of OMD for Subject 523, an 11 year old male.

OMD Indicators	Results
Use liquid to wash food down/difficulty swallowing dry foods	Yes. Difficulty swallowing peanut butter, pancakes, and crackers.
Food avoidances	Triscuit crackers.
Difficulty swallowing pills	Needs a lot of water to swallow pills.
Messy eater	Mother reported "inside his mouth is messy" and that he smacks loudly.
Noxious oral habits	Reported to bite nails as for as long as he could remember. Sucked thumb in the first grade. Used a pacifier until 3 years of age and off-and-on until 5 years of age. On the medical history form, a history of cheek biting was also indicated.
Open bite	Slightly lateral open bite noted on the left side.
Malocclusion	Class II.
Orthodontic treatment	MARA appliance on top and bottom teeth to correct overbite. Has had braces on top

	and bottom teeth since Thanksgiving.
Tongue elevation	Relied on mandible to move tongue.
Tongue weakness	Researcher noted weakness in the tongue tip and in the lateral borders.
Ankyloglossia	Yes. Researcher provided appropriate referral information to subject and his mother.
Lip rest posture	Lips open.
Mentalis muscle tension	Researcher observed a lot of tension in the mentalis muscle throughout the entire evaluation.
Mouth breather	Yes.
Nasal breathing	Can breathe through nose but reported it is easier to breathe through his mouth.
Upper respiratory issues	No issues other than typical colds. On the medical history form, subject's mother wrote "Not that I know of – but maybe" next to deviated septum.
Tonsils	Subject still had tonsils. Upon observation, the tonsils appeared slightly enlarged. Subject's mother reported last year the subject had strep throat 3-4 times and has previous years of recurrent strep throat. No discussion with physicians about removal.
Speech	Speech sounded slightly distorted, but the researcher questioned if the productions of sounds were affected by the MARA device.
History of speech therapy services	Received therapy at 4-4 ½ years of age for fronting, gliding, and backing speech sound error patterns. Received services for 6 months.
Tongue protrudes to presentation	Protruded to spoon and straw.
Large presentations	Subject took large bites of foods.
Poor lip seal	Subject's lips were occasionally noted to open while chewing foods.
Pursing lips	Lips pursed during the STTP and study protocol.
Multiple swallows	Reported multiple swallows on food trials.
Audible swallow	Yes. Observed on liquid trials
Chin lift	Observed twice during study protocol.
Head tilt back	Observed once during study protocol.
Open mouth chewing	Observed during study protocol.

The subject reported it is difficult to swallow dry foods, specifically peanut butter, pancakes, and crackers. When asked about food avoidances on the

medical history form, Triscuit crackers were reported by his mother. The subject reported difficulty swallowing pills and needs to drink a lot of water to wash the pills down. The subject's mother reported the subject is a messy eater "in his mouth" and that he smacks loudly while he eats.

Upon observation the researcher noted a slight lateral open bite on the left side and a class II malocclusion. The subject's mother reported on the medical history form that the subject had open spaces during mixed dentition and current open spaces in dentition. The subject was currently receiving orthodontic treatment. He had a Mandibular Anterior Repositioning Appliance (MARA) on his upper and lower teeth; the reported purpose of a MARA appliance is to correct overbite. Additionally, the subject had orthodontic braces on his upper teeth, which he has had since November 2014.

During tongue-tip elevation tasks on the STTP, the subject relied on his mandible to move his tongue. When the researcher pressed against his tongue with a tongue depressor, the researcher noted weakness in the tongue tip and lateral borders. During the evaluation, the researcher diagnosed the subject with ankyloglossia and gave appropriate referral information to both the subject and his mother.

The subject retracted and protruded his lips when asked to do so by the researcher. The movements were judged to be smooth, coordinated, and symmetrical. However, at rest, the researcher noted visible tension in the mentalis muscle. The subject reported that his tongue typically rests against his upper teeth and that his lip rest posture is lips open.

The subject and his mother confirmed that he is a mouth breather and that, although he can breathe through his nose, he reported it is easier to breathe through his mouth. No known allergies were reported and no upper respiratory issues were reported, other than typical colds. However, on the case history form which asks whether or not the subject has a deviated septum, the subject's mother wrote "Not that I know of – but maybe." The subject still had his tonsils but upon observation, the researcher deemed the tonsils to be slightly enlarged. The subject's mother reported last year the subject had strep throat 3-4 times. She also reported previous years of recurrent strep throat. There has been no discussion with subject's physicians about removal of tonsils.

During conversation, the researcher noted some distortions of sounds, although the researcher questioned whether or not the distortions were caused by the MARA appliance. The subject has a history of receiving speech therapy services. He received therapy at 4-4 ½ years of age for fronting, gliding, and backing speech sound error patterns; after six months of responding positively to treatment, the subject was discharged from therapy.

During the food and liquid trials on the STTP, the subject's tongue protruded to presentation of the spoon and straw. The subject took large bites and occasionally had open lips while chewing. His lips pursed during swallowing of liquids and he reported multiple swallows on food trials. Finally, audible swallows were observed on liquid trials.

During the study protocol food and liquid trials, the subject was observed to purse his lips, which is consistent with initial observations. On two occasions,

the subject was observed to lift his chin up during the swallow and on one occasion, the subject was observed to tilt his head back. Mentalis tension was observed, which is consistent with findings from the STTP. Finally, the subject was noted to chew with his mouth open.

Table 3.10 reveals objective data obtained via the IOPI and EMG, as well as behavioral and observational data obtained during the evaluation. IOPI data reveal significantly reduced lip strength (iopilipsavg) when compared with the results of the norming population; the subject received a score of 0 due to his reliance on his teeth to compress the bulb between his lips. EMG data results reveal no differences relating to masseter contraction but do reveal significant results relating to the subject's swallow timing. Specifically, the subject's results indicate significantly increased swallow timing for the following: ½ tsp pudding (stcpud1avg), 1 ½ tsp pudding (stcpud2avg), 10 cc water (stc10ccavg), and Triscuit cracker (stccrackavg).

Table 3.10. Instrumental and observational data for Subject 523, an 11 year old male.

	Normative Mean	**Std Dev**	**Std Err**	**Observed Score**	***t*-score**	***p*-value**
iopitipavg	48.25	14.35	3.59	40.33	0.55	0.585
iopidorsavg	46.56	12.06	3.01	41	0.46	0.648
iopilipsavg	18.21	5.46	1.37	0	3.34	0.002**
mcbARMSav	336.1	168.73	42.18	130.43	1.22	0.232
mcbBRMSav	252.89	133.24	33.31	59.93	1.45	0.157
mcpud1ARMS	165.03	170.11	42.53	11.64	0.90	0.374
mcpud1BRMS	139.09	117.6	29.4	9.54	1.10	0.279
mcpud2ARMS	178.04	150.31	37.58	13.1	1.10	0.280
mcpud2BRMS	179.95	164.11	41.03	10.21	1.03	0.309

mc10ccARMS	148.57	125.58	31.4	9.51	1.11	0.276
mc10ccBRMS	155.61	131.32	32.83	9.57	1.11	0.274
mccrackARMS	281.38	232.31	58.1	25.99	1.10	0.280
mccrackBRMS	261.18	222.8	55.7	14.38	1.11	0.276
stcpud1avg	0.94	0.06	0.01	1.38	7.33	0.000***
stcpud2avg	0.98	0.05	0.01	1.41	8.60	0.000***
stc10ccavg	0.81	0.08	0.02	1.48	8.38	0.000***
stccrackavg	1.02	0.03	0.01	1.65	21.00	0.000***
tppud1	0.25	0.68	0.17	3	4.04	0.000***
tp10cc	0.38	0.72	0.18	3	3.64	0.001***
tpcrack	0.5	1	0.24	3	2.50	0.018*
boluscoh	1.75	0.87	0.22	5	3.74	0.001***
bolusres	1.75	0.87	0.22	5	3.74	0.001***
ope_p	0.19	0.4	0.1	0	0.48	0.638
ope_d	0.69	0.79	0.2	2	1.66	.11
cough	0	0	0	0	[1]	[1]
CB	0	0	0	1	[1]	[1]
FP	0	0	0	10	[1]	[1]
CTP	0	0	0	1	[1]	[1]
NT	0	0	0	3	[1]	[1]
OMP	0	0	0	6	[1]	[1]
TP	0	0	0	2	[1]	[1]

***** $p \leq .05$. ****** $p \leq .01$. ******* $p \leq .001$. [1] no data available from normative sample

Results of testing reveal differences in bolus cohesion (boluscoh) and bolus residue (bolusres) during Triscuit cracker trials. When compared to the results of the normative sample, the subject's bolus cohesion was judged to be more disorganized and the subject's bolus residue was judged to be more prominent. During the lip pull down trials, in which the researcher noted the presence or absence of tongue protrusion, the subject was observed to protrude his tongue 100% of opportunities, while swallowing ½ tsp pudding (tppud1), 10 cc water (tp10cc), and Triscuit cracker (tpcrack). These results are significantly higher than the results obtained from the norming population. The following

observed variables were also found to occur more frequently in the subject than the norming population: clavicular breathing, forward posture, chin tuck position, neck tension, open mouth posture, and tongue protrusion. Decreased lip strength, high occurrence of tongue protrusion, disorganized bolus cohesion, and significant bolus residue post-swallow are indicators of OMD. Significantly increased swallow timing is a potential sign of OPD.

Subject 524

Subject 524 was a 17 year old female whose participation in the study included one session, which was conducted at her home. Her mother, who also participated in the study, was present during the entire study and her sisters and father were present during portions of the study. All EMG and IOPI data were collected in a single evaluation.

Table 3.11 indicates that subject 524 has tongue thrust secondary to behavioral and clinical indicators of an oromyofacial disorder. The subject's mother was the referral and the one who identified the subject as having tongue thrust. The subject reported she uses liquids to wash food down and that she has a difficulty swallowing crackers without drinking any liquids. Foods that were reported to be avoided include peanut brittle, toffee, and caramel because "it hurts to chew." The subject reported she chews gum "all the time." Although the subject reported she is a slow eater, she raised the possibility that it may be due to her braces and trying to keep food out of her braces.

Table 3.11. Indicators of OMD, Subject 524, a 17 year old female.

OMD Indicators	Results
Use liquid to wash food down/difficulty swallowing dry foods	Yes. Reported crackers.
Food avoidances	Peanut brittle, toffee, and caramels. Did report frequent gum chewing.
Slow eater	Yes. Researcher questions if due to keeping food out of her braces.
Noxious oral habits	Reported pacifier use until approximately 2 years of age. Bite nails when younger. Was observed to bite her lips during study protocol.
Open bite	Central.
Malocclusion	Class III.

Crossbite	Left side.
Missing teeth	Reported missing the following: two top bicuspids and right third molar was not fully erupted but was buried in her gums.
Orthodontic treatment	Active. Has had braces 1 ½ years. Braces will come off in the fall of 2015, between September and November. Reported upcoming jaw surgery to expand palate out and forward and to pull front teeth and jaw forward because it "didn't fully grow."
Tongue size	Reported tongue size feels large, but no signs of macroglossia.
Tongue elevation	Relied on mandible to move tongue.
Tongue weakness	Slight weakness noted in the tip of the tongue and lateral borders.
Ankyloglossia	Yes. Provided referral information to subject and mother.
High and narrow palate	Yes.
Gag reflex	Mildly sensitive. Reported it used to be even more sensitive.
Gargling	Demonstrated difficulty.
Tongue rest posture	Reported against upper teeth. However, during evaluation, reported her tongue sometimes "floats" in her mouth.
Lip rest posture	Lips open. Reported experiences chapped lips.
Lip movements	Were smooth and coordinated but were not judged as symmetrical.
Mouth breather	Yes. Also reported that she is often reminded to chew with mouth closed.
Nasal breathing	Can breathe through nose but for short durations.
Allergies	"Strange chemicals." Chemicals in the skin prepping gel and alcohol swabs were not included in subject's known skin allergies.
Upper respiratory issues	Yes. Had a sinus infection day of evaluation and was on medication.
Tonsils	Reported to be enlarged on medical history form. Inspection confirmed tonsils were enlarged, especially the right tonsil. Reported strep throat six times in one year when subject was 7 years old.
Speech	Slight frontal lisp. Researcher questioned whether it was due to tongue position during speech or to subject's braces. During speech, researcher noted the subject's tongue was visibly forward.
Tongue protrudes to presentation	Protruded to straw, cup, spoon, and cracker across all trials on the STTP.

Chewing pattern	Reported a preference to chewing on the right side of her mouth and lateralizing boluses to the right side of her mouth. Also observed chewing with mouth open.
Back teeth apart	Reported back teeth were apart across food and liquid trials.
Poor lip seal	Wiped sides of mouth during food trials on the STTP.
Pursing lips	Noted during STTP and study protocol.
Audible swallow	Noted on liquid trials.
History of GERD	Yes.
Food presentation	Subject turned her spoon upside down and slid pudding down tongue for approximately half of the study protocol duration.
Head tilt back	Observed twice during study protocol.

The subject reported no history of cheek biting or digit sucking. However, she reported to the researcher that she bit her nails when she was younger and used a pacifier until she was approximately two years old. The subject reported allergies to “strange chemicals” that affect her skin. However, her allergies did not include any chemicals in the skin prepping gel or alcohol swabs.

Upon observation the researcher noted a central open bite. The researcher noted the presence of a class III malocclusion and a crossbite on the left side. When asked if she was missing any teeth, the subject reported she was missing her two upper bicuspids and that her right third molar was not fully erupted but was buried in her gums. The subject was a current patient in an orthodontic treatment program; she reported she has had her braces for 1 ½ years and they will be taken off between September and November. Additionally, a jaw surgery will be scheduled in the future to expand her palate out and forward, to pull her front teeth and jaw forward because “it didn’t fully grow.”

Upon inspection of the tongue, the researcher did not find any signs of macroglossia, although the subject reported that her tongue feels large in her mouth. During tongue elevation tasks, the subject relied on her mandible to move her tongue. When asked to press against a tongue depressor, the subject demonstrated weakness in the tip of her tongue and slight weakness on the borders of the tongue. Finally, the researcher diagnosed the subject with ankyloglossia and provided the subject and her mother on referral information. It is important to note that the subject's mother, who also participated in the study, also had ankyloglossia.

The subject's gag reflex was reported to be mildly sensitive, although she reported it was even more sensitive in the past. Additionally, the subject demonstrated difficulty gargling when asked to do so by the researcher. The subject reported her tongue rest posture to be against her upper teeth, but later during the evaluation, the subject reported that her tongue sometimes "floats" in her mouth. She reported that her lip rest posture is lips open and that she frequently experiences chapped lips. The subject retracted and protruded her lips upon request from the researcher. The movements were smooth and coordinated, but the movements were not symmetrical.

Both the subject and her mother agreed that the subject is a "mouth breather." When asked about nasal breathing, the subject reported she can breathe through her nose but only for a short duration. The subject had a sinus infection the day of the evaluation and was taking medication for the infection. In regards to tonsils and adenoids, the subject still has both, but she reported that

when she was 7 years old she had strep throat six times in one year. Upon inspection of the tonsils, the researcher noted that the tonsils appeared enlarged, especially the right tonsil.

When asked to count from 60-70, the researcher noted a slight frontal lisp, but questioned whether this could be due to the subject's braces. Although there were no interdental productions of /t, l, d, n/, the researcher noted that the tongue was forward and visible during speech. The subject's history included no previous speech therapy services.

During food and liquid trials on the STTP, the subject's tongue protruded to presentation of the straw, cup, soon, and cracker. In regards to chewing pattern, subject reported she prefers to chew on the right side and she reported lateralizing boluses to the right side. The researcher noted frequent open mouth chewing. When asked about her back teeth during swallows, the subject reported her back teeth were apart across food and liquid trials. The researcher noted the subject wiping the sides of her mouth during food trials. Pursing of lips was noted across food and liquid trials, while an audible swallow was observed on liquid trials. Finally, the subject reported a history of GERD symptoms.

During food and liquid trials of the study protocol, the subject was noted to purse her lips, which is consistent with previous observations. Approximately halfway through the protocol, the subject was noted to turn her spoon upside down, sliding pudding on her tongue. In between trials, the researcher observed the subject biting her lip. Finally, the subject was observed to tilt her head back twice during swallow trials.

Table 3.12 reveals objective data obtained via the IOPI and EMG, as well as behavioral and observational data obtained during the evaluation. EMG data results indicate significantly delayed swallow timing for 1 ½ tsp pudding (stcpud2avg) and Triscuit cracker (stccrackavg), when compared to the means of the normative sample.

Table 3.12. Instrumental and observational data for Subject 524, a 17 year old female.

	Normative Mean	**Std Dev**	**Std Err**	**Observed Score**	***t*-score**	***p*-value**
iopitipavg	45.04	11.19	2.64	44.67	0.03	0.974
iopidorsavg	41.44	12.74	3	38.67	0.22	0.829
iopilipsavg	33.1	12.45	2.93	13.00	1.61	0.115
mcbARMSav	115.38	98.87	23.3	30.56	0.86	0.397
mcbBRMSav	107.31	96.34	22.71	53.13	0.56	0.577
mcpud1ARMS	34.61	36	8.47	19.8	0.41	0.683
mcpud1BRMS	40.8	47.8	11.26	25.94	0.31	0.758
mcpud2ARMS	37.28	27.166	6.4	19.45	0.66	0.516
mcpud2BRMS	65.93	80.42	19	25.26	0.51	0.616
mc10ccARMS	112.75	307.34	72.44	22.72	0.29	0.771
mc10ccBRMS	200.28	340.03	80.15	25.7	0.51	0.611
mccrackARMS	108.13	117.34	27.66	34.41	0.63	0.534
mccrackBRMS	128.76	171.57	40.44	31.46	0.57	0.574
stcpud1avg	0.98	0.215	0.05	1.31	1.53	0.134
stcpud2avg	0.98	0.28	0.07	2.21	4.39	0.000***
stc10ccavg	1	0.22	0.05	1.35	1.59	0.120
stccrackavg	1	0.23	0.05	4.16	13.74	0.000***
tppud1	0.83	0.92	0.22	3.00	2.36	0.024*
tp10cc	1.22	1.06	0.25	3	1.68	0.102
tpcrack	0.72	1.02	0.24	3	2.24	0.032*
bolusres	2.24	1.12	0.26	1.67	0.51	0.614
ope_p	0	0	0	1	[1]	[1]
ope_d	0.28	0.96	0.23	3	2.83	.008**
cough	0.06	0.24	0.06	0	0.25	0.804
CB	0	0	0	0	[1]	[1]

FP	0.06	0.24	0.06	5	20.58	0.000***
CTP	0	0	0	1	[1]	[1]
NT	0	0	0	11	[1]	[1]
OMP	0	0	0	15	[1]	[1]
TP	0.39	1.65	0.39	5	2.79	0.008**

***** $p \leq .05$. ****** $p \leq .01$. ******* $p \leq .001$. [1] no data available from normative sample

During lip pull down trials, the subject was found to protrude her tongue across all attempts while swallowing ½ tsp pudding (tppud1) and Triscuit cracker (tpcrack).The number of times the subject demonstrated forward posture and tongue protrusion during swallow trials were statistically significantly higher than the occurrence found in the norming population. The following subjective variables were also found to occur more frequently in the subject than the norming population: chin tuck position, neck tension, and open mouth posture. Finally, the subject was also judged to have a high and narrow palate, which was not observed in the norming population.

High occurrence of tongue protrusion and the presence of a high and narrow palate are indicators of OMD. Delayed swallow timing is a potential sign of OPD.

Subject 525

Subject 525 was a 23 year old female, whose participation included two separate sessions at the Idaho State University Speech, Language, and Hearing Clinic. The first session included completion of the consent form and medical history form, assessment for tongue thrust via the STTP, EMG swallow timing, and IOPI for tongue and lip strength. As the researcher put new electrodes on to measure masseter contraction, the subject reported a “shocking” and “barely there” sensation when the electrodes were placed on the masseter. The researcher immediately ended the session and scheduled another session to obtain masseter contraction via EMG with new electrodes. The second session was successful in obtaining the measures with no reports of pain or discomfort.

Table 3.13 indicates that subject 525 has tongue thrust secondary to behavioral and clinical indicators of an oromyofacial disorder. The subject self-diagnosed herself with tongue thrust, based on her case history and current signs and symptoms of tongue thrust. The subject reported she has difficulty swallowing dry cereals (especially Mini Wheats), chips, and crackers. She also reported frequent buccal pocketing that she often cannot reach with her tongue, so she cleans the inside of her cheeks with her finger. She reported herself to be a slow eater and that, although certain foods are difficult for her to chew, she does not avoid any foods based on difficulty chewing. When asking about swallowing pills, the subject reported she used to have trouble but not as much trouble anymore. She made a comment that pills occasionally get “stuck.”

Table 3.13. Indicators of OMD for Subject 525, a 23 year old female.

OMD Indicators	Results
Use liquid to wash food down/difficulty swallowing dry foods	Yes. Dry cereals, especially Mini Wheats, chips, and crackers. Reported frequent pocketing.
Slow eater	Yes.
Food avoidances	Acknowledged that foods are sometimes difficult to chew, but doesn't avoid any foods.
Difficulty swallowing pills	Reported previous difficulty, not as much difficulty anymore. Reported pills occasionally get "stuck."
Messy eater	Used to be a messy eater. Not as messy anymore.
Noxious oral habits	Reported used to chew a pencil, used to bite the front lip sides, and used a bottle until 4 years of age. Reported still bites sides of cheeks at night.
Open bite	No current open bite, although it was reported she used to have a severe open bite.
Orthodontic treatment	Braces on upper and lower teeth and a palatal expander were reported. A second application of braces was warranted after an incorrectly placed permanent retainer on the bottom teeth caused the subject's teeth to move.
Malocclusion	Class II.
Tongue elevation	Relied on teeth and mandible to move tongue.
Tongue weakness	Noted in the tip and back of tongue.
Tongue rest posture	Reported on the bottom of the mouth, touching lower teeth.
Ankyloglossia	Yes. Provided referral information to subject.
Gag reflex	Hypersensitive.
Gargling	Some difficulty. Reported she sometimes gags or aspirates while gargling.
Lip rest posture	Lips open.
Mouth breather	Yes. Reported especially at night and that she often drools, needs water in the morning, and experiences chapped lips. Subject's grandmother would often shut the subject's mouth while growing up.
Nasal breathing	Reported she can breathe through her nose during the day when she makes a conscious effort.

Upper respiratory issues	Reported sinus infections are a constant problem.
Speech	Researcher noted a slight frontal lisp and described the subject's speech as having a sibilant quality at times. Occasional interdental productions of /t, d/ were noted.
Tongue protrudes to presentation	Protruded to straw and spoon.
Chewing pattern	Anterior munching observed.
Back teeth apart	Reported back teeth were apart while swallowing across food and liquid trials on the STTP.
Tongue protrusion	Tongue was observed to protrude during food and liquid trials. One liquid swallow included the tongue escaping the mouth.
Pursing lips	Observed across food and liquid trials.
Audible swallow	Noted on liquid trials.
History of GERD	Yes.
Multiple swallows	Yes, across all food trials.
Compensatory strategy	Combination of forward posture and chin tuck was observed during study protocol. Described as "forward and out" motion by researcher.
Residue post-swallow	Subject reported during pudding trials of study protocol that the back of her throat felt coated and that she could feel pudding on the roof of her mouth.

In regards to noxious oral habits, the subject reported she used to chew a pencil, used to bite the front sides of her lips, and used a bottle until she was 4 years old. She also reported herself to be a current cheek biter during the night. No other noxious oral habits were reported.

The researcher judged the subject to have a class II malocclusion. Upon inspection, no open bite was observed, although the subject reported she used to have a severe open bite, which was corrected with orthodontic braces on top and bottom teeth and a palatal expander. The subject also reported a second application of braces, due to an incorrectly placed permanent retainer on her

bottom teeth which caused her teeth to shift.

During tongue elevation tasks, the subject relied on the mandible to move the tongue. When the researcher pressed against the tongue with a tongue depressor, some weakness was noted in the tip and back of the tongue. The subject reported her tongue rest posture to be on the bottom of her mouth, touching her lower teeth.

The researcher diagnosed the subject with ankyloglossia, which could explain the subject's reported pocketing of food, due to limited range of motion. The researcher provided appropriate referral information to the subject. The subject's gag reflex was judged to be hypersensitive. When asked to gargle, the subject demonstrated some difficulty and reported she sometimes gags or aspirates when she gargles.

The subject's lip rest posture was open. She was also a self-reported mouth breather, especially at night. The subject also informed the researcher that when she was growing up, her grandmother would often shut the subject's mouth when it was open at rest. During the night, the subject reported she drools, needs water in the morning, and experiences chapped lips. When asked about nasal breathing, the subject reported she can breathe through her nose during the day when she makes a conscious effort; this may suggest open mouth breathing during the night when she is not making a conscious effort. The subject reported frequent sinus infections; the tonsils did not look enlarged upon examination. During conversation with the researcher and during counting tasks, the researcher noted a slight frontal lisp and described the subject's speech as

having a sibilant quality at times. Occasional interdental productions of /t, d/ were also noted.

During food and liquid trials, as outlined on the STTP, the subject's tongue protruded to the straw and spoon. The subject demonstrated anterior munching while chewing foods. When asked about her posterior teeth during the swallow, the subject reported that they were not occluded across food and liquid trials. The researcher observed tongue protrusion during food and liquid trials; during a liquid swallow, the tongue came out of the mouth. The subject pursed her lips across food and liquid trails and produced an audible swallow on liquid trails. The subject reported a history of GERD and reported multiple swallows across food trials.

During the study protocol, the subject demonstrated a compensatory swallow strategy which was a combination of forward posture and chin tuck; the researcher described it as a "down and out" motion on the evaluation protocol. During pudding trials, the subject reported that the back of her throat felt coated and that she could feel pudding on the roof of her mouth.

Table 3.14 reveals objective data obtained via the IOPI and EMG, as well as behavioral and observational data obtained during the evaluation. IOPI results indicate no significant differences in the subject's tongue strength or lip strength, compared to the norms. EMG results indicate no significant differences in the subject's masseter strength, compared to the norms. However, EMG results do indicate a significantly longer swallow timing during 1 ½ tsp trials (stcpud2avg) when compared to the mean swallow timing of the normative

sample.

Table 3.14. Instrumental and observational data for subject 525, a 23 year old female.

	Normative Mean	**Std Dev**	**Std Err**	**Observed Score**	***t*-score**	***p*-value**
iopitipavg	37.44	15.13	3.9	44	0.43	0.667
iopidorsavg	34.21	9.43	2.16	28	0.66	0.514
iopilipsavg	24.33	12.67	2.91	7.67	1.31	0.196
mcbARMSav	153.15	110.23	25.29	85.71	0.61	0.544
mcbBRMSav	159.43	104.11	23.89	50.68	1.04	0.303
mcpud1ARMS	27.7	14.92	3.42	48.27	1.38	0.176
mcpud1BRMS	48.88	72.52	16.64	5.37	0.60	0.552
mcpud2ARMS	39.67	29.39	6.74	6.55	1.13	0.267
mcpud2BRMS	49.62	82.78	19	11.78	0.46	0.650
mc10ccARMS	22.04	8.79	2.02	14.56	0.85	0.400
mc10ccBRMS	26.2	22.8	5.23	10.79	0.68	0.503
mccrackARMS	108.9	79.56	18.25	31.48	0.97	0.336
mccrackBRMS	152	140.6	32.3	30.75	0.86	0.394
stcpud1avg	1.34	0.33	0.08	1.92	1.76	0.087
stcpud2avg	1.29	0.27	0.06	2.32	3.81	0.000***
stc10ccavg	1.03	0.16	.04	1.16	0.81	0.421
stccrackavg	1.2	0.22	0.05	1.51	1.41	0.167
tppud1	0.21	0.71	0.16	3	3.93	0.000***
tp10cc	1.05	1.31	0.3	3	1.49	0.145
tpcrack	0.37	0.83	0.19	3	3.17	0.003*
bolusres	1.28	0.56	0.13	3	3.07	0.004*
ope_p	0.21	0.42	0.1	0	6.64	0.000***
ope_d	0.58	1.46	0.34	2	0.40	0.693
cough	0	0	0	2	[1]	[1]
CB	0	0	0	1	[1]	[1]
FP	0	0	0	16	[1]	[1]
CTP	0.05	0.23	0.05	13	69.35	0.000***
NT	0	0	0	12	[1]	[1]
OMP	0	0	0	16	[1]	[1]
TP	0	0	0	13	[1]	[1]

***** $p \leq .05$. ****** $p \leq .01$. ******* $p \leq .001$. [1] no data available from normative sample

During Triscuit cracker trials, the subject was determined to have significantly greater residue post-swallow (bolusres) when compared to the mean of the norming population. Tongue protrusion was observed to be significantly higher in the subject during ½ tsp (tppud1) and Triscuit cracker (tpcrack) trials in which the lip pull down method was used. Subjective observations of the following variables were also observed to occur more frequently during the evaluation when compared to the norms: clavicular breathing, forward posture, chin tuck position, neck tension, open mouth posture, and tongue protrusion. As indicated in Table 3.14, the normative sample reported no incidences of coughing, whereas the subject was observed to cough twice during the evaluation. The subject's high occurrence of tongue protrusion and significant residue post-swallow are indicators of OMD. The subject's delayed swallow timing and significant frequency of coughing post-swallow are suggestive of a compromised swallow, which may be predictive of OPD.

Reliability

Inter-judge reliability. To ensure inter-judge reliability, consensus coding was conducted between two researchers for all six subjects on oropharyngeal transit time. All EMG oropharyngeal transit time graphs were examined by the researchers at the same time. Both researchers came to a consensus for each trial for each food/liquid presentation for oropharyngeal transit time.

Intra-judge reliability. To examine intra-judge reliability, all EMG oropharyngeal transit time graphs for 16% of trials were re-measured by the researcher and cast into a Pearson Product Moment Correlation, revealing a coefficient of $r = 0.947795323$.

Summary

All raw scores obtained during the study were converted into *t*-scores and *p*-values to determine if significant differences exist between the subjects of the present study and the normative data (Holzer et al., 2011). For measures in which the *p*-value was .05 or smaller, when compared to the norms, the data were considered to be statistically significant. Significant differences were found on the following measures: IOPI lip strength, EMG oropharyngeal transit time, and subjective variable measurements.

Subjects from the present study had significantly decreased lip strength, when compared to the normative data. No significant differences were found for masseter contraction, both at baseline and during the swallows across bolus consistencies. Significant differences were indicated for oropharyngeal transit time for the following bolus consistencies: ½ tsp pudding, 1 ½ tsp pudding, 10 cc

water, and Triscuit cracker. Finally, *t*-scores and *p*-values obtained from the present study revealed increases in the following subjective variables in individuals with tongue thrust when compared to the normative data: tongue protrusion for ½ tsp pudding, tongue protrusion for 10 cc water, tongue protrusion for Triscuit cracker trials, forward posture, bolus cohesion, bolus residue, forward posture, chin tuck position, and tongue protrusion.

Chapter 4: Discussion

The purpose of the present study was to collect measurements on various OPD measures to determine if there are diagnostic indicators of OPD in individuals with tongue thrust. Six subjects, ranging from 11-40 years of age, were included in the study. All six subjects had tongue thrust secondary to behavioral and clinical indicators of OMD. Measurements were collected via the IOPI, EMG, and clinical observation. Specifically, the researcher collected measurements for tongue tip strength, tongue dorsum strength, lip strength, masseter contraction, and oropharyngeal transit time. Data obtained from the study were compared to the normative data of individuals without tongue thrust to determine if significant differences exist. The hypotheses for the present study are as follows:

Question 1:

H_{0a}: No significant difference exists in masseter contraction as measured by EMG between individuals diagnosed with tongue thrust and normative data.

H_{1a}: A significant difference exists in masseter contraction as measured by EMG between individuals diagnosed with tongue thrust and normative data.

Question 2:

H_{0b}: No significant difference exists in force, as measured by IOPI, based on location or between individuals diagnosed with tongue thrust and normative data.

H_{1b}: A significant difference exists in force, as measured by IOPI, based on

location or between individuals diagnosed with tongue thrust and data.

Question 3:

H_{0c}: No significant difference exists in oropharyngeal transit time based on bolus type, and/or measurement type between individuals in the experimental and normative data.

H_{1c}: A significant difference exists in oropharyngeal transit time based on bolus type, and/or measurement type between individuals diagnosed with tongue thrust and normative data.

Research Findings

Question 1: *Are there significant differences between masseter contraction, as measured by EMG, between individuals diagnosed with tongue thrust and the normative data?*

Masseter contraction was an OMD variable measured via EMG in the present study. Masseter contraction was measured at baseline and during swallow trials of the following boluses: ½ tsp pudding, 1 ½ tsp pudding, 10 cc water, and Triscuit cracker. Objective data results from the study revealed no significant differences in masseter contraction between the six subjects of the study and the norming population of Holzer (2011).

Based on these findings, the null hypothesis is accepted. However, although no statistically significant differences were found between the subjects and the norming population, several EMG masseter contraction measures did indicate decreased masseter contraction values in the subjects with tongue thrust.

In comparison, Evers (2013) found significant differences for masseter contraction during trials of right and left masseter baseline, 10 cc of water, and Triscuit cracker. Additionally, Evers (2013) found significant differences for left masseter contraction during ½ tsp pudding and 1 ½ tsp pudding trials. Differences between the current study and Evers' study may be attributable to differing underlying causes of tongue thrust and/or individual variability among subjects. Additionally, because the measurements were based upon EMG amplitude, variability arising from electrode impedance could potentially account for the observed differences.

Question 2: *Are there significant differences in force, as measured by the IOPI, based on location or between individuals diagnosed with tongue thrust and the normative data?*

Tongue tip strength, tongue dorsum strength, and lip strength are OMD variables that were measured in the present study via the IOPI. Results from the study revealed statistically significant differences for IOPI force measurements of lip strength. All tongue dorsum strength and lip strength values were found to be lower than the normative data. It is important to note that four of the six subjects received scores of 0 on the IOPI lip strength task due to the inability to compress the IOPI bulb without unclenching the back molars. Additionally, the researcher was unable to collect date for tongue dorsum strength for one subject due to recurrent elicitation of the subject's gag reflex during bulb placement; therefore, data results were missing for this subject on the task. Based on these findings, the null hypothesis is rejected.

Four subjects received lower tongue tip strength averages when compared to the norms. Only one subject received a higher average for tongue dorsum strength when compared to the normative data. Two subjects successfully completed IOPI lip strength tasks and although no statistically significant differences were found between the two subjects and the norming population on the task, both subjects had decreased lip strength when compared to the averages of the norming population. Overall, the subjects from the study presented with decreased tongue tip, tongue dorsum, and lip strength, when compared to the norms of Holzer (2011). Because the IOPI is an extremely reliable measurement tool, the researcher of the present study suggests that the variability is likely due to individual differences.

Evers (2013) concluded that no significant differences existed between the norms and the subjects included in her study. However, Evers (2013) did determine that the mean data of subjects included in her study were nominally lower than the normative data, just not significantly lower.

Figure 4.1 illustrates IOPI tongue tip strength results from the present study and Evers' (2013) study. For age groups that included results for more than one subject, the results were averaged and the average results were reported. The averages from the subjects with tongue thrust have been compared to the normative data of Holzer (2011):

Figure 4.1. Graphical comparisons of IOPI tongue tip strength.

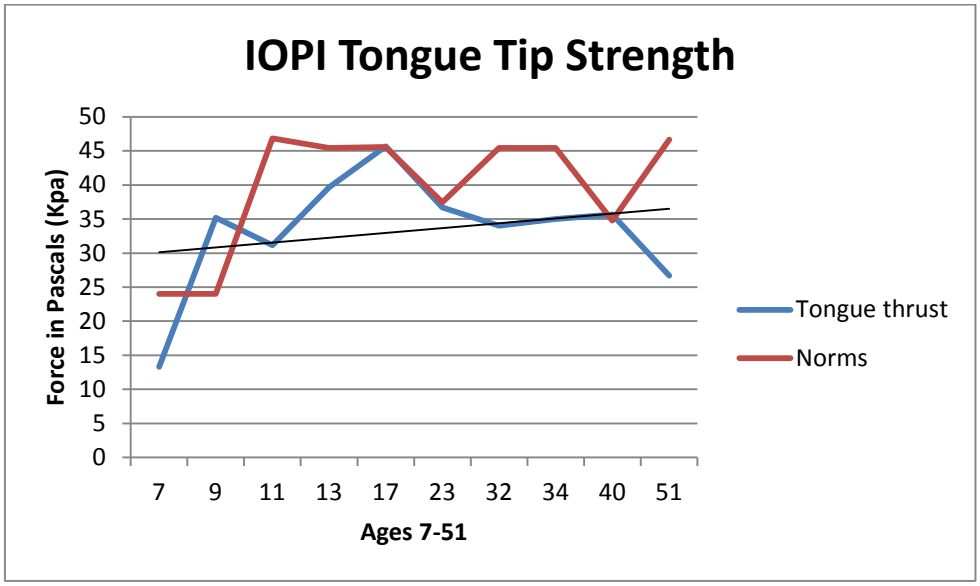


Figure 4.2 illustrates IOPI tongue dorsum strength results from the present study and Evers' (2013) study. Once again, results were averaged for instances in which groups contained more than one subject. The averages of the subjects with tongue thrust have been compared to the norming population of Holzer (2011).

Figure 4.2. Graphical comparisons of IOPI tongue dorsum strength.

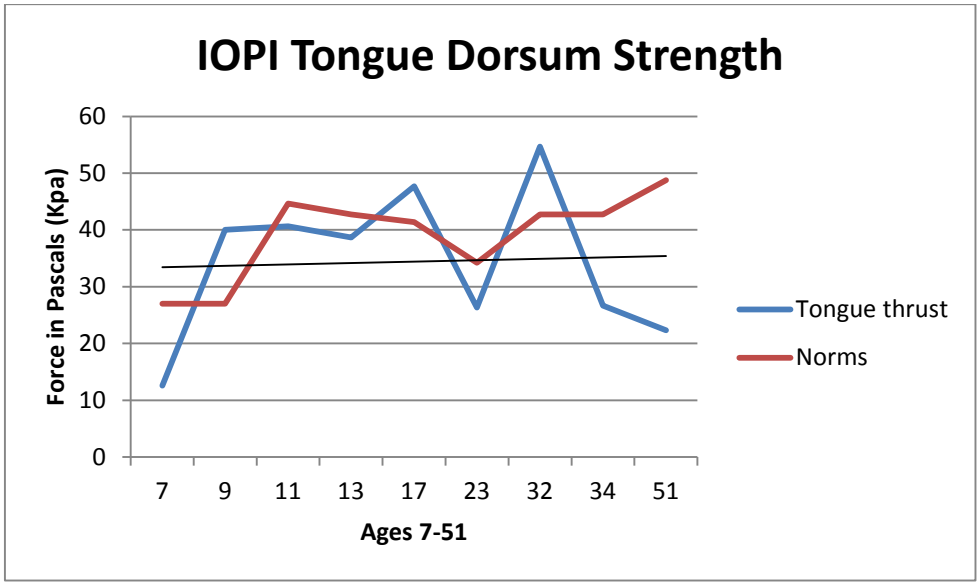
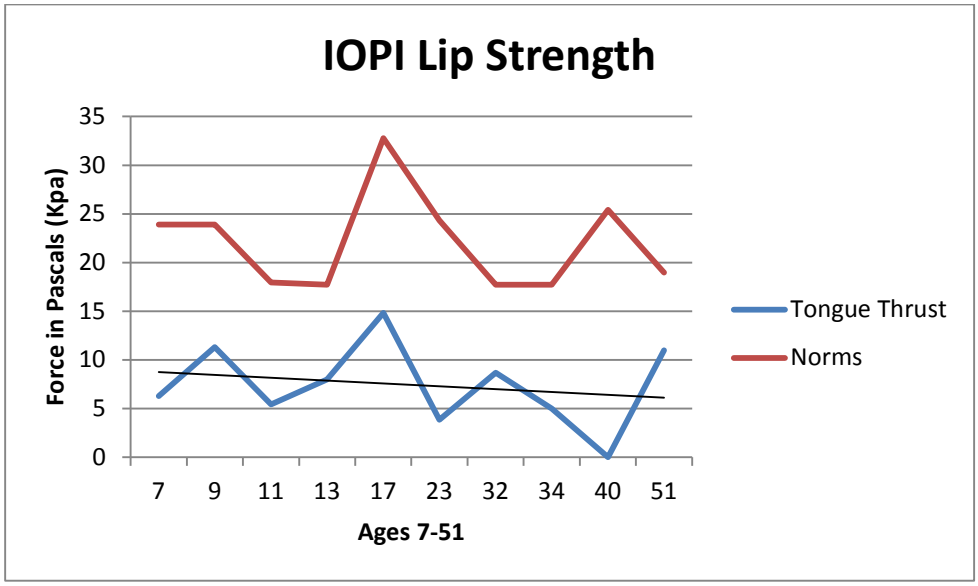


Figure 4.3 illustrates IOPI lip strength results from the present study and Evers' (2013) study. The results were averaged for instances in which age groups contained more than one subject. The combined averages of the subjects with tongue thrust have been compared to the averages of norming population of Holzer (2011). As depicted in the figure, the results for individuals with tongue thrust follows a similar trend as the norming population with decreased force values:

Figure 4.3. Graphical comparisons of IOPI lip strength.



Question 3: *Are there significant differences in oropharyngeal transit time based on bolus type between individuals diagnosed with tongue thrust and the normative data?*

Oropharyngeal transit time was the variable observed in the study associated with OPD. Results from the study indicate statistically significant

differences between subjects from the present study and individuals from the norming population. Significant differences were found for the following boluses: ½ tsp pudding, 1 ½ tsp pudding, 10 cc water, and Triscuit cracker. For all of the aforementioned boluses, subjects from the study with tongue thrust were found to have longer oropharyngeal transit times than the normative data of Holzer (2011). Based on these findings, the null hypothesis is rejected.

An observation made by the researcher, which was also noted by Evers (2013), was that some subjects required multiple swallows across bolus trials. Extraneous movements, such as pumping or false starts, were also noted by the researcher upon palpation of the swallow. The researcher used best clinical judgment, indicating onset and offset of the "true swallow" by depressing the space bar on the laptop, which placed event markers on EMG graphs.

Another observation made during evaluation of EMG graphs, in regards to oropharyngeal transit time, is that the subjects frequently demonstrated "pre-swallow activity." The "pre-swallow activity," which is not observed in individuals with normal swallow patterns, was deemed by the researcher to be part of the swallow and included in oropharyngeal transit time.

Results from the present study closely replicate the findings of Evers (2013) who found significantly longer oropharyngeal transit times in individuals with tongue thrust for ½ tsp pudding, 1 ½ tsp pudding, and 10 cc water. Evers (2013) also observed "pre-swallow activity," which was observed in the present study.

Figures 4.4, 4.5, 4.6, and 4.7 illustrate oropharyngeal transit times for ½ tsp pudding, 1 ½ tsp pudding, 10 cc water, and Triscuit Cracker. The results obtained from the present study have been combined and averaged with the results obtained by Evers (2013). The data have been compared to the normative sample of Holzer (2011). Overall, as depicted by the figures, the results for the subjects identified with tongue thrust appear to have longer oropharyngeal transit times, when compared to the normative data of Holzer (2011):

Figure 4.4. Graphical comparisons of oropharyngeal transit time ½ tsp pudding.

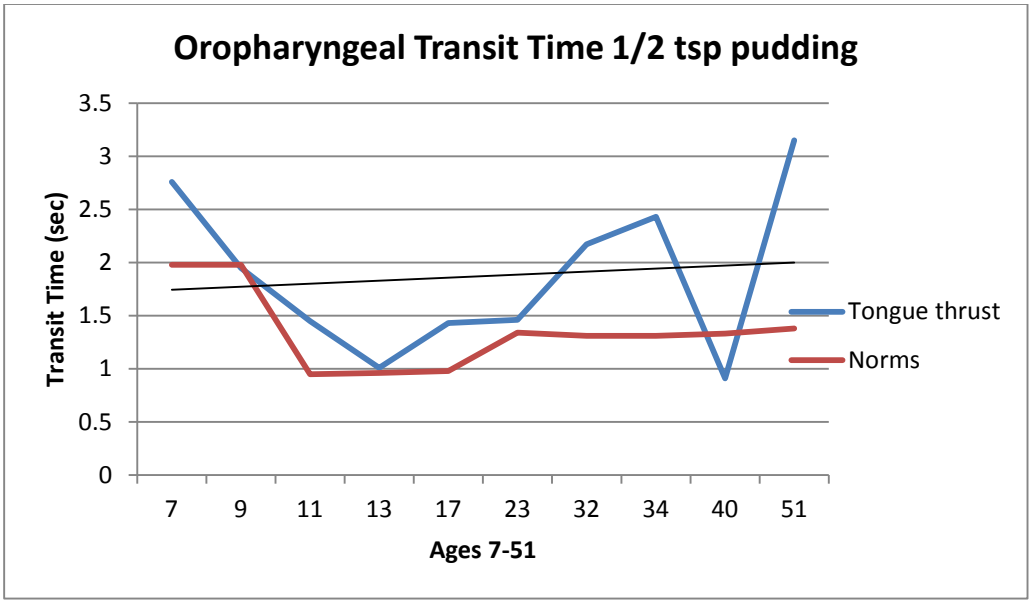


Figure 4.5. Graphical comparisons of oropharyngeal transit time 1 ½ tsp pudding.

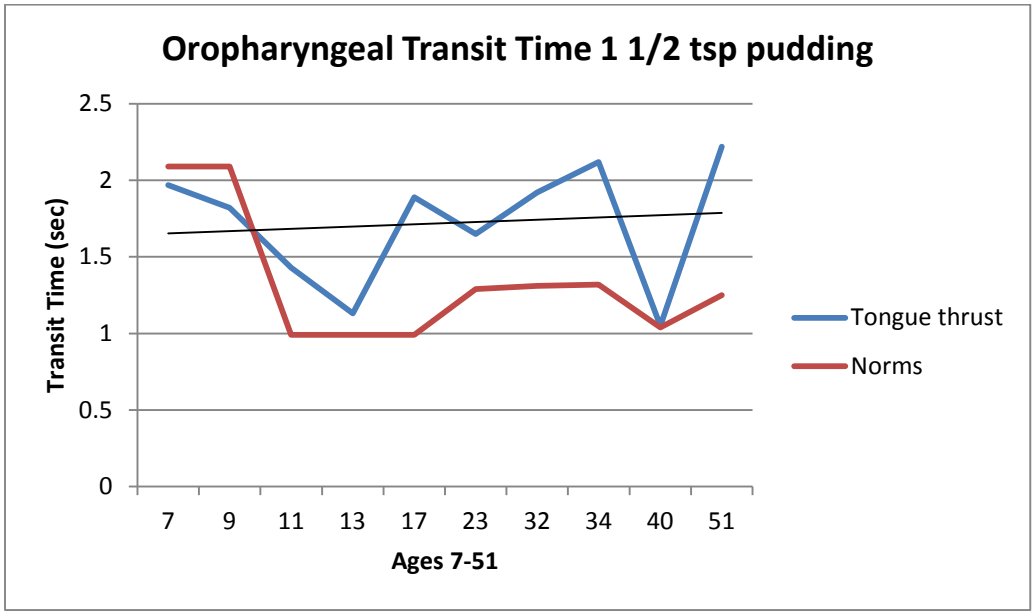


Figure 4.6. Graphical comparisons of oropharyngeal transit time 10 cc water.

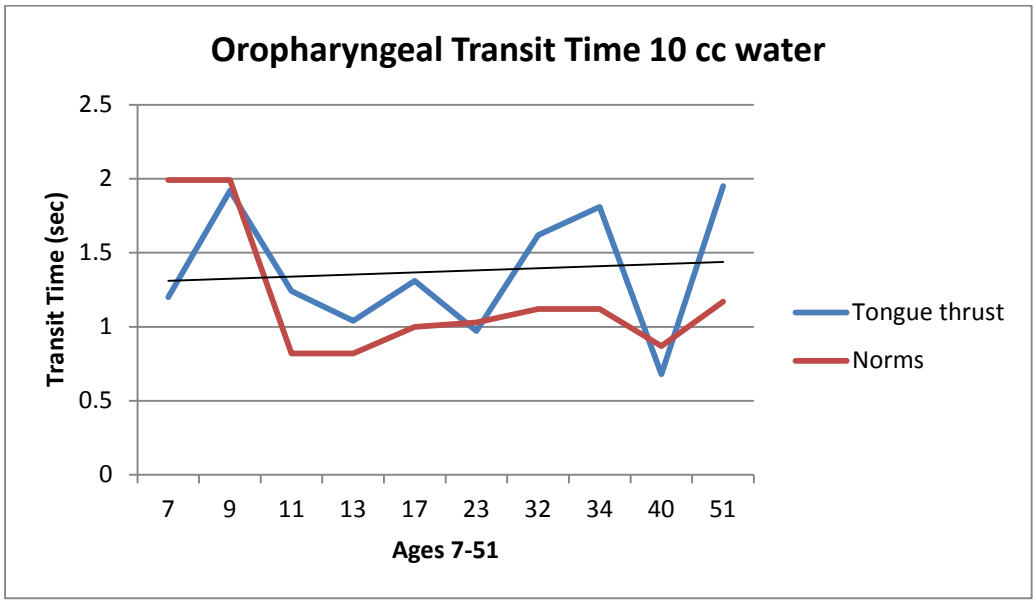
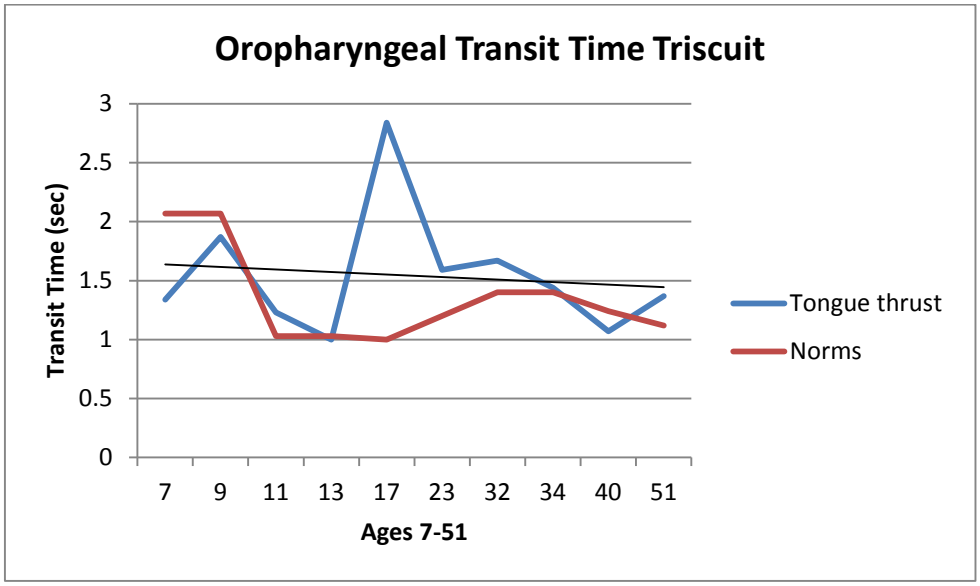


Figure 4.7. Graphical comparisons of oropharyngeal transit time Triscuit.



Additional Findings

A trend noted by the researcher is that tongue thrust was reported to run in some of the subjects' families. Subject 521 and subject 524, a mother-daughter pair, were both identified as having tongue thrust. Subject 522 was also found to have relatives with tongue thrust. During the initial evaluation, Subject 522's caregiver reported that the subject's older brother and grandfather also have tongue thrust; Subject 522's caregiver added that the grandfather's tongue thrust was severe. The trend of tongue thrust among family members raises the question of whether or not tongue thrust, or the underlying cause for the tongue thrust, has a hereditary link. Future studies could explore the occurrence of tongue thrust among family members and could examine whether or not the underlying causes of tongue thrust are the same between family members.

Another consistent trend found among subjects relates to ankyloglossia. Four out of 6 subjects were identified as having ankyloglossia. Furthermore, the researcher observed ankyloglossia in two subjects that were family members. Subject 521 and Subject 524, a mother-daughter pair who participated in the study, were both diagnosed with ankyloglossia during the initial evaluation. Subject 521, the mother, questioned whether or not her two other daughters also have ankyloglossia. This observation suggests that ankyloglossia may be hereditary, which is supported by the findings of Han, Kim, Choi, Lim, and Han (2013). Further research could explore the potential hereditary link of ankyloglossia.

Clinical Applications

In the field of speech-language pathology, tongue thrust has traditionally been given less attention by the speech-language pathologist. Many consequences of OMDs, such as improper dental development and growth, misarticulation of speech sounds, negative impacts on facial structure, and negative impacts on management of salivary secretions are not commonly viewed to be dangerous (American Speech-Language-Hearing Association, n.d.; Hanson & Mason 2003; International Association of Orofacial Myology, n.d.; Mason, 2009). On the other hand, OPD has been widely recognized to be a more severe disorder. OPD can lead to aspiration pneumonia, lack of proper nutritional intake, or dehydration, all of which are potentially life-threatening (Logemann, 1998; Matsuo & Palmer, 2008; Smith-Hammond & Goldsetin, 2006).

Based on the results from the present study, which support previous

findings of Evers (2013), there is strong evidence that suggests individuals with tongue thrust are potentially at risk for developing OPD, based on significantly increased oropharyngeal transit time. These findings suggest that the impact of OMDs, specifically tongue thrust, is larger than commonly recognized by professionals.

If there is in fact a link between tongue thrust and OPD, identification and treatment of underlying causes of tongue thrust are warranted. Rather than viewing tongue thrust as “cosmetic” or a less severe disorder, professionals should recognize the severity of the disorder and the potentially harmful consequences tongue thrust may have if left untreated. It is the hope of the researcher that more speech-language pathologists and other related professionals (e.g. dentists, orthodontists, dental hygienists, and physicians) will gain more knowledge on the negative impacts of tongue thrust, increase screenings in clients for tongue thrust, and encourage referrals to resolve underlying causes of tongue thrust. It is the hope of the researcher that more individuals with tongue thrust will receive treatment to correct underlying causes of tongue thrust, that more professionals will recognize the severity of untreated tongue thrust, and that more professionals will work in interdisciplinary teams to identify and treat OMDs.

Limitations

Potentially the biggest limitation to the present study is that it does not address the underlying cause of each subject’s tongue thrust. In other words, if an individual’s underlying cause for his or her tongue thrust was corrected, would

the individual still present with tongue thrust? Future studies could evaluate the swallow function of individuals before and after treating or correcting the underlying cause(s) of tongue thrust.

Another limitation to the study found by the researcher was the variability of severity of tongue thrust in the subjects. Some subjects presented with "milder" presentations of tongue thrust, while other subjects were considered more "severe." There is currently no tongue thrust severity rating in the field. There is potential that results could differ depending on how "severe" an individual's tongue thrust is judged to be by the researcher.

Although the data from the present study support and add new evidence to previous findings of Evers (2013), the sample size of six participants is a limitation. Five subjects were European American and one subject was White Hispanic; the subjects of the study lacked ethnic background diversity. A larger, more diverse sample of participants would be recommended for future studies. Including subjects of age groups not yet explored is also encouraged. By further investigating the current research question across a wider variety of ages and ethnic backgrounds, relevant findings could be applied to the general population rather than smaller subgroups of the general population.

Implications for Future Research

Data obtained from the present study supports previous findings that individuals with tongue thrust differ from the normative data on various OPD measures. OMD, specifically tongue thrust, and OPD share many signs and symptoms but are commonly treated separately in the field of speech-language

pathology. Little research currently exists in which a relationship between the two disorders has been investigated. Although the findings from the present study support previous findings of Evers (2013), further research is warranted to determine if a relationship does in fact exist between tongue thrust and OPD.

Future studies should aim to include more subjects of ages and ethnic backgrounds that have not yet been explored. Because tongue thrust is often a sign that something else is occurring, it is encouraged that future researchers further explore the underlying cause(s) of each subject's tongue thrust; researchers could assess individuals before and after correcting the underlying cause(s) of tongue thrust to determine if treatment has any effects on tongue strength, lip strength, masseter contraction, or swallow function. Another direction for future research could be to follow subjects across the lifespan to observe any changes, such as increased oropharyngeal transit time with age or decreased musculature strength. This could provide future insight as to when we may expect to observe changes in performance.

Conclusions

The present study investigated a hypothesized relationship between OMD, specifically tongue thrust, and OPD. The study included six participants, ranging from 11-40 years of age, who were all identified as having tongue thrust. Data were collected for the following measures: tongue dorsum strength, tongue tip strength, lip strength, masseter contraction, and oropharyngeal transit time. Results of all subjects were analyzed, converted into *t*-scores and *p*-values, and compared to gender and age matched normative data (Holzer et al., 2011) to

determine if significant differences were present.

Lip strength was found to be significantly lower in the subjects with tongue thrust. No significant differences were found for masseter contraction at baseline or across swallow trials. Significant differences were found for oropharyngeal transit time. Oropharyngeal transit time was found to be significantly longer than the duration of the norming population on the following stimuli: ½ tsp pudding, 1 ½ tsp pudding, 10 cc water, and Triscuit crackers. Prolonged oropharyngeal transit time, which was evident in all subjects of the present study, is a potential indicator of OPD. The findings from this study should encourage speech-language pathologists, OMD professionals, orthodontists, dentists, and other health professionals in identifying and treating the underlying cause(s) tongue thrust, given the possible relationship with OPD.

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Appendix A

Stone Tongue Thrust Protocol (STTP) Oral Evaluation

Stone Tongue Thrust Protocol (STTP)

Oral Evaluation

Name: _____ **Parents:** _____

Date of Evaluation: _____ **DOB:** _____ **Age:** _____

Orthodontist/Dentist: _____

I. History	Yes	No
Does patient to use liquid to wash down food?		
Is it difficult to swallow dry foods without washing them down?		
Is patient a fast/slow eater? *(circle which)*		
Does patient resist foods that are hard to chew?		
Is it difficult for patient to swallow pills?		
Is the patient a messy eater?		
Did patient suck his/her thumb? (*If so, how long?* _____)		
Did patient use pacifier? (*if so, how long?* _____)		
II. Oral/Motor Exam	**Yes**	**No**
Teeth:		
Is there an open bite?		
Is there protrusion of teeth?		
Is there an overbite?		
Is there a crossbite?		
Is there jumbled dentition?		
Are there any teeth missing?		
Has the person been, or is patient now, in an active orthodontic treatment program? *(Circle which)* Notes: _____ _____		
Tongue:		
Is the tongue large in relation to the oral cavity?		

Does patient have difficulty with tongue-tip elevation?		
Is there any weakness in the tip or back of the tongue? *(Circle which)*		
Is there weakness in the lateral borders of the tongue?		
When tongue is in resting position, is it pressed against the upper teeth, lower teeth, or between the teeth? *(Circle which)*		
Does the tongue rely on the mandible to move it?		
Does the patient have ankyloglossia (tongue tied)? If yes, has patient had surgery to fix it? _____		
Palate:		
Is the palatal vault high and/or narrow?		
Is mobility of the soft palate decreased?		
Does the patient have a normal gag reflex?		
Are the rugae sharply defined (bumps on the alveolar ridge)?		
Is it difficult for patient to gargle?		
What is patient's habitual resting oral posture? Lips open or Lips closed *(Circle which)*		
II. Oral/Motor Exam (Continued)	**Yes**	**No**
Lips (ROM/Strength/Coordination):		
Is the patient able to retract lips?		
Is the patient able to protrude lips?		
Is lip movement smooth, coordinated and symmetrical?		
Can the patient seal lips to hold air in oral cavity?		
Breathing:		
Is patient a mouth breather?		
Can patient breathe through his nose?		
Does the patient have allergies, sinus problems, etc.?		
Does the patient still have tonsils? If no, when was surgery performed? _____		
Are tonsils enlarged?		
Speech:		
When counting from 60-70, is there a frontal lisp?		
Is there interdental production of t, l, d, and/or n?		

Has the patient been enrolled in speech therapy? How long? _____ For what? _____		

III. Clinical Swallow Eval Oral Prep Phase	Liquids		Solids			Saliva
	Straw	Cup	Puree	Soft	Reg.	
+ = Yes - + No / = Inconsistent						
Oral Prep Phase:						
Tongue protrudes to presentation						
Large presentation/stuffing mouth						
Oral Phase:						
Rotational Chew						
Anterior munching						
Lateralization of bolus						
Excessive and/or /limited chewing (*Circle which*)						
Poor labial seal/anterior leakage/drooling						
Back teeth apart						
Does tongue protrude from mouth during swallow?						
Does patient suck lips in during swallow to keep liquid from escaping?						
Does patient burp during or after swallow?						
Is swallow audible?						
Does patient have history of GERD or complain of heartburn?						
Pharyngeal Phase:						
Timely swallow trigger (< / sec)						
Base of tongue movement/laryngeal elevation						
Multiple swallows						

IV. Comments / Impressions

V. Recommendations			
☐	Tongue Thrust Therapy	☐	Articulation Therapy
☐	ENT Referral	☐	Eliminate Oral Habits
☐	Orthodontic Referral		

Appendix B

Recruitment Letters

Dear potential volunteers,

My name is Lyndsey Evans and I am currently in my final year of the Speech-Language Pathology graduate program at Idaho State University. I am currently working on my thesis study, investigating the relationship between tongue thrust and oropharyngeal dysphagia (OPD). Tongue thrust and OPD share many characteristics but are treated as separate disorders in the field of speech-language pathology. I will examine data from individuals with tongue thrust to data from individuals without tongue thrust to determine if a relationship exists between the two. This study has been conducted before and the evidence suggests that a relationship exists. With your help, it is my hope to replicate these results and increase awareness of the importance of treating tongue thrust.

I am currently seeking participants between 5-95 years of age who have had, think they have, or currently have tongue thrust. I will first evaluate volunteers using the *Stone Tongue Thrust Protocol* (STTP) *Oral Evaluation* to confirm the presence of tongue thrust. If you are in fact diagnosed with tongue thrust, you will be a selected participant. You may withdraw from the study at any point. I will begin the study by asking you to fill out a survey and will inspect your mouth. During the study I will record data as you consume varying amounts of water, pudding, and a cracker. To measure the strength of your lips and tongue, I will insert a small plastic bulb (the IOPI) in your mouth. I will also record strength and timing of the swallowing using EMG, placing electrodes on your cheeks and throat region. The study carries minimal-no risk and should not cause any discomfort. The entire process will involve 1-2 visits and each visit will last approximately 1-2 hours. You can benefit from this study by receiving referral information for tongue thrust treatment. Your participation will be completely anonymous.

I ask that you please consider participating in my study or encourage someone you know with tongue thrust to volunteer. With your help we can add more evidence to the field of speech-language pathology relating to tongue thrust and OPD. Your participation is voluntary and you can choose to discontinue at any time. If you would like additional information please do not hesitate to contact me at (208) 241-6439 or evanlynd@isu.edu

Lyndsey Evans, B.S.
Graduate Student
Communication Sciences & Disorders
Idaho State University

October 19, 2014

Dear Dr._____,

I am writing to tell you about a research study being conducted at Idaho State University through the Department of Communication Sciences and Disorders. We are currently seeking individuals with orofacial myofunctional disorders, specifically tongue thrust. We are seeking participants ranging from 5-95 years of age.

We are studying the relationship between oropharyngeal dysphagia (OPD) and tongue thrust. OPD and tongue thrust are treated as distinct, separate disorders in the field of speech-language pathology. Nonetheless, the disorders share many characteristics. This study will examine various measures to determine if a relationship exists between the two. We are seeking your assistance to identify patients who may be interested in our study. Patients may also benefit from our study in terms of remediation of tongue thrust via referrals/recommendations for tongue thrust therapy.

The principal researcher is looking for patients 5-95 years of age, with tongue thrust. Participation would involve 1-2 visits, either at the Idaho State University Speech and Hearing Clinic (Pocatello), the Idaho State University Speech and Hearing Clinic (Meridian), or in the patient's home. Each visit would last 1-2 hours. Participation includes an initial tongue thrust assessment using the Stone Tongue Thrust Protocol (STTP) Oral Evaluation to determine concrete existence of the disorder in the patients. Following the diagnostic evaluation, a demographic survey, as well as observational and instrumental measurements of the patient's orofacial musculature and swallowing mechanism will occur. Instrumental measurements will be obtained using the IOPI and EMG. IOPI instrumentation will involve placing the bulb in the patient's mouth and between the lips to obtain muscular force measurements. EMG use will involve placing electrodes on the patients face and neck to obtain muscular and laryngeal timing measurements. Participants will be asked to consume varying amounts of water, pudding, and a cracker.

Please contact the primary researcher, Lyndsey Evans at (208) 241-6439 if you would like to learn more about the study. Your participation, as well as that of any identified patients, is voluntary. In the event that you wish to assist in identifying participants, we will provide you with a summary sheet that you can give to individuals who you think might qualify for the study, and they would be able to contact us directly with questions or interest. Your assistance will greatly contribute to this research study and assist in the growing body of knowledge regarding orofacial myofunctional disorders and swallowing disorders.

Thank you in advance for considering this request,

Sincerely,

Lyndsey Evans, BS
Graduate Student
Idaho State University

Joni G. Loftin, MSP-CCC-SLP, COM
Clinical Professor
Idaho State University

Appendix C

Medical History Form

Medical History

Subject ID#_____

Medical History Form

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)

Heart & Blood

a. Heart & Blood Problems (including chest pain due to heart problems, irregular heart beat, high blood pressure, blood clots, anemia, hypertension, blood transfusion, high cholesterol, heart failure, or heart bypass surgery)

☐ Yes ☐ No

b. COPD (Chronic Obstructive Pulmonary Disorder)

☐ Yes ☐ No

c. Bleeding GI (stomach, throat, intestines)

☐ Yes ☐ No

Psychiatric

d. Psychiatric Treatment for depression or anxiety

☐ Yes ☐ No

Illness

e. Cancer (what kind _____?)

☐ Yes ☐ No

f. Rheumatologic Disease (Sjogren's, Lupus, Arthritis)

☐ Yes ☐ No

Neuromedical Risks/Condition

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

_____

_____

☐ Yes ☐ No

h. Loss of consciousness (how long?) _____

☐ Yes ☐ No

i. Seizures

☐Yes ☐ No

j. Stroke/TIA

☐Yes ☐ No

k. Sleep Apnea

☐Yes ☐ No

l. Toxin/Chemical Exposure (what kind?) _____

☐Yes ☐ No

m. Parkinson's Disease (when diagnosed?)_____

☐ Yes ☐ No

n. Huntington's Disease (when diagnosed?) _____

☐ Yes ☐ No

o. Brain Masses (location) _____

☐ Yes ☐ No

p. Multiple Sclerosis (when diagnosed?) _____

☐ Yes ☐ No

q. Cerebral Palsy

☐ Yes ☐ No

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

_____

☐ Yes ☐ No

s. Oral Apraxia (when diagnosed?) _____

☐ Yes ☐ No

t. Spinal Injury (describe) _____

☐ Yes ☐ No

u. Brain Surgery (describe) _____

☐ Yes ☐ No

v. Poliomyelitis (when diagnosed?) _____

☐ Yes ☐ No

w. Guillain-Barre (when diagnosed?) _____

☐ Yes ☐ No

aa. Riley-Day Syndrome or Dysautonomia (when diagnosed?) _____

☐ Yes ☐ No

bb. ALS (when diagnosed?) _____

☐ Yes ☐ No

cc. Werdig- Hoffmann Disease (when diagnosed?) _____

☐ Yes ☐ No

dd. Myasthenia Gravis (when diagnosed?) _____

☐ Yes ☐ No

ee. Muscular Dystrophy (when diagnosed?) _____

☐ Yes ☐ No

ff. Dystonia (when diagnosed?) _____

☐ Yes ☐ No

Oromyofunctional Risks/Conditions

gg. Recurrent Pneumonia

☐ Yes ☐ No

hh. Frequent Temperature Spikes

☐ Yes ☐ No

ii. History of Artificial Airway

☐ Yes ☐ No

jj. Mouth Breather

☐ Yes ☐ No

kk. History of Finger Sucking

☐ Yes ☐ No

ll. History of Cheek Biting

☐ Yes ☐ No

mm. Deviated Septum

☐ Yes ☐ No

nn. Enlarged Tonsils/Adenoids

☐ Yes ☐ No

oo. Tonsils/Adenoids Removed

☐ Yes ☐ No

pp. Open Spaced During Mixed Dentition

☐ Yes ☐ No

qq. Current Open Spaces in Dentition

☐ Yes ☐ No

rr. Allergies (explain) _____

☐ Yes ☐ No

ss. TMJ Syndrome

☐ Yes ☐ No

tt. Eating Disorders

☐ Yes ☐ No

uu. Oral Surgery (explain) _____

☐ Yes ☐ No

vv. Neck Surgery (explain) _____

☐ Yes ☐ No

ww. Oral Sores

☐ Yes ☐ No

Other

xx. Other Surgery (explain) _____

☐ Yes ☐ No

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

_____
_____
_____

Medications

6. Have you taken any medication today? ☐ Yes ☐ No

If yes, list medication, dose, time taken, and reason for taking it. (Use back of page for more room)

Name of medication	Time Taken	Dose	Reason for Taking
_____	_____	_____mg	_____
_____	_____	_____mg	_____
_____	_____	_____mg	_____
_____	_____	_____mg	_____
_____	_____	_____mg	_____
_____	_____	_____mg	_____
_____	_____	_____mg	_____
_____	_____	_____mg	_____
_____	_____	_____mg	_____
_____	_____	_____mg	_____

Alcohol and Tobacco

7. Do you consume alcohol? ☐ Yes ☐ No

8. If you answered yes to question 7, how much alcohol do you typically consume in 1 month?

_____ glasses/month

9. Do you chew tobacco? ☐ Yes ☐ No

10. If you answered yes to question 9, how much do typically use in a month?

_____

cans/month

11. Do you smoke? ☐ Yes ☐ No

12. If you answered yet to question 11, how much do you smoke in a month?

_____ packs/month

Food Information

13. What are your three favorite foods? _____

14. What are your three least favorite foods? _____

15. Are there any foods that you avoid?

_____

16. How often do you chew gum? _____

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

Appendix D

Study Protocol – Group A

Subject number _____ Group _____ Date_____

1. Set up videocamera. Press record.
2. Open Biograph Infiniti Program
3. Select Options and Notch Filters
4. Set them to EMG and 60 Hz and choose okay
5. Select Start Open Display Session
6. 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)
7. Choose desired client from subjects and Define New session
8. Select Skeletal Muscle Rehab and M1revw- 2 ch Open Display.scr (be sure you have selected MyoTrac Infiniti as encoder type).
9. 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.
10. 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.
11. 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).
12. Choose not to review the session.
13. Continue recording with the same client set-up until you have completed the protocol for that client, following step 8-10.
14. 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	"Please answer the following	Give subject the medical	

	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."	history form and consent form.	
3. Stone Tongue Thrust Protocol: Oral Evaluation			
STTP: Oral Evaluation	"I am now going to evaluate you using the Stone Tongue Thrust Protocol: Oral Evaluation. This will allow me to determine the presense or absence of tongue thrust."	Perform oral evaluation following STTP protocol (see attached).	Mark appropriate answers on record form. No names will be written on record form. 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	Push "reset"	

	say /a/"		
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**	Use Nuprep to exfoliate skin (masseter and clavicle). Rub for 30 seconds	

	skin allergies don't use Nuprep, use alcohol swabs).	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	Watch for swallow initiation and press space bar	_____ Cough (+/-) _____ Clavicle breathing (+/-)

	spoon, & swallow when I say swallow"	to mark swallow time.	_____ 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		Press pause	_____Check EMG for completion of task

(10 cc water)			_____ 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	Watch for swallow initiation and	_____ Cough (+/-) _____ Clavicle breathing (+/-)

	until I say swallow."	press space bar to mark swallow time.	_____ 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 mouth when you are ready to swallow. Signal to me when you are ready to swallow."	Press record	

Masseter Activity – Trial 1 (Triscuit)		Look in mouth & rate bolus	
Masseter Activity – Trial 1 (Triscuit)			1 3 5 Organized in ball or tube in middle of tongue / Some evidence of cohesion, some scattering / 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 3 5 Minimal/No residue (few to no / Some evidence of / Significant amount of

			parts of residue residue 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 3 5 Organized in ball or tube in middle of tongue / Some evidence of cohesion, some scattering / 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)			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)	"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 Organized in ball or tube in 3 Some evidence of 5 Disorganized or scattered

			middle of tongue cohesion, some scattering on tongue
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 – **Trial 1**		Measure 1/2 teaspoon of	

(1/2 tsp pudding)		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 (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 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	"Place the pudding in your mouth, cleaning	Have subject place the pudding in their	

(1/2 tsp pudding)	the whole spoon, & swallow when I say swallow"	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		Measure 1/2	

(1/2 tsp pudding)		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 (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 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	Have subject place the pudding in their	_____ Tongue protrusion (+/-)

	the whole spoon, & swallow when ready"	mouth Pull down lip while swallowing and watch for protrusion of tongue.	
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 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 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	"Say ah"		_____ Gurgly voice (+/-)

(1 ½ tsp pudding)			
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 (10 cc water)		Press pause	_____Check EMG for completion of task _____ 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	Pull down lip while swallowing and watch for protrusion of	_____ Tongue protrusion (+/-)

	ready”	tongue.	
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 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 (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		Participant signals ready to swallow. Feel	_____ Cough (+/-)

(Triscuit)		for swallow initiation and press space bar to mark laryngeal elevation and depression	_____ 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 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:

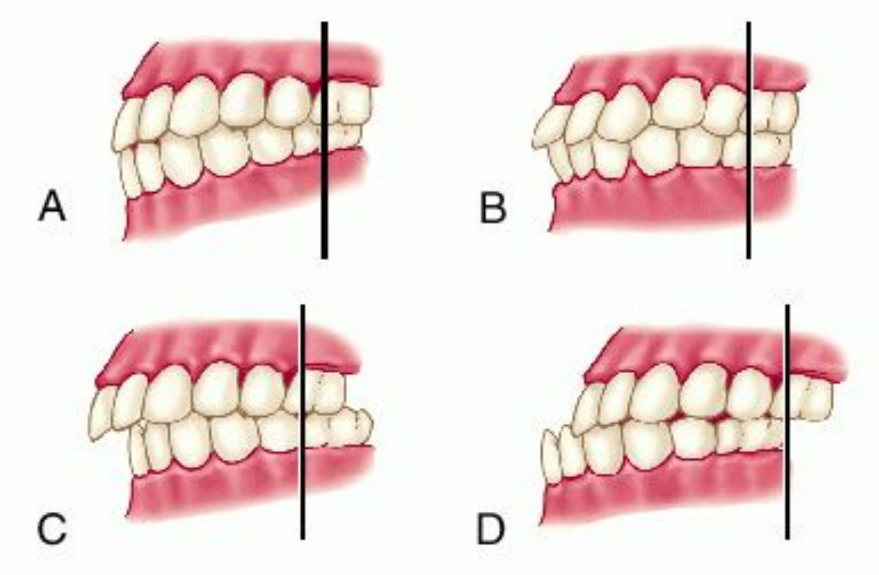
LE – Trial 3 (Triscuit)		Press pause	_____Check EMG for completion of task _____ Swallow initiation time
LE – Trial 3 (Triscuit)	"Say ah"		_____ Gurgly voice (+/-)
LE		Stop recording and save without reviewing in non compressed format.	
LE/protrusion	"I'm going to have you chew the cracker. Let me know 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 E

Abbreviations Used in Results

Abbreviation	**Description**
iopitipavg	average force for IOPI tongue tip measure
iopidorsavg	average force for IOPI tongue dorsum measure
iopilipsavg	average force for IOPI lips measurement
mcbARMSav	right masseter contraction baseline average
mcbBRMSav	left masseter contraction baseline average
mcpud1ARMS	right masseter contraction for ½ tsp pudding trials
mcpud1BRMS	left masseter contraction for ½ tsp pudding trials
mcpud2ARMS	right masseter contraction for 1 ½ tsp pudding trials
mcpud2BRMS	left masseter contraction for 1 ½ tsp pudding trials
mc10ccARMS	right masseter contraction for 10 cc water trials
mc10ccBRMS	left masseter contraction for 10 cc 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 trials
stc10ccavg	average swallowing timing with contraction for 10cc water trials
stccrackavg	average swallowing timing with contraction for Triscuit cracker trials
tppud1	tongue protrusion for ½ tsp pudding trials
tp10cc	tongue protrusion for 10 cc water trials
tpcrack	tongue protrusion for Triscuit cracker trials
boluscoh	bolus cohesion during Triscuit cracker trials
bolusres	bolus residue following Triscuit cracker trials
ope_p	oral peripheral exam of palate (1= presence of high vaulted palate, 0= absence of high vaulted palate)
ope_d	oral peripheral exam of teeth (0 = normal, 1 = type 1, 2 = type 2, 3 = type 3, 4= open bite, 5= other)

cough	any cough during bolus trials
CB	indicates clavicular breathing during bolus trials
FP	forward posture during bolus trials
CTP	chin tuck position
NT	neck tension during bolus trials
OMP	open mouth posture during bolus trials
TP	tongue protrusion during bolus trials

Appendix F

t-scores and *p*-values by Subject

Subject 520						
	Normative Mean	**Std Dev**	**Std Err**	**Observed Score**	***t*-score**	***p*-value**
iopitipavg	37.44	15.13	3.9	29.33	0.54	0.595
iopidorsavg	34.21	9.43	2.16	24.67	1.01	0.318
iopilipsavg	24.33	12.67	2.91	0.00	1.92	0.062
mcbARMSav	153.15	110.23	25.29	87.30	0.60	0.554
mcbBRMSav	159.43	104.11	23.89	179.57	0.19	0.848
mcpud1ARMS	27.7	14.92	3.42	18.32	0.63	0.533
mcpud1BRMS	48.88	72.52	16.64	23.49	0.35	0.728
mcpud2ARMS	39.67	29.39	6.74	28.06	0.40	0.695
mcpud2BRMS	49.62	82.78	19	59.23	0.12	0.908
mc10ccARMS	22.04	8.79	2.02	25.21	0.36	0.720
mc10ccBRMS	26.2	22.8	5.23	36.1	0.43	0.667
mccrackARMS	108.9	79.56	18.25	26.23	1.04	0.305
mccrackBRMS	152	140.6	32.3	57.61	0.67	0.506
stcpud1avg	1.34	0.33	0.08	0.99	1.06	0.295
stcpud2avg	1.29	0.27	0.06	0.98	1.15	0.258
stc10ccavg	1.03	0.16	.04	0.77	1.63	0.112
stccrackavg	1.2	0.22	0.05	1.66	2.09	0.043*
tppud1	0.21	0.71	0.16	3	3.93	0.000***
tp10cc	1.05	1.31	0.3	3	1.49	0.145
tpcrack	0.37	0.83	0.19	3	3.17	0.003**
bolusres	1.28	0.56	0.13	3	3.07	0.004**
ope_p	0.21	0.42	0.1	0	6.64	0.000***
ope_d	0.58	1.46	0.34	2	0.40	0.693
cough	0	0	0	0	[1]	[1]
CB	0	0	0	1	[1]	[1]
FP	0	0	0	2	[1]	[1]
CTP	0.05	0.23	0.05	12	8.48	0.000
NT	0	0	0	2	[1]	[1]
OMP	0	0	0	22	[1]	[1]
TP	0	0	0	8	[1]	[1]

***** $p \leq .05$. ****** $p \leq .01$. ******* $p \leq .001$. [1] no data available from normative sample

Subject 521						
	Normative Mean	**Std Dev**	**Std Err**	**Observed Score**	***t*-score**	***p*-value**
iopitipavg	34.79	12.92	2.5	35.67	0.07	0.946
iopidorsavg	48.42	10.78	1.88	NA	NA	NA
iopilipsavg	25.43	9.3	1.62	0.00	2.73	0.008**
mcbARMSav	94.6	105.63	18.39	3.13	.87	.39
mcbBRMSav	151.84	207.74	36.16	2.40	.72	.48
mcpud1ARMS	71.98	146.08	25.43	.9	.49	.63
mcpud1BRMS	229.36	407.94	71.01	.94	.56	.58
mcpud2ARMS	75.54	131.47	22.89	1.07	.57	.57
mcpud2BRMS	189.78	306.97	53.43	1.23	.61	.54
mc10ccARMS	92.62	175.37	30.53	.61	.52	.60
mc10ccBRMS	160.9	248.88	43.32	.95	.64	.52
mccrackARMS	143.88	242.78	42.26	1.14	.59	.56
mccrackBRMS	194.51	286.9	49.94	1.87	.67	.51
stcpud1avg	1.33	0.69	0.12	0.91	0.61	0.545
stcpud2avg	1.04	0.21	0.04	1.05	0.05	0.962
stc10ccavg	0.87	0.36	0.063	0.68	0.53	0.600
stccrackavg	1.24	0.41	0.07	1.07	0.41	0.680
tppud1	0.16	0.45	0.08	3	6.31	0.000***
tp10cc	0.19	0.6	0.1	3	4.68	0.000***
tpcrack	0.23	0.56	0.1	3	4.95	0.000***
bolusres	1.51	0.89	0.15	3	1.67	0.100
ope_p	0	0	0	0	[1]	[1]
ope_d	0.3	0.59	0.1	2	2.88	.006**
cough	0	0	0	1	[1]	[1]
CB	0	0	0	1	[1]	[1]
FP	0.06	0.24	0.04	4	16.42	0.000***
CTP	0	0	0	7	[1]	[1]
NT	0	0	0	0	[1]	[1]
OMP	0	0	0	14	[1]	[1]
TP	0.06	0.35	0.06	10	28.40	0.000***

***** $p \leq .05$. ****** $p \leq .01$. ******* $p \leq .001$. [1] no data available from normative sample

Subject 522						
	Normative Mean	**Std Dev**	**Std Err**	**Observed Score**	***t*-score**	***p*-value**
iopitipavg	48.25	14.35	3.59	43.67	0.32	0.752
iopidorsavg	46.56	12.06	3.01	53.67	0.59	0.560
iopilipsavg	18.21	5.46	1.37	0.00	3.34	0.002**
mcbARMSav	336.1	168.73	42.18	15.19	1.90	0.066
mcbBRMSav	252.89	133.24	33.31	192.86	0.45	0.655
mcpud1ARMS	165.03	170.11	42.53	2.63	0.95	0.347
mcpud1BRMS	139.09	117.6	29.4	18.2	1.03	0.311
mcpud2ARMS	178.04	150.31	37.58	3.05	1.16	0.253
mcpud2BRMS	179.95	164.11	41.03	20.47	0.97	0.338
mc10ccARMS	148.57	125.58	31.4	4.06	1.15	0.258
mc10ccBRMS	155.61	131.32	32.83	20.63	1.03	0.311
mccrackARMS	281.38	232.31	58.1	5.94	1.19	0.244
mccrackBRMS	261.18	222.8	55.7	29.37	1.04	0.306
stcpud1avg	0.94	0.06	0.01	2.10	19.33	0.000***
stcpud2avg	0.98	0.05	0.01	1.90	18.40	0.000***
stc10ccavg	0.81	0.08	0.02	1.45	8.00	0.000***
stccrackavg	1.02	0.03	0.01	0.78	8.00	0.000***
tppud1	0.25	0.68	0.17	3.00	4.04	0.000***
tp10cc	0.38	0.72	0.18	3	3.64	0.001***
tpcrack	0.5	1	0.24	3	2.50	0.018*
boluscoh	1.75	0.87	0.22	5	3.74	0.001***
bolusres	1.75	0.87	0.22	2.33	0.67	0.510
ope_p	0.19	0.4	0.1	0	0.48	0.638
ope_d	0.69	0.79	0.2	0	0.87	0.389
cough	0	0	0	0	[1]	[1]
CB	0	0	0	2	[1]	[1]
FP	0	0	0	1	[1]	[1]
CTP	0	0	0	1	[1]	[1]
NT	0	0	0	0	[1]	[1]
OMP	0	0	0	5	[1]	[1]
TP	0	0	0	0	[1]	[1]

***** $p \leq .05$. ****** $p \leq .01$. ******* $p \leq .001$. [1] no data available from normative sample

Subject 523						
	Normative Mean	**Std Dev**	**Std Err**	**Observed Score**	***t*-score**	***p*-value**
iopitipavg	48.25	14.35	3.59	40.33	0.55	0.585
iopidorsavg	46.56	12.06	3.01	41	0.46	0.648
iopilipsavg	18.21	5.46	1.37	0	3.34	0.002**
mcbARMSav	336.1	168.73	42.18	130.43	1.22	0.232
mcbBRMSav	252.89	133.24	33.31	59.93	1.45	0.157
mcpud1ARMS	165.03	170.11	42.53	11.64	0.90	0.374
mcpud1BRMS	139.09	117.6	29.4	9.54	1.10	0.279
mcpud2ARMS	178.04	150.31	37.58	13.1	1.10	0.280
mcpud2BRMS	179.95	164.11	41.03	10.21	1.03	0.309
mc10ccARMS	148.57	125.58	31.4	9.51	1.11	0.276
mc10ccBRMS	155.61	131.32	32.83	9.57	1.11	0.274
mccrackARMS	281.38	232.31	58.1	25.99	1.10	0.280
mccrackBRMS	261.18	222.8	55.7	14.38	1.11	0.276
stcpud1avg	0.94	0.06	0.01	1.38	7.33	0.000***
stcpud2avg	0.98	0.05	0.01	1.41	8.60	0.000***
stc10ccavg	0.81	0.08	0.02	1.48	8.38	0.000***
stccrackavg	1.02	0.03	0.01	1.65	21.00	0.000***
tppud1	0.25	0.68	0.17	3	4.04	0.000***
tp10cc	0.38	0.72	0.18	3	3.64	0.001***
tpcrack	0.5	1	0.24	3	2.50	0.018*
boluscoh	1.75	0.87	0.22	5	3.74	0.001***
bolusres	1.75	0.87	0.22	5	3.74	0.001***
ope_p	0.19	0.4	0.1	0	0.48	0.638
ope_d	0.69	0.79	0.2	2	1.66	.11
cough	0	0	0	0	[1]	[1]
CB	0	0	0	1	[1]	[1]
FP	0	0	0	10	[1]	[1]
CTP	0	0	0	1	[1]	[1]
NT	0	0	0	3	[1]	[1]
OMP	0	0	0	6	[1]	[1]
TP	0	0	0	2	[1]	[1]

***** $p \leq .05$. ****** $p \leq .01$. ******* $p \leq .001$. [1] no data available from normative sample

Subject 524						
	Normative Mean	**Std Dev**	**Std Err**	**Observed Score**	***t*-score**	***p*-value**
iopitipavg	45.04	11.19	2.64	44.67	0.03	0.974
iopidorsavg	41.44	12.74	3	38.67	0.22	0.829
iopilipsavg	33.1	12.45	2.93	13.00	1.61	0.115
mcbARMSav	115.38	98.87	23.3	30.56	0.86	0.397
mcbBRMSav	107.31	96.34	22.71	53.13	0.56	0.577
mcpud1ARMS	34.61	36	8.47	19.8	0.41	0.683
mcpud1BRMS	40.8	47.8	11.26	25.94	0.31	0.758
mcpud2ARMS	37.28	27.166	6.4	19.45	0.66	0.516
mcpud2BRMS	65.93	80.42	19	25.26	0.51	0.616
mc10ccARMS	112.75	307.34	72.44	22.72	0.29	0.771
mc10ccBRMS	200.28	340.03	80.15	25.7	0.51	0.611
mccrackARMS	108.13	117.34	27.66	34.41	0.63	0.534
mccrackBRMS	128.76	171.57	40.44	31.46	0.57	0.574
stcpud1avg	0.98	0.215	0.05	1.31	1.53	0.134
stcpud2avg	0.98	0.28	0.07	2.21	4.39	0.000***
stc10ccavg	1	0.22	0.05	1.35	1.59	0.120
stccrackavg	1	0.23	0.05	4.16	13.74	0.000***
tppud1	0.83	0.92	0.22	3.00	2.36	0.024*
tp10cc	1.22	1.06	0.25	3	1.68	0.102
tpcrack	0.72	1.02	0.24	3	2.24	0.032*
bolusres	2.24	1.12	0.26	1.67	0.51	0.614
ope_p	0	0	0	1	[1]	[1]
ope_d	0.28	0.96	0.23	3	2.83	.008**
cough	0.06	0.24	0.06	0	0.25	0.804
CB	0	0	0	0	[1]	[1]
FP	0.06	0.24	0.06	5	20.58	0.000***
CTP	0	0	0	1	[1]	[1]
NT	0	0	0	11	[1]	[1]
OMP	0	0	0	15	[1]	[1]
TP	0.39	1.65	0.39	5	2.79	0.008**

***** $p \leq .05$. ****** $p \leq .01$. ******* $p \leq .001$. [1] no data available from normative sample

Subject 525						
	Normative Mean	**Std Dev**	**Std Err**	**Observed Score**	***t*-score**	***p*-value**
iopitipavg	37.44	15.13	3.9	44	0.43	0.667
iopidorsavg	34.21	9.43	2.16	28	0.66	0.514
iopilipsavg	24.33	12.67	2.91	7.67	1.31	0.196
mcbARMSav	153.15	110.23	25.29	85.71	0.61	0.544
mcbBRMSav	159.43	104.11	23.89	50.68	1.04	0.303
mcpud1ARMS	27.7	14.92	3.42	48.27	1.38	0.176
mcpud1BRMS	48.88	72.52	16.64	5.37	0.60	0.552
mcpud2ARMS	39.67	29.39	6.74	6.55	1.13	0.267
mcpud2BRMS	49.62	82.78	19	11.78	0.46	0.650
mc10ccARMS	22.04	8.79	2.02	14.56	0.85	0.400
mc10ccBRMS	26.2	22.8	5.23	10.79	0.68	0.503
mccrackARMS	108.9	79.56	18.25	31.48	0.97	0.336
mccrackBRMS	152	140.6	32.3	30.75	0.86	0.394
stcpud1avg	1.34	0.33	0.08	1.92	1.76	0.087
stcpud2avg	1.29	0.27	0.06	2.32	3.81	0.000***
stc10ccavg	1.03	0.16	.04	1.16	0.81	0.421
stccrackavg	1.2	0.22	0.05	1.51	1.41	0.167
tppud1	0.21	0.71	0.16	3	3.93	0.000***
tp10cc	1.05	1.31	0.3	3	1.49	0.145
tpcrack	0.37	0.83	0.19	3	3.17	0.003*
bolusres	1.28	0.56	0.13	3	3.07	0.004*
ope_p	0.21	0.42	0.1	0	6.64	0.000***
ope_d	0.58	1.46	0.34	2	0.40	0.693
cough	0	0	0	2	[1]	[1]
CB	0	0	0	1	[1]	[1]
FP	0	0	0	16	[1]	[1]
CTP	0.05	0.23	0.05	13	69.35	0.000***
NT	0	0	0	12	[1]	[1]
OMP	0	0	0	16	[1]	[1]
TP	0	0	0	13	[1]	[1]

***** $p \leq .05$. ****** $p \leq .01$. ******* $p \leq .001$. [1] no data available from normative sample

Appendix G

Raw Data

subject	female	agegroup	agemo	iopitip1	iopitip2	iopitip3	iopitipavg
520	1	20	282	25	34	29	29.33
521	1	40	490	33	37	37	35.67
522	0	10	137.7	45	43	43	43.67
523	0	10	134.4	39	39	43	40.33
524	1	15	209.6	52	40	42	44.67
525	1	20	283.9	43	49	40	44

iopidors 1	iopidors 2	iopidors 3	iopidors avg	iopilips 1	iopilips 2	iopilips 3	iopilips avg
20	32	22	24.67	0	0	0	0
NA	NA	NA	NA	0	0	0	0
51	53	57	53.67	0	0	0	0
36	38	49	41	0	0	0	0
46	34	36	38.67	13	13	13	13
34	20	30	28	9	7	7	7.67

mcbARMSmax	mcbARMSav	mcbBRMSmax	mcbBRMSav
112.97	87.3	239.7	179.57
4.51	3.13	5.69	2.4
21.63	15.19	283.68	192.86
204.84	130.43	91.02	59.93
49.78	30.56	83	53.13
128.69	85.71	75.9	50.68

mcpud1 ARMS	mcppud1 BRMS	mcpud2 ARMS	mcpud2 BRMS
18.32	23.49	28.06	59.23
.9	.94	1.07	1.23
2.63	18.2	3.05	20.47
11.64	9.54	13.1	10.21
19.8	25.94	19.45	25.26
48.27	5.37	6.55	11.78

mc10ccARMS	mc10ccBRMS	mccrackARMS	mccrackBRMS
25.21	36.1	26.23	57.61
.61	.95	1.14	1.87
4.06	20.63	5.94	29.37
9.51	9.57	25.99	14.38
22.72	25.7	34.41	31.46
14.56	10.79	31.48	30.75

stcpud11	stcpud12	stcpud13	stcpud1avg	stcpud21	stcpud22	stcpud23	stcpud2avg
.95	1.17	.86	.99	1.03	.89	1.03	.98
.89	.96	.87	.91	1.04	1.34	.77	1.05
1.86	1.95	2.48	2.10	2.51	1.65	1.53	1.90
1.57	1.32	1.24	1.38	1.01	1.06	2.16	1.41
1.08	1.56	1.29	1.31	2.75	2.28	1.61	2.21
1.69	1.64	2.42	1.92	2.25	1.47	3.23	2.32

stc10cc1	stc10cc2	stc10cc3	stc10ccavg	stc crack1	stc crack2	stc crack3	stc crack avg
.72	.69	.91	.77	1.62	1.91	1.44	1.66
.68	.67	.70	.68	1.37	.89	.96	1.07
1.98	1.11	1.27	1.45	.78	.80	.77	.78
1.36	1.21	1.88	1.48	1.51	1.79	1.66	1.65
.89	.96	2.19	1.35	2.17	3.26	7.06	4.16
1.19	1.25	1.03	1.16	1.51	1.27	1.74	1.51

tppud1	tp10cc	tpcrack	bolus coh	bolus res	ope_p	ope_d	cough
3	3	3	1	3	0	2	0
3	3	3	1.67	3	0	2	1
3	3	3	5	2.33	0	0	0
3	3	3	5	5	0	2	0
3	3	3	3	1.67	1	3	0
3	3	3	3	3	0	2	2

CB	FP	CTP	NT	OMP	TP	protocol
1	2	12	2	22	8	A
1	4	7	0	14	10	B
2	1	1	0	5	0	C
1	10	1	3	6	2	A
0	5	1	11	15	5	B
1	16	13	12	16	13	C