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Examining the Effects of Tongue Thrust on Swallow Function

by

Lisa Ellgen

A thesis

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Master of Science in the Department of Communication Sciences and Disorders

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Committee Approval

To the Graduate Faculty:

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

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December 23, 2014

Lindsay Evans
6171 Indian Tree Lane
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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

Acknowledgments

I would like to thank my committee members, Dr. Tony Seikel, Nancy Devine, and Joni Loftin for their continuous support, input, and time commitment in helping me finish this in time. Especially Dr. Seikel, who bent over backwards to help at any moment and offered the mental support needed in the craziest of weeks. His patience, kindness, enthusiasm, and guidance were truly priceless throughout this process. I will always be grateful for the opportunity to have worked with him.

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Thank you all for your faith in me.

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Abstract

This study analyzes the correlation between oromyofunctional disorders (OMD), specifically tongue thrust, and oral pharyngeal dysphagia (OPD). Typically, OMD and OPD are treated as two separate disorders. However, this study, and many studies before (Evans, 2015; Evers, 2013) are building evidence to support that the two disorders are connected. This study includes five subjects, one male and four females, ranging in age from 18-27 years. Each subject was assessed to confirm the presence/absence of tongue thrust, after which several objective and subjective measures were taken. Objective measures were obtained through the use of EMG and IOPI, and included tongue tip strength, tongue dorsum strength, lip strength, masseter contraction, and oropharyngeal transit time. Subjective measures observed by the researcher or reported by the subject included items such as: coughing, clavicular breathing, forward posture, chin-tuck posture, neck tension, open mouth posture, tongue protrusion, and a gurgly voice.

Results were analyzed and compared to normative data, presented by Holzer (2011) who looked at the same measures in individuals with a typical swallow function. The comparison between the raw data and the normative data represented significant differences in oropharyngeal transit time. The results of the data collected demonstrated changes in these OPD measures, suggesting that OMD and OPD may be more correlated than previously thought. It suggests that OMD may lead to later-life OPD, if tongue thrust, or the underlying cause of tongue thrust, is not resolved.

Chapter 1: Review of the Literature

Introduction

Consumption of food and liquids is necessary to survive and includes the process of mastication and deglutition, or chewing and swallowing, both of which involve voluntary and involuntary aspects. While it may seem simple and insignificant due to its 2-3 second duration, the act of swallowing is a complex process involving many areas of the body, including the central nervous system, respiration and airway control, the digestive tract, and various muscles (Seikel, King, & Drumright, 2010). More specifically, facial, lingual, velar, pharyngeal, and laryngeal muscles combine with various signals from the brain via 5 cranial nerves to execute a precise and functional swallow (Seikel et al., 2010).

There are far reaching consequences physically, emotionally, and psychologically for all ages when one or more of the four stages of the swallow is compromised. In these varying stages, it is crucial for the events to be coordinated to prevent negative impacts on the overall function of the swallow (Kendall, 2002). Logemann (1998) explains the importance of understanding the difference between the underlying disorder and the symptoms that are present. Common symptoms, such as aspiration and food or liquid residue, are different from the source of the problem, or the deficit. Frequent deficits include, but are not limited to: reduced or absent muscle contraction, reduced or absent sensory awareness, difficulty in sealing off the airway, inability to properly open the upper esophageal sphincter (UES), gastroesophageal reflux disease, and many others (Seikel et al., 2010).

Chapter one will provide a review of the literature surrounding the stages of the swallow, the development of the swallow function, oropharyngeal dysphagia (OPD), oromyofunctional disorders (OMD), the relationship between OMD and OPD, bedside evaluation, and instrumentation used to assess swallowing.

Stages of the Swallow

The act of deglutition is a series of stages, including the oral stage, pharyngeal stage, and esophageal stage. However, the oral stage is commonly divided into two stages: the oral preparatory stage and the oral transit stage (Tutor & Gosa, 2012). The oral preparatory stage includes both sensory and motor aspects to ensure a safe and effective swallow. While the processes involved in preparing the food for swallowing are voluntary (meaning the process may be started or stopped when desired), chewing and food preparation is rarely a conscious effort. Initially, food must be presented. Once the bolus of food or liquid is presented to the mouth, the lips create a seal around the food, both to remove residue from the utensil, as well as to create a seal to prevent anterior spillage (Logemann, 1998). Mastication, or the motion and action of chewing follows, which includes the introduction of saliva to break down the bolus, as well as the impounding of food by the facial musculature to prevent buccal residue. In preparation for the oral transit stage, the bolus is moved to the tongue to assess the consistency (Logemann, 1998).

Upon the completion of the oral preparatory stage, resulting in the bolus achieving the appropriate consistency, the oral stage is initiated. In a matter of 1-1.5 seconds, the bolus is transferred from the oral cavity to the pharynx through the movement and pressure generated by the tongue (Logemann, 1998). The tip of the tongue begins at the alveolar ridge and squeezes the bolus up against the palate and back toward the pharynx through a squeeze-pump motion (Peng, Jost-Brinkmann, Yoshida, Miethke, & Lin, 2003). Upon reaching the fauces, posterior tongue, and soft palate, the swallow is triggered, which then begins the pharyngeal stage (Sonies, Parent, Morrish, & Baum, 1988).

Although brief in nature, the pharyngeal stage of the swallow involves a vital series of events. These involuntary events take place almost simultaneously upon the initiation of the swallow to ensure a safe and adequate transit of the bolus. It begins with the velum elevating to seal off the nasal cavity, which is necessary to keep the bolus from moving into the nasal area, as well as to produce the buildup of pressure in the pharynx needed for an adequate swallow (Logemann, 1998). Perhaps one of the most important aspects of the pharyngeal stage of the swallow is to ensure that respiration is discontinued and the airway is protected. To do so, epiglottic inversion, or the movement of the epiglottis into a downward position to cover the opening of the larynx, as well as the closure of both the true and false vocal folds, is necessary before the movement of the bolus is continued (Logemann, 1998). Hyolaryngeal excursion, or the elevation and anterior protrusion of the larynx and hyoid bone, contributes to the airway closure, but also plays a key role in the opening of the UES, or upper esophageal sphincter (Kim, McCullough, & Asp, 2005). With the airway protected, the mandibular muscles (masseter, temporalis, and pterygoids) contract and the tongue base makes direct contact with the pharyngeal wall. Once the bolus leaves the tongue base, the pharyngeal constrictors in the pharyngeal wall contract to move the bolus downward (Fletcher, Casteel, & Bradley, 1961). The UES is made up of three main muscles: the inferior pharyngeal constrictor, upper esophageal muscle, and the cricopharyngeus, all of which are necessary for a proper opening for the bolus to pass from the pharynx to the esophagus. The opening of the UES, commonly referred to as the cricopharyngeal opening, is primarily accomplished through three contributing factors: hyolaryngeal excursion, relaxation of the muscle portion of the UES, and the pressure from the downward movement of the bolus (Logemann, 1998). With the cricopharyngeous open, the bolus is free to pass through the UES and into the esophagus.

The esophageal stage begins once the bolus has passed through the UES (Logemann, 1998). Respiration is resumed for the esophageal stage, meaning the velum and larynx are moved back into a depressed position. At this time, the vocal folds open, the epiglottis elevates, and the UES closes. Similar to the pharyngeal stage, the esophageal stage is also involuntary. The purpose is to move the bolus from the UES to the LES (lower esophageal sphincter) and into the stomach (Logemann, 1998). This movement happens through a wave like muscle contraction known as peristalsis, which moves the bolus into the stomach in approximately 10-20 seconds (Seikel, King, & Drumright, 2016).

Development of the Swallow

The development of the swallow is first seen in the 10^{th} or 11^{th} week of gestation and appears to be the first motor responses in the pharynx. However, it takes until 32-34 weeks into gestation to adequately perform the suckle and swallow in order to support nutritional needs (Arvedson & Brodsky, 2002). At birth, the anatomy of a newborn is different from that of an older child, though the same structures are present. The oral cavity of a newborn is much smaller, is almost completely filled by the tongue, has sucking pads, or extra fatty tissue, in the cheeks, lacks a definite orophaynx, and has a narrow, vertical epiglottis (Arvedson & Brodsky, 2002). As children grow and change, their eating habits and these anatomical structures are altered to prepare for a more functional and mature swallow.

Additionally, research has shown that two naturally occurring reflexes are an important part of developing a healthy swallow, as well as for survival in the early months of life (Seikel et al., 2010). From birth through six months of age, until solid foods begin to be presented, infants rely on reflexive responses for their nutritional needs (Seikel et al., 2010). Seikel et al. (2010) describe the two reflexive responses used for the oral stage, which are the rooting reflex and the sucking reflex. The rooting reflex is elicited by stroking the cheek, which initiates the movement of the head and opening of the mouth in the direction from whence the stimulation came (Seikel et al., 2010). Similarly, the sucking reflex relies on tactile stimulation of the lips to initiate the tongue and jaw protrusion. Along with rooting reflex, the sucking reflex is critical, both for the immediate nutritional needs, as well as in the development of structures and strength for future mastication, deglutition, and speech. It involves the repetitive motion of protrusion and retraction of the tongue and mandible (jaw) with enough force to begin the flow of milk from the breast into the oral cavity (Meyer, 2008). This type of swallow is often referred to as the immature or visceral swallow because of the typical forward movements of the tongue (Dworkin & Culatta, 1980).

The immature or visceral swallow is crucial to receiving adequate nutrition to survive as a newborn and infant; however, it is also important for the immature or visceral swallow to eventually transition into a more mature, adult-like swallow. A gradual transition from an immature swallow to a more mature form of swallowing, which is defined as an anterior to posterior movement of the tongue against the hard and soft palate of the oral cavity, occurs between 2-4 years of age (Peng, Jost-Brinkmann, Yoshida, Chou, & Lin, 2004). If this transition is not made, the child is at risk for an oral myofunctional disorder, such as tongue thrust. Tongue thrust, as will be discussed later, follows the same pattern as the immature or visceral swallow. While the focus of this paper does not include children in this age range, it is important to understand the initial form of swallowing, as well as the transition into a mature swallow, to recognize difficulties later.

Oral-Pharyngeal Dysphagia

Oral-pharyngeal dysphagia (OPD) is a broad term used to describe the difficulty in the transfer of food or liquid from the mouth to the stomach and can occur at any age, "from newborns to the elderly, and can occur as a result of a variety of congenital abnormalities, structural damage, and/or medical conditions" (Logemann, 1998, p. 1). In addition, the breakdown can occur in one or more of the stages of the swallow: oral preparatory, oral transit, pharyngeal, and/or esophageal; however, impairment of the esophageal stage is more frequently treated through medical or surgical methods rather than behavioral therapy due to its involuntary nature (Logemann, 1998). Types of impairments, as well as the etiology, symptoms, and the impact of OPD will be discussed in the following section.

As mentioned, deficits can occur at any stage of the swallow and may appear in more than one stage. In most stages, the impairments can be due to sensory or motor deficits, depending on the symptom and the etiology. Deficits seen in the oral preparatory stage often are associated with a decreased ability for adequate mastication and can include: decreased sensation, weak buccal, lingual, or labial muscles, and weak mastication muscles (Seikel et al., 2010). As the swallow progresses to the oral stage, deficits can be seen in the transit time from the oral cavity to the tongue base, and in that transit, sensory deficits may be seen if the reflexive swallow is not triggered as the bolus passes the posterior fauces (Seikel et al., 2010). Deficits in the pharyngeal stage of the swallow tend to be of more danger. The location may lead to the airway being compromised if an area is not performing efficiently. Examples may include slowed or reduced velum elevation, a lack of mandibular, pharyngeal, or lingual muscle contraction, reduced or absent hyolaryngeal excursion, an inability to close and protect the airway, and an inability to properly open the UES for the bolus to pass through (Seikel et al., 2010). Lastly, the esophageal stage may experience deficits due to gastroesophageal reflux disease, a hiatal hernia, or even from decreased peristalsis in moving the bolus from the upper esophageal sphincter to the lower esophageal sphincter (LES) (Seikel et al., 2010).

The deficits and stage of the swallow that is impaired are affected by the etiology or the cause of the dysphagia. The etiology also affects the speed of onset of dysphagia, manifesting in either an acute onset, or slow, gradual development. A few of the most common etiologies in adults will be briefly discussed, including: neurologic, degenerative, and age-related. The term “neurologic swallowing disorders” envelops two types of disorders: acute swallowing disorders, or those that came on quickly due to a medical condition, and dysphagia that begins slowly over time, such as with degenerative disorders (Logemann, 1998). Sudden onset neurologic conditions that may cause acute swallowing disorders include, among others: stroke, traumatic brain injury (TBI), treatment of head/neck cancer, and spinal cord injury. In these scenarios, the dysphagia is a sign accompanying the medical condition. The type, location, and severity of these conditions largely determine the difficulties that might be present in dysphagia, and which type of treatment may be the most useful.

Degenerative conditions, on the other hand, are slower to show signs and deficits, including swallowing, and will lead to a more gradual decline in all aspects. Examples of common degenerative conditions include dementia, Amyotrophic lateral sclerosis (ALS), multiple sclerosis (MS), Parkinson's disease, and myasthenia gravis (Logemann, 1998). Treatments for degenerative disorders include treatment options similar for neurological disorders, while also taking into account their progressive medical condition. Treatment options must include an understanding of the ongoing disorder, and should focus on helping the patients maintain their current ability for independence, rather than regain lost abilities. Logemann (1998) states that the clinician should focus more on how to maintain the patient's abilities rather than gaining previous abilities back.

Age is also a frequent factor in oral-pharyngeal dysphagia. Structures and functions of the stages of the swallow tend to slow and become less effective as age increases (Yoshida, Kikutani, Tsuga, Utanohara, Hayashi, & Akagawa, 2006). Some geriatric adults do not notice a difference as they increase in age, due to the body's ability to adjust as things change. Commonly, however, the overall function of the swallowing structures slows or decreases enough for the patient to notice and find difficulty with the results (Yoshida et al., 2006).

Dysphagia presents in various deficits and with varying etiologies, as mentioned previously. However, it is important to understand the difference between the source of a condition and symptoms of a condition. Signs are objective physical or mental features that indicate a condition or disease as seen by the doctor or clinician. Therefore, common signs of dysphagia include, but are not limited to: coughing (before, during, or after a swallow), aspiration or penetration, inability to control/manipulate a bolus in the oral cavity resulting in anterior spillage or residue on the palate or in the buccal cavity, recurring pneumonia due to aspiration, a gurgly voice following swallows or meals indicating residue, unexplained weight loss, and patient complaint of difficulty swallowing (Logemann, 1998). The process of swallowing is often taken for granted due to its natural and effortless nature for most individuals. Deficits and their symptoms brought on by dysphagia have long-lasting effects both physically and mentally for those who suffer. When there is an error in the process, it affects more than a person's ability to eat. Sonies et al. (1988) state that, "since mealtime remains the primary focus of social and interpersonal activity for many elderly people, disordered swallowing would have a negative impact on their health, nutritional status, and quality of life (p.1).

Oral Myofunctional Disorders

As stated in Hanson and Mason (2003), oral myofunctional disorders (OMD) refers to "a collection of oral patterns that are variably related to psychological and physiological factors" (p. 3). The most commonly seen OMDs are oral breathing, open mouth posture and lack of labial seal, reduced upper lip movement, restricted lingual frenum, tongue thrust, low and forward tongue position at rest, inefficient chewing due to temporomandibular joint (TMJ) disorders, atypical swallow, oral habits, oro-facial habits, and forward position of the head at rest (Paskay, 2012). Regardless of the OMD, there appears to be a reoccurring trait in each: an increase in vertical dimension or the freeway space, which is the space between the upper and lower incisors while in resting position (Mason, 2009). While many of these are likely to affect swallowing, the focus of this study is specifically tongue thrust; therefore, it is important to have an understanding of what tongue thrust is, along with its symptoms and possible effects on the swallowing system.

Tongue thrust is the most common form of OMD and is defined as abnormal patterns in tongue placement or pressure primarily on the anterior teeth (Hanson & Mason, 2003; International Association of Orofacial Myology, 2014). Frequent characteristics of tongue thrust include, but are not limited to: depressed tongue resting postures, mouth breathing, reverse swallow, presence of oral residue after swallow, strongly defined rugae on alveolar ridge, dental malocclusions, high vaulted palate, decreased range of motion, articulation errors, and eating difficulties (Stone, 2015). It is important to note that not all of these signs are present in each patient; signs vary often depending on the etiology. There is not one set etiology, but rather a group of attributes that tend to contribute to the development of tongue thrust. As mentioned previously, tongue thrust is considered a typical behavior in infancy and slowly fades between the ages of 2-4 years (Peng et al., 2004). Therefore, it is important to examine etiologies that are causing the tongue thrust to persist, rather than slowly fade (Hanson & Mason, 2003). Neiva and Wertzner (1996) analyzed subjects both with and without tongue thrust, and identified six potential etiologies and symptoms that may predict tongue thrust. These include the size of hole in the nipple of the feeding bottle, breathing deviations, lip resting posture, lip tonus, swallow, and breathing. Due to these early habits, developmental tongue thrust may persist until adulthood; however, tongue thrust may also be a result of adaptive behaviors. Adaptive tongue thrust may appear due to anatomical or physiological differences. Some of these differences may be due to alterations in respiration caused by hyperplastic tonsils and adenoids that reduce nasal air flow, and/or sleep disorders in which the body tries to keep the tongue forward and depressed to maintain an open airway. Other factors may include structural abnormalities or dysfunctions, particularly an excessive overjet of dentition, poor Eustachian tube function and clearance, and temporomandibular joint (TMJ) dysfunction. Neurological or developmental abnormalities, as well as several other factors, may also contribute to adaptive tongue thrust (International Association of Orofacial Myology, 2014; Paskay, 2012). By recognizing and identifying the etiologies, treatment can be more focused and therefore more efficient (Hanson & Mason, 2003).

When assessing the presence or absence of tongue thrust in an individual, it is critical to understand the variation of structures from normal and abnormal behavior, primarily with the jaw, tongue, and lips in the resting position (Hanson & Mason, 2003). For example, the resting position of the tongue and lips are highly connected to nose and mouth breathing. For those who naturally and more frequently use nose breathing, the tongue tip rests on the alveolar ridge with mild contact with the upper incisors, the teeth maintain the appropriate free space of 2-3 mm at the molars and 4-6 mm at the incisors, and lastly, the lips are comfortably closed with no abnormal muscle activity or tension. On the other hand, when mouth breathing is more dominantly used, the lips are open, the freeway space increases, and the tongue rests at the lower anterior incisors (Hanson &

Mason, 2003). Additionally, the ability to handle saliva secretions is interrupted if open mouth posture is used. As mentioned earlier, the transfer of the bolus in a swallow during the oral stage begins by the tongue meeting the alveolar ridge and moving the bolus in a pump-squeeze motion posteriorly. Mouth breathing changes that process; the molars may not come together, and the depressed tongue pushes forward to seal the excessive freeway space to produce the pressure needed to move the saliva posterior. In contrast, during a typical swallow, the tongue tip in resting position is already making contact with the alveolar ridge and the lips are occluded. All that remains is the closing of the molars, as well as the lips and buccal muscles sucked in towards the teeth, and the pump-squeeeze motion can take place (Hanson & Mason, 2003). These behaviors are but a few examples of the changes that may occur when tongue thrust becomes habitual.

Tongue thrust is often a topic of controversy due to its wide range of possible causes and symptoms. While it is labeled as an OMD, tongue thrust plays an important role in dysphagia, articulation, and even oral health. Bell and Hale (1963) indicated that several habits of swallowing in some circumstances could affect articulation. The prevalence of tongue thrust in the general population is approximately 38%, yet can increase up to 81% in children with accompanying articulation errors (International Association of Orofacial Myology, 2014). The most common sounds that are produced incorrectly in children with OMD are: /s/, /z/, "sh," "zh," "ch," and "j." Other sounds including /t/, /d/, /n/, and /l/ can be made difficult from a lack of tongue tip muscle strength (American Speech-Language Hearing Association, 2015a).

Dental health and hygiene is also frequently affected in those with OMD. The degree of correlation between tongue thrust and various types and severity of malocclusions is uncertain. Wadsworth, Maul, and Stevens (1998) found that the prevalence of OMD and an associated open bite position were significantly related. However, Mason (2009) indicated that tongue and lip pressures do not have a correlation to dentition and that many individuals with tongue thrust have normal occlusion. The International Association of Orofacial Myology (2014) explains that just as the forces exerted on dentition through orthodontic appliances can change and affect the oral cavity, the same is true for the abnormal patterns and functions used by those with OMD. This applies especially to children who are acquiring their more permanent dentition; the pattern of the rest posture associated with tongue thrust causes abnormal eruption of the new teeth.

In addition to the effects of OMDs on dentition and communicative skills, OMDs may also affect an individual's personal appearance and eating habits (Hanson & Mason, 2003). As mentioned in the previous paragraph, there are varying opinions on the degrees to which dentition is affected by OMDs. However, other cosmetic factors, such as breathing posture and lip position may be altered from the OMD. Several eating habits were mentioned as symptoms of tongue thrust, which include: choking, messy or loud eating, abnormal gag reflex, avoidance of certain foods, and the need for liquid to clear bolus (Stone, 2015). Symptoms such as these may not cause concern in private and personal settings, but cause awareness and embarrassment in public and social situations, which may serve as an incentive to address these issues.

Understanding the impact on the dentition has changed in the past several decades. Swallowing, and the pressure exerted on the dentition during the swallow, was thought to be the source of malocclusions. However, it is now more clearly understood that the malocclusions are a result of the resting posture of the lips and tongue, which is a more consistent source of pressure, rather than occasional pressure during a swallow (Hanson & Mason, 2003). While malocclusions, articulation errors, and other signs are the reason for referral, it is crucial to understand and treat the cause rather than the presenting signs and symptoms. To do so, a variety of professions have become more involved to effectively evaluate and treat those who present with tongue thrust. These include, but are not limited to, speech-language pathologists, orthodontists, dentists, otolaryngologists, pediatricians, and/or allergists (Hanson & Mason, 2003).

Relationship between Tongue Thrust (OMD) and Oropharyngeal Dysphagia (OPD)

In a study conducted in 2011, Holzer reported normative data on measures related to swallow, more particularly lingual strength, orofacial strength, and oral transit times. While the study was a normative study, Holzer (2011) did find a significant predictive relationship between clinical signs of OMD and OPD, based on both qualitative and quantitative data. Essentially, this study demonstrated indications that unresolved tongue thrust predicts OPD.

As follow up studies, Evers (2013) and Evans (2015) utilized the same measures as the Holzer study; but, rather than taking normative data, these studies examined oral function of individuals with tongue thrust. Evers (2013) found that masseter contraction and oral transit time were mostly affected in individuals with tongue thrust as compared to the normative data in the Holzer (2011) study. While tongue and lip strength were decreased, the differences were not found to be significant. However, the participants in the study presented by Evans (2015) demonstrated a significant difference in tongue strength, lip strength, and oral transit time with no significant differences found in masseter contraction. Taken together, these three studies reveal an emerging relationship between OMD and OPD. Both Evans (2015) and Evers (2013) found a pattern of increased oral pharyngeal transit time as age of subject increased. This implies that the strength of the causal factor increases with age. That is, there is growing evidence that OMD will lead to later-life OPD.

Instrumental Evaluation of Swallow Function

After examining the various disorders of swallowing, it is equally important to understand the most efficient ways to assess swallowing. The most common and frequently used instruments for measurement include clinical observations, videofluoroscopy swallow study, fiberoptic endoscopic examination of swallowing, electromyography, and the Iowa Oral Performance Instrument. Each of these evaluations has advantages and disadvantages, as well as wide ranges of purpose; therefore, understanding the uses and purpose of these primary assessments is the first key component.

The first assessment is the clinical evaluation. It is often viewed as a dysphagia screener to provide information in a minimally invasive fashion. Information gained often includes: the likelihood that dysphagia exists, the need for further assessment, the safety of the patient oral intake, and the need for alternative nutritional intake (Weinhardt, Hazelett, Barrett, Lada, Enos, & Keleman, 2008). The evaluation itself involves many aspects, such as gathering new data and observations, reviewing patient history, consulting with the primary physician, and performing new assessments, such as an oral peripheral examination and bedside evaluation (Logemann, 1998). Initially, before meeting or having a session with a client, the clinician will review the patient's chart to be aware of medical history, current or past medications, and any previous therapy. Observation begins upon entering a room to perform the evaluation. Observations include, but are not limited to: the presence of tracheostomy tube, patient posture, alertness, cognitive level, and reaction to a clinician entering the room and introducing oneself (Logemann, 1998). The clinical evaluation often involves an oral-peripheral examination, as well as a bedside evaluation.

An oral peripheral examination should include careful observation of structures both at rest and in motion. Structures to assess include the lips, dentition, tongue, hard palate, and the velum. Initially, the face and oral structures are assessed in a resting position to look for asymmetry, breathing habits, and other deviations that are atypical (Logemann, 1998). Once the structures have been observed at rest, the appearance, strength, and function of those same structures should be assessed while in motion or in use. Beginning with the structures most visible or superficial, the clinician asks the patient to do various oral motor tasks to determine the range, rate, and accuracy of the motions (Logemann, 1998). Diadochokinetic rates, or the repeated production of the sounds /p/, /t/, and /k/, and the ability to cough and clear the throat are also frequently assessed (Logemann, 1998).

Continuing from the information gained during an oral peripheral examination, a bedside evaluation, also known as a clinical evaluation, of the swallow follows. Before the initiation of the swallow trials, it is important for the clinician to ask patients or caregivers information about the difficulty that they are having. This benefits the clinician by giving clues as to which consistencies and textures are more difficult, while also understanding the stage of the swallow with which the patient is experiencing difficulty (Logemann, 1998). Following the chart review, the oral mechanism exam, and speaking with the patient and caregiver, clinicians use their clinical judgment on whether to move forward with the swallow trials (Logemann, 1998).

Collecting data through swallow trials includes a series of textures and consistencies, both with liquid and solid foods. While there is a norm for swallow trials, clinicians typically have their own style in accomplishing them. Depending on the state and severity of the patient, the presence or absence of a tracheostomy, a previous diet, or other factors, clinicians may vary in how they begin and how each trial is presented (Logemann, 1998). Some patients may have the ability to feed themselves, while others need assistance; and some may benefit from a straw, while others may not have the labial seal and oral pressure needed to use a straw. Again, the typical form is to begin with thin liquid, which may be presented with a spoon, a straw, or a cup. If the patient coughs or struggles with the thin liquid, it can be thickened to nectar and honey consistencies to assess if the thickened nature of the liquid allows more time for the pharyngeal swallow to trigger, thereby allowing a safer swallow for the patient (Logemann, 1998). Following each trial of liquid, the clinician should ask the patient to phonate “ah” to listen for a wet or gurly voice (Logemann, 1998). Continuing on from the liquid trials, if the patient is tolerating the previous trials, the clinician will move to the solid food. There are varying consistencies of the solid foods, as well. These include: pureed solids, neurosoft or dysphagia level 2 solids, mechanical soft or dysphagia level 3 solids, and regular solids. The trials are similar to the liquids in the way they are presented. If the patients are able, it is best to have them feed themselves, since that is the most natural for them. However, if the patient is unable, the clinician presents each consistency to the client in tolerable sizes. Following each trial for the solid foods, it is again important to have the patient phonate, as well as to have the clinician look in the mouth for any residue, particularly in the buccal cavities (Logemann, 1998).

Logemann (1998) discusses laryngeal palpation using the four fingers. The index finger is placed immediately behind the mandible, the middle finger is placed on the hyoid bone, the third finger placed on the thyroid notch of the thyroid cartilage, and the fourth finger at the bottom of the thyroid cartilage, or right above the cricoid cartilage. Laryngeal palpation occurs in a very sensitive area, making it mandatory that the contact of the fingers is light, not adding pressure to the specific areas. During each swallow trial, Logemann suggests using this placement to feel for tongue movement, hyoid bone movement, and hyolaryngeal elevation and excursion (Logemann, 1998).

A disadvantage of the measurement used in bedside evaluations is that they are subjective, or based entirely on clinical judgment (Yoshida et al, 2006). They do not offer concrete data. One clinician may perform the evaluation differently, or perceive observations to be less or more severe compared to another clinician. Because of the screening nature of the clinical evaluation, when the clinician detects aspiration, penetration, weakness, or other deficits, further testing or assessments may be warranted. The bedside evaluation also does not accurately indicate whether a patient is, or is not, aspirating (Leder & Espinosa, 2002). The remaining assessments discussed are those that may be used for further testing.

The second form of assessment that is frequently used is referred to as videofluoroscopy. Videofluoroscopic swallow study (VFSS), also known as a modified barium swallow study (MBSS), is defined by the American Speech-Language-Hearing

Association (2015c) as continuous x-rays that observe motion providing a real time image. According to Logemann (1998), VFSS, along with bedside evaluation, is one of the most frequent techniques used in the assessment process of swallowing therapy. She continues by stating that VFSS has two primary purposes: to define the etiology that is causing the symptoms, and to evaluate the efficiency of treatment strategies for safe intake. Furthermore, it “provides information on bolus transit times, motility problems, and amount and, most important, etiology of aspiration” (p. 60). VFSS has a primary advantage to the many other types of assessment, which is the ability to view the entire swallow, spanning from the oral preparatory stage to the esophageal stage. However, as with all assessment techniques, there are disadvantages. Most importantly, patients that participate in VFSS are exposed to radiation throughout the assessment (Logemann, 1998). Therefore, it is important to have a goal and a purpose when performing a VFSS to reduce the amount of radiation exposure. During the evaluation, the patient is presented with a variety of food that follows the same procedure as the swallow trials in a bedside evaluation. As the food is presented to the patient, barium, which is the substance that allows the bolus to appear in the videofluoroscopy, is mixed with it. While a radiologist is not directly needed at the time of a VFSS, Logemann (1998) states that it is better for both the swallowing therapist and a radiologist to be present. Radiologists may not have a complete understanding of the process of the swallow, but they are certified to detect abnormalities in the surrounding structures and, if necessary, can scan further down to assess the function of the esophagus (Logemann, 1998).

A third form of assessment that is used is the fiberoptic endoscopic examination of swallowing (FEES). FEES is an imaging procedure using a live camera that is attached to a fiberoptic cable inserted through the nasal cavity to look at pharyngeal and laryngeal anatomical structures, as well as pre-and-post swallow function (Logemann, 1998). Resting the scope near the tip of the epiglottis has shown to be the most effective view to assess airway closure. Since the scope is placed through the nose and into the pharynx, the oral preparatory and oral phases of the swallow are not evaluated during a FEES assessment. FEES has become a reliable tool for assessing the function of the pharyngeal swallow (Leder & Murray, 2008). Various studies, as cited in Leder and Murray (2008), have noted that FEES and VFSS are both specific and sensitive in assessing a delay in the trigger of a swallow, exposing pharyngeal residue following a swallow, and aspiration or penetration of both liquids and solids (Leder & Murray, 2008). FEES has many advantages and disadvantages when compared to other instruments of measurement available to assess swallowing. In comparison to VFSS, FEES does not expose the patient to barium substances or any form of radiation at any time. It also allows evaluation of the velum before moving into the pharynx to assess the structures and function of the airway (Leder & Murray, 2008). However, FEES is rather intrusive and may not be a feasible option for children under 8, as well as adults with cognitive disorders (Logemann, 1998). Another downfall of FEES is the inability to view the oral phase or the trigger of the actual swallow of foods or liquids, due to the placement of the camera (American Speech-Language Hearing Association, 2015b). Since the tube is placed through the nose, the velum closure during the swallow blocks the camera (Logemann, 1998).

Electromyography, or EMG, is another form of assessment used during a swallowing evaluation that, in opposition to VFSS and FEES, is not a direct measurement. A non-imaging assessment technique, EMG is the assessment of muscle activity during events, such as speech, falsetto, gagging, and swallowing (Logemann, 1998). It can be utilized through primarily three methods: surface electrodes, hook-wire electrodes, and suction cup electrodes; however, for the purpose of this study, EMG through surface electrodes, or sEMG, will primarily be discussed. As demonstrated in the name, surface electrodes are used on muscles that can be felt through the skin (superficial muscles). According to Stepp (2013), sEMG detects and measures motor unit action potentials (MUAP) from muscles, which correlates with muscle activation. sEMG detects muscle activation signals from a larger area than would be seen with a hook-wire electrode. While this may be beneficial in understanding the overall activation of a muscle of interest, the larger area may also give you "cross-talk" from other muscles (Stepp, 2012). Cross-talk may be especially true in measuring muscles used in speech and swallowing, as these muscles are small and may have overlapping fibers with other nearby muscles (Stepp, 2012). In relation to speech and swallowing, muscles surrounding the mandible, as well as muscles used for laryngeal elevation and excursion during a swallow, are measured to evaluate the initiation of the swallow (Logemann, 1998). Ozdemirkiran, Secil, Tarlaci, and Ertekin noted that sEMG, when appropriate, is frequently used due to its noninvasive nature (2007). This noninvasive nature, coupled with its simplicity and real time information of muscle movement and activation, are just a few of the reasons why many researchers find sEMG to be a good option (Stepp, 2012). However, there are limitations. sEMG requires a certain level of knowledge concerning the signals, technical limitations, as well as the anatomy and physiology of the head and neck musculature. Without a concrete understanding of these issues, the use of sEMG in assessment and treatment of voice, speech, and swallowing may demonstrate inconsistencies (Stepp, 2012).

The fifth and final assessment that will be discussed is the Iowa Oral Performance Instrument (IOPI). Luschei (2011) explained that the IOPI is a non-imaging assessment with three main purposes: to assess the strength of the tongue and lips, to demonstrate the effectiveness of treatment and exercises on tongue and lip strength, and to prove to the patient that strengthening exercises are beneficial. Therefore, the IOPI, like EMG, is not a direct assessment of dysphagia, but rather determines the strength and function of the tongue and lips, which are factors in dysphagia. When using the IOPI for assessment, a bulb is placed on the tongue and the patients are asked to push the tongue up to the roof of their mouth as hard as they can (Luschei, 2011). The same procedure takes place when used to assess the structure and function of the lips: the bulb is placed between the lips and the patients are asked to squeeze the bulb between the lips with as much force as they can. It is vital that in both the evaluation of the tongue and the lips, the mandible is set/closed so that results indicate the strength of the lips or tongue rather than the mandible. Decreased tongue strength may be a sign of many neurological diseases seen on a speech-language pathologist’s caseload. For example, stroke patients, head and neck cancer patients, individuals with Parkinson’s, and elderly persons, all demonstrate loss of tongue strength that has a negative effect on their swallow (IOPI Medical, 2013). While many clinicians believe that tongue strength can be adequately measured through applying force via a tongue depressor, these data are subjective. IOPI provides an objective measure of tongue strength, and therefore is more reliable than subjective measures (IOPI Medical, 2013).

Conclusion

Thus far, the stages of the swallow, developmental aspects of swallowing, oral pharyngeal dysphagia, oral myofunctional disorders, the relationship between OMD and OPD, and instruments for evaluation of a swallow have been discussed in detail to provide a foundation for this study. The purpose of the study is to replicate studies by Diana Evers (2013), and most recently by Lyndsey Evans (2015). The Evers (2013) study included 11 subjects ranging from ages 7-51, while Evans (2015) included 6 subjects between the ages of 11-40. These studies followed similar procedures as seen in Holzer (2011) who looked at normative data of individuals with no known pathology; however, Evers' (2013) and Evans' (2015) studies focused on individuals diagnosed with tongue thrust. Together, these two studies both found that individuals with OMD show evidence of OPD, and also that signs of OPD increase with age in individuals with OMD, as seen in oropharyngeal transit time (Evans, 2015; Evers, 2013). The question of the present study is: *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?*

Chapter 2: Methodology

This study was a replication of two previous studies (Evans, 2015; Evers, 2013). Due the replication nature of this study, this methodology was largely adapted from the Evans (2015) study. The current study was conducted to increase the evidence regarding whether or not individuals with tongue thrust vary from the norm in oral pharyngeal dysphagia measures. The following measures were used to assess those diagnosed with tongue thrust: tongue tip strength, tongue dorsum strength, lip strength, masseter contraction, and oropharyngeal transit time. Normative data from a previous study (Holzer et al., 2011) was the comparison point used to determine whether or not these differences were statistically significant. Data from this study were matched to same age and gender of individuals without tongue thrust. This study includes 5 subjects, who range in age from 18-27. This study was part of a larger group of studies, all of which build on the evidence that lip strength, tongue strength, masseter contraction, and oropharyngeal transit time demonstrate differences across the lifespan.

Research Hypothesis

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 consisted of 5 subjects identified with tongue thrust, with the individuals ranging in age from 18-27. Detailed demographic data is reported for each subject in Chapter 3. Participants were recruited through participant networks and social media (recruitment poster located in Appendix A).

The Stone Tongue Thrust Protocol (refer to Appendix B) was used to confirm the presence of tongue thrust in all participants before further involvement in the study. By using the same inclusion procedure for each participant, the researcher ensured that identical criteria were used to qualify participants as having tongue thrust. The STTP was used to gather case history information for each participant. Each subject was also given a medical history form (Appendix C), which included: date of birth, gender, ethnicity, medical conditions and/or disorders, OMD risks and/or conditions, surgeries, medications, alcohol consumption, tobacco use, food preferences, and food avoidances. Any additional information provided by the clients during the course of data collection was audio recorded and reported by the researcher.

Exclusion criteria for the study was gathered through the medical history form filled out by each subject. Subjects with a history of structural or neurogenic impairments of the head or neck, not resulting from tongue thrust, were excluded from the study. If subjects reported a concussion resulting in a loss of consciousness for less than 5 minutes, with no associated motor or cognitive deficits, they were not excluded from the study.

Variables

Independent variables for this study included: subject age and gender, protocol group assignment, and bolus characteristics. Food and liquids that were used are replicated exactly from previous studies, which consisted of a ½ teaspoon and 1½ -teaspoon measurements of chocolate pudding, a subject-determined “typical” bite of Triscuit cracker, and 10cc of water served in a cup.

The researcher used clinical observation and professional judgment to measure subjective variables. Subjective variables included: dental occlusions or malocclusions, the presence or absence of a vaulted palate, open or closed mouth posture at rest, the absence or presence of residue in the sulci or on the tongue following a swallow, and a “gurgly” voice quality post swallow. During each trial, which consisted of a ½ tsp of pudding, 10 cc of water, and a Triscuit cracker, subjects were assessed for tongue protrusion, as noted by the researcher, by pulling downward on the lower lip during a swallow. Pre-swallow bolus cohesion was also assessed for the Triscuit cracker trials, using 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), as well as post-swallow residue on a similar 1-3-5 rating scale (1= minimal/no residue, 3= some evidence of residue, 5= significant amount of residue). Other characteristics, such as: open mouth posture, coughing, clavicular breathing, forward posture, chin-tuck, neck tension, and tongue protrusion were also recorded as being present or absent during swallow trials. Any additional observations made by the researcher were noted on the study protocol.

Instruments and Materials

Before each session with the individual subjects, a video recorder was set up to allow for videotaping of all the sessions from beginning to end. Upon subject arrival, the recording began and each subject, or his or her guardian if subject is a minor, was asked to complete and sign both the consent form, verifying their consent to participate in the study (Appendix D), and the medical history form (Appendix C). The Stone Tongue Thrust Protocol (STTP) created by Cally Stone, is a protocol to determine the presence or absence of tongue thrust, including the procedure and swallow trials for determining the diagnosis. This protocol was used to assess all of the subjects in this study for consistently determining tongue thrust. As outlined in the STTP protocol, trials of water, diced peaches, chocolate pudding, and Triscuit crackers were consumed while the researcher observed and made note of accompanying characteristics, as previously mentioned, for each of the given consistencies. Along with the STTP, the researcher asked subjects to participate in "smile swallows," a common practice performed by other OMD professionals in assessing for the presence of tongue thrust. A "smile swallow" is a procedure in which the subjects are asked to smile with the lips open while swallowing a small sip of water, which allows the professional to have an improved view of the forward movement of the tongue during the swallow. In previous studies, the results from the STTP swallow trials, as seen in the protocol, and the "smile swallows" have been in agreement in confirming the presence or absence of tongue thrust.

Following the diagnosis of tongue thrust, the researcher proceeded to follow the study protocol (see Appendix E). 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 will be used to measure masseter contraction and oropharyngeal transit time, using surface electrodes. EMG data is to be recorded on a Samsung Notebook laptop, Model NP74OU3E. 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 presented on a spoon, and subjects were instructed to take a "typical" bite of Triscuit cracker. Other clinical materials 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 5 individuals who had either been previously diagnosed with tongue thrust, had 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 are minors, were asked to sign consent forms to participate in medical research (see Appendix D). In the case of a minor subject, the caregiver was to remain present and assist in the completion of consent and history forms; however, no minor subjects were used in this particular study. Next, the researcher evaluated all subjects using the STTP (see Appendix B) to evaluate and diagnose each subject as either having tongue thrust or not 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

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 had the option to be present for evaluations that included minors; the caregivers may have 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 that they should not experience any pain or discomfort and that they could end their participation in the study at any time.

Oral peripheral examination. The oral peripheral examination, which followed the protocol found in the STTP, was used to evaluate the structure and function of the oral mechanism. The researcher noted any deviations of the teeth, tongue, tonsils, palate and lips. Palate height was recorded, as well as the presence of any the following features: crossbite, labioverted teeth, normal occlusion, class I malocclusion, class II malocclusion, or class III malocclusion.

Tongue tip, tongue dorsum, and lip strength. Objective measures of lip, tongue tip, and tongue dorsum strength were all gathered using the Iowa Oral Performance Instrument (IOPI). The strength of the tongue tip was measured first. In order to localize the measurements to the tongue tip, the IOPI bulb was placed anteriorly on the tip of the tongue. The subject was directed to keep their lips and teeth closed, without biting down on the tubing, and compress the bulb against the alveolar ridge with as much force as possible for approximately two seconds. Each subject repeated this measurement for three trials, while the researcher recorded the force reported by the IOPI. At the start of each new attempt, the researcher repositioned the IOPI bulb on the tongue.

Next, the dorsal strength of the tongue was measured. For this task, the IOPI bulb needed to be placed further back in the mouth on the tongue dorsum. The researcher, by referencing the juncture of the hard and soft palates, must identify the precise location for bulb placement. This was facilitated by having the subjects sustain phonation of the vowel /a/. Each subject was asked to occlude his or her teeth and lips while pushing upward against the bulb with maximal force and without biting down on the IOPI's tubing. As with the previous measure, subjects repeated this action in two-second intervals for a total of three trials. The researcher dried and repositioned the bulb after each attempt, and recorded results on the protocol form following each trial.

Lastly, lip strength was measured by placing the IOPI bulb parallel to the lips and instructing the subjects to press their lips closed against the bulb with as much force as possible. Before the first trial, subjects were asked to wipe their lips with a tissue so that saliva or chapstick did not interfere with their ability to grip the bulb with their lips. To prevent subjects from utilizing their teeth, specific instruction and monitoring was given to keep the back teeth clenched. Subjects were also instructed not to bite down onto the tubing, as this would invalidate the IOPI measurement. If the participants were unable to hold the bulb in place with their back teeth in a clenched position, the readings were given a score of “0.” Lip strength measurements were broken into three two-second trials. The IOPI bulb was dried of saliva and repositioned between each new attempt. Readings were recorded between each trial by the researcher.

EMG masseter contraction. Electromyography measurements for masseter contraction were collected through electrodes placed along the belly of the masseter in a vertical plane. Prior to skin preparation for placing electrodes, all subjects were interviewed about skin allergies or sensitivities. If none were reported, the researcher prepared the skin for electrode placement by using NuPrep skin prepping gel. Gel was applied using a gauze pad and was rubbed into the skin for approximately 30 seconds. Alcohol swabs were then used to remove residue from the skin. If subjects presented with allergies/skin sensitivity, only alcohol swabs were used to prepare the skin for electrode placement.

Correct placement over the belly of the masseter was determined by instructing subjects to clench their back teeth during palpation by the researcher. Marks were made on the skin with a nontoxic pen to ensure proper placement. Channel A was assigned to the right masseter and Channel B to the left masseter. Ground electrodes for both channels were positioned over the left clavicle.

A baseline for the masseter was recorded before the onset of trials by instructing the subjects to bite down with their back teeth as forcefully as possible for three seconds. The researcher directed the subjects on when to begin and when to relax. This baseline was repeated for a total of three trials. Trials were then performed, and included a ½ tsp of pudding, 1 ½ tsp of pudding, 10cc water and a subject-determined bite of Triscuit cracker. Each stimulus presentation received three trials. Subjects were instructed to hold the bolus in his or her mouth until instructed to swallow. The four-finger laryngeal palpation method, developed by Logemann, was utilized to detect initiation and termination of the swallow (1998). The researcher used her free hand to depress the spacebar of the laptop computer as soon as initiation and termination of the swallow were detected. This placed timing markers on the EMG readings, which was displayed on the laptop screen, and were recorded by the researcher throughout the trials.

The swallow trial that included the Triscuit cracker required a slightly different process in order to be minimally disruptive to the natural timing of the swallow. Subjects were instructed to chew until ready to swallow, and then signal to the researcher. After being signaled, the researcher examined the Triscuit bolus for cohesion. Pre-swallow cohesion was rated using 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). Post-swallow residue was also rated using a 1-3-5 rating scale (1= minimal/no residue, 3= some evidence of residue, 5= significant amount of residue).

After each trial, the researcher recorded subjective findings. Subjective information that was collected for each participant consisted of the following: the presence or absence of a gurgly voice post-swallow, coughing, clavicular breathing, forward posture, chin-tuck posture, neck tension, open-mouth posture, tongue protrusion, and any additional findings. The presence or absence of tongue protrusion was determined by using the lip pull-down method for all stimulus presentations except the 1 ½ tsp pudding trial. Due to the multitasking required of the researcher, obvious signs were noted in real-time, while less obvious findings were noted upon viewing the recordings of each participant.

EMG and behavioral swallow timing. Oropharyngeal transit time was measured both behaviorally and instrumentally. The researcher defined the moment of swallow initiation as the upward movement of the larynx, as recorded by the EMG of the submental region. Termination of the swallow was determined through palpation of the throat and defined as the depression of the larynx. This was marked in the measurement system by the researcher as soon as depression was detected.

The same skin preparation procedure that was implemented for masseter contraction was also utilized for oral-pharyngeal transit time. Channel A was placed on the submental region, approximating the mylohyoid muscle, with the first electrode placed two centimeters posterior from the chin point, and the second electrode placed two centimeters posterior to the first, as measured with a ruler. Channel B electrodes were placed vertical to the thyroid lamina on the left side. Ground electrodes remained on the collarbone.

Subjects were given ½ tsp pudding, 1 ½ tsp pudding, 10cc water and a participant-determined bite of Triscuit, just as in the masseter contraction portion of the study, with each stimulus presented three times. Each time the subjects were instructed to hold the bolus in the oral cavity until told to swallow by the researcher, for both the pudding and the water trials. For the Triscuit trial, each subject was instructed to chew until ready to swallow, then signal the researcher directly before swallowing, which allowed the researcher to check for cohesion of the pre-swallow bolus. Once directed to swallow, the initiation and termination of the swallow were marked, followed by the researcher asking the subject to open their mouth to assess post-swallow residue. The researcher marked initiation and termination of the swallow each time by depressing the spacebar on the laptop to place marks on the EMG recordings.

The researcher recorded subjective findings following each trial. Subjective information that was collected for each participant consisted of the following: the presence or absence of a gurgly voice post-swallow, coughing, clavicular breathing, forward posture, chin-tuck posture, neck tension, open-mouth posture, tongue protrusion, and any additional findings. The presence or absence of tongue protrusion was determined by using the lip pull-down method for all stimulus presentations, aside from the 1½ tsp pudding trial. Due to the multitasking required of the researcher, obvious signs were noted in real-time, while less obvious findings were noted upon viewing the recordings of each participant.

Reliability

Inter-judge reliability: inter-judge reliability was ensured through the use of consensus coding. The researcher, and a colleague trained in the tests, examined all subjects' oropharyngeal transit time data, including all EMG oropharyngeal transit time graphs, together. Both researchers came to a consensus for each trial of oropharyngeal transit time.

Intra-judge reliability: to safeguard intra-judge reliability the researcher re-measured all EMG oropharyngeal transit time graphs for 20% of trials.

Data Analysis

Raw scores obtained by the researchers during the study were converted into t-scores and p-values to determine statistical significance. Subjects of the present study were compared with normative data from Holzer (2011); however, only the IOPI measures and the oral-phrayngeal transit times were converted to t-scores based on the norms. Following comparison, if the p-value was .05 or smaller, the data was considered to be significant. Significant measures were found in oral pharyngeal transit times for all subjects.

Chapter 3: Results

This study was a replication of two prior studies analyzing the relationship between individuals with tongue thrust and measures of oral pharyngeal dysphagia. The purpose was to examine whether there were differences in OPD measures between individuals with tongue thrust and individuals without tongue thrust. For this study, there were 5 subjects, one male and four females, ranging in age from 18-27. After an initial assessment, using the STTP, all subjects were confirmed to have tongue thrust and continued on with the study. This relationship was further assessed through gathering data pertaining to OPD measures including: tongue tip strength, tongue dorsum strength, lip strength, masseter contraction, and oral pharyngeal transit time. Objective measures were taken through the use of an EMG and the IOPI giving raw scores. Raw scores were then compared to normative data from Holzer (2011).

Medical History Form

Each participant was asked to complete a medical history form before the initiation of the study. It gave information pertaining to age, ethnicity, and past and current medical conditions. There were five subjects included in this study. Of those five subjects, one was male, with the remaining four being female. The range of age was relatively small, between 18-27, with a mean age of 21.4. Because the young age of the subjects, many of the medical conditions on the medical history form did not apply to them. Four subjects were European American and one was White Hispanic. One reported having a head injury, which she labeled as a mild concussion, though she did not ever lose consciousness. In relation to oromyofunctional disorders, two reported to be mouth breathers, one being specifically worse at night. Two subjects reported finger sucking and three subjects reported cheek biting. Only one of the subjects had previously had their tonsils removed. The remaining subjects did not show evidence of enlarged tonsils, although the researcher was unable to see two of the subjects' tonsils due to their hyperactive gag reflex.

Allergies were reported by two of the subjects, specifically seasonal allergies, and allergies to cats and horses. Four subjects reported oral surgery, all specifying the removal of their wisdom teeth as the cause for the oral surgery. Only one other surgery was noted for one of the subjects, in which a hernia was repaired in the abdominal area. One subject reported consumption of alcohol several times a month. One subject has previously been enrolled in speech therapy for a frontal lisp, as well as for tongue thrust therapy, though she reported the tongue thrust has consistently persisted after therapy.

The remainder of the areas listed in the medical history form (Appendix C) were not listed as present. A review of the medical histories for the five subjects is listed in Table 3.1.

Table 3.1. Medical history form results. Individual subjects listed in parenthesis.

	Males	**Females**	**Total**
European American	0	4 (1, 2, 4, 5)	4
White Hispanic	1 (3)	0	1
Head injury	0	1 (4)	1
Mouth breather	0	2 (1, 2)	2
History of finger sucking	0	2 (1, 2)	2
History of cheek biting	0	3 (1, 2, 5)	3
Tonsils/adenoids removed	0	1 (1)	1
Allergies	0	2 (2, 5)	2
Oral surgery	1 (3)	3 (1, 2, 5)	4
Other surgery	0	1 (2)	1
Alcohol consumption	0	1 (1)	1
Previous tongue thrust therapy	0	1 (5)	0

Oropharyngeal Transit Time Trends

In this study, and studies done previously (Evans, 2015; Evers, 2013), several of the EMG graphs demonstrated a trend of extraneous movement prior to the initiation of a swallow. This was observed both through palpations of the larynx and in the data charts from the EMG readings (Appendix H). In several cases, movement of the tongue, or pumping to move the bolus, as well as false starts were observed. This often posed a challenge for the researcher to mark the exact initiation of the swallow. However, the researcher used clinical judgment to mark the onset and offset of the "true" swallow throughout each of the trials. Extraneous activity of the muscles outside of the "true swallow" was not included in the swallow time.

Multiple swallows were also seen in the 1 ½ pudding trials and the Triscuit trials, often occurring 2-10 seconds following the first, main swallow. These extra swallows were not included in the oral pharyngeal transit time, or included in the data in any way. Holzer (2011) examined the normative data on the same measures in typically swallowing individuals, but only on a single swallow. Therefore, additional swallows were not recorded so the current data could be compared to the normative data.

In several cases, the EMG readings of the oropharyngeal transit time were not always clearly defined as a peak in elevation on the EMG graph, lacking a clear onset and offset. Onset was defined as a palpable elevation of the larynx; offset was defined as a palpable depression of the larynx. However, the EMG readings varied enough from the baseline to make it clear to the researcher the physiological onset and offset of the swallow. Upon palpation of the larynx, a tick mark was made in the EMG reading upon feeling the larynx beginning to elevate. The researcher was able to find the beginning of the swallow approximately ½ of a second before the initial mark was made to mark the initiation of the swallow. Typically within one second following the onset, the swallow would conclude and the larynx would begin to depress, marking the end of the swallow, which was marked again by a final tick mark on the EMG readings. These tick marks on the EMG readings were supported by the upward movements/peaks in the graphs.

The remaining sections of the results will include individual summaries of each subject, such as medical history, diagnostic and informational results from the STTP, and any additional observations made by the researcher. Additionally, each subject summary includes two tables to summarize the written results. The first table outlines the individual OMD indicators from the STTP. A second table shows the results from the EMG and IOPI measures, listing the average and standard deviations from the Holzer (2011) normative data, as well as the observed score, the t-score, and the p-value from each subject's data. In each summary, the observed score from the EMG measures was compared to the norm for consistent deviations in masseter and behavioral measures, while a t-score was calculated for IOPI and EMG measures for tongue tip strength, tongue dorsum strength, lip strength, and oral pharyngeal transit time. The following chart summarizes the abbreviations for the various measures used throughout the study.

Table 3.2 Abbreviations Used in Results.

Abbreviation or Variable Name	**Description/Criteria**
iopitipavg	iopi tongue tip average
iopidorsavg	iopi dorsum average
iopilipsavg	iopi lips average
mcbARMSav	masseter contraction baseline ARMS av.
mcbBRMSav	masseter contraction baseline BRMS av.
mcpud1ARMS	masseter contraction ½ tsp ARMS
mcpud1BRMS	masseter contraction ½ tsp BRMS
mcpud2ARMS	masseter contraction 1 ½ tsp ARMS
mcpud2BRMS	masseter contraction 1 ½ tsp BRMS

mc10ccARMS	masseter contraction 10 cc ARMS
mc10ccBRMS	masseter contraction 10 cc BRMS
mccrackARMS	masseter contraction cracker ARMS
mccrackBRMS	masseter contraction cracker BRMS
stcpud1avg	Swallow timing w/ contraction ½ tsp av.
stcpud2avg	Swallow timing w/ contraction 1 ½ tsp av.
stc10ccavg	Swallow timing w/ contraction 10cc av.
stccrackavg	Swallow timing w/ contraction cracker av.
tppud1	tongue protrusion ½ tsp (lip pulled down, sum of 3 trials)
tp10cc	tongue protrusion 10 cc (lip pulled down, sum of 3 trials)
tpcrack	tongue protrusion cracker (lip pulled down, sum of 3 trials)
bolusres	bolus residue
ope_p	oral peripheral exam of palate
ope_d	oral peripheral exam of dentition: 0=normal; 1=type 1; 2=type 2; 3=type 3; 4=open bite; 5=other
Cough	cough
CB	clavicular breathing
FP	forward posture
CTP	chin tuck
NT	neck tension
OMP	open mouth posture
TP	tongue protrusion (on trials without pulling lip down)

Subject 1

Subject 1 was a 23-year-old female recruited through personal contact with the researcher. Participation included one two-hour session at the Idaho State University Speech, Language, and Hearing Clinic. Upon arriving at the clinic, in accordance with the protocol, the subject completed the medical history form and was assessed for tongue thrust using the STTP. Following the confirmation of tongue thrust, the researcher obtained measures such as masseter contraction and oropharyngeal swallow timing, using EMG instruments. Additionally, IOPI measurements for tongue tip, tongue dorsum, and lip strength were collected. The researcher was successful in obtaining all necessary information during the two-hour session with the subject.

Table 3.3 summarizes the information received from the STTP, indicating that the subject did present with a tongue thrust. The subject reported several noxious oral habits as a young child, such as pacifier use, prolonged finger sucking until approximately 3 years of age, and cheek biting. While allergies were not mentioned to be a problem for her, she did mention frequent cases of pneumonia as a young child, and several other illnesses, leading to the removal of her tonsils at an early age.

The subject reported no previous orthodontic treatment. Upon examination of oral cavity, it revealed a class II malocclusion with the upper incisors labially tipped, a mild lateral open bite, and a short upper lip. Habitual tongue rest posture reported to be pressed against the lower, anterior teeth. The subject reported to have a lip closed rest posture except at night, when she indicated that she slept with an open mouth; however, the researcher also noted times of open lip rest posture during approximately one-third of the evaluation. After reviewing the video for this subject, the researcher noted significant tension and pursing of the lips together during the Triscuit trials of the study. The researcher observed a high, vaulted palate, with clearly defined rugae.

During the STTP, the subject was observed to have a large presentation of the bolus during the soft solid trial, and only protruded her tongue to meet the bolus presentation when using the straw with the water trials. She reported that her back teeth were apart in most of the trials, aside from the cup presentation of the water and the regular solid. Sucking in of the lips for closure was observed across food and liquid trials, except the regular solid Triscuit trial. During the Triscuit trial, throughout the EMG masseter contraction and swallow timing measures, the subject did present with significant lip pursing. The swallow was audible throughout all of the liquid and solids trials. The researcher only observed multiple swallows during the regular solid Triscuit trial.

Throughout the solid trials of the study, both the STTP and EMG measures, the subject was observed to clean out teeth and buccal cavities following each trial. The subject also reported to be a slow eater, which was evident throughout the study, though limited chewing was observed during the soft and regular solid trials.

Table 3.3 Indicators of OMD for Subject 1

OMD Indicators	Results
Fast/slow eater	Reported “slow” in comparison to people around her.
Noxious oral habits	Used pacifier as a baby, reported that she sucked her thumb until around the age of 3, and participated in cheek biting.
Open bite	Yes. Lateral to central incisors.
Malocclusion	Class II.
Difficulty gargling	Yes. Subject reported occasional coughing when gargling.
Palate	High, vaulted palate with defined rugae.
Lip rest posture	Lips closed. Though reported that lips are

	apart at night while breathing through the mouth.
Mouth breather	Occasionally during the day; definitely at night.
Tonsils	Removed between the ages of 2-3. Adenoids remain intact.
Speech	No audible frontal lisping or interdental productions of speech sounds noted.
Tongue protrusion	Observed tongue protruding to presentation only during the straw presentation.
Back teeth apart	Subject reported back teeth apart during the liquid presented with the straw, the puree, soft solid, and saliva trials.
Pursing lips	Noted across all trials, except the regular solid trial.
Chewing	Observed limited chewing during soft and regular solid trials.
Audible swallow	Yes. Observed during all of the swallow trials.
Multiple swallows	Yes. Observed multiple swallows during the regular solid trial.
Swallow timing	Initiation and depression of the swallow was delayed during the regular solid trial upon palpation of the larynx.
Head tilt back	Observed only when lip was pulled away during swallow trials to observe tongue protrusion.

Table 3.4 Instrumental and Observational Data for Subject 1. Normative Data based on Female Age Group 20-24.

	Normative Mean	**Std Dev**	**Observed Score**	**# of SD from the mean**	**SD above or below the mean**	**t-score**	**p-value**
iopitipavg	37.18	15.75	38.00	1	above	50.52	ns
iopidorsavg	33.75	10.60	42.33	1	above	58.09	$p < 0.05$
iopilipsavg	23.33	13.66	9.33	2	below	39.75	ns
mcbARMSav	152.86	107.29	22.38	2	below	*	*
mcbBRMSav	168.38	108.95	65.12	1	below	*	*
mcpud1ARMS	29.12	15.85	56.49	2	above	*	*
mcpud1BRMS	55.92	77.29	124.67	1	above	*	*
mcpud2ARMS	44.66	36.30	38.61	1	below	*	*
mcpud2BRMS	49.62	82.78	20.53	1	below	*	*
mc10ccARMS	22.44	8.73	118.24	2+	above	*	*

mc10ccBRMS	30.73	30.06	17.79	1	below	*	*
mccrackARMS	108.90	79.56	48.00	1	below	*	*
mccrackBRMS	151.99	140.59	71.32	1	below	*	*
stcpud1avg	1.39	0.48	1.28	1	below	47.71	ns
stcpud2avg	1.32	0.37	1.44	1	above	53.24	ns
stc10ccavg	1.03	0.20	1.43	2	above	70.00	p < 0.01
stccrackavg	1.20	0.28	3.15	2+	above	119.64	p < 0.01
tppud1	0.20	0.70	3	2+	above	*	*
tp10cc	1.00	1.30	3	2	above	*	*
Tpcrack	0.35	0.81	3	2+	above	*	*
Bolusres	1.27	0.55	3	2+	above	*	*
ope_p	0.20	0.41	1	2	above	*	*
ope_d	0.70	1.53	2	1	above	*	*
Cough	0	0	0	0	n/a	*	*
CB	0	0	0	0	n/a	*	*
FP	0	0	0	0	n/a	*	*
CTP	0.05	0.22	0	1	below	*	*
NT	0	0	0	0	n/a	*	*
OMP	0	0	0	0	n/a	*	*
TP	0	0	0	0	n/a	*	*

***** Unable to calculate t-score from normative data

Table 3.4 summarizes the objective data taken through the EMG and IOPI, as well as several measures analyzing the behavioral data observed by the researcher throughout the evaluation. IOPI results indicate tongue strength to be near or above the norm for the tongue tip and tongue dorsum, but lip strength to be two standard deviatons from the mean. However, the IOPI measures were not found to be statistically significant when compared to the normative data using t-scores. Scores for the EMG masseter contraction are broken up between a baseline measure of strength and the strength/use of the masseter while swallowing. Baselines were relatively decreased compared to the normative means. During swallow trials, the observed scores varied in their relation to the averages of the normative data. T-scores were not calculated for masseter contraction.

EMG data for the swallow timing demonstrated statistically significant scores for the water and Triscuit trials, indicating increased swallow time for those boluses.

During trials in which the researcher utilized the lip pull down method to assess the presence/absence of tongue protrusion, the subject's tongue was visible through the lateral open bite in all of the tongue protrusion trials, which far exceeds the averages seen in the normative data. It was also difficult for her to swallow without the use of her lips, as was demonstrated by her head tilting back to compensate for the removal of that labial seal. Following the EMG laryngeal elevation swallow trials, the subject was asked to open her mouth for the researcher to observe the level of residue. The amount of residue was relatively consistent following each trial, with some evidence of residue left on the tongue and surrounding the lower teeth, which was, again, significantly more than the averages of the norms. The subject did not demonstrate any of the behavioral characteristics listed in the protocol. The frequency of the tongue protrusions through the teeth, remaining residue, as well as other factors on the STTP indicate an OMD, resulting in an increased swallow timing, which may indicate current or future OPD.

Subject 2

Subject 2 was an 18-year-old female recruited through personal contact with the researcher. Participation included two sessions at the Idaho State University Speech, Language, and Hearing Clinic. The subject completed the medical history form and was assessed for and confirmed to have tongue thrust using the STTP. After confirming tongue thrust, masseter contraction and oropharyngeal swallow timing measures were assessed, using EMG instruments. Additionally, IOPI measurements for tongue tip, tongue dorsum, and lip strength were collected. Following the initial session and review of the EMG data, the cords connecting the EMG device to the electrodes proved to be faulty, resulting in inaccurate information. The subject agreed to return for reevaluation of the EMG data.

Table 3.5 summarizes the information received from the STTP, confirming the presence of a tongue thrust. As with Subject 1, this subject also reported several noxious oral habits as a young child, including: pacifier use and prolonged finger sucking until approximately 3 years of age, and cheek biting. Several allergies were listed, such as cats, horses, and seasonal allergies. She mentioned frequent sinus problems, particularly with allergies and especially when sick with the seasonal cold, reporting that the majority of symptoms were related to congestion of the nasal cavities. While the tonsils remain intact, she had undergone oral surgery for wisdom teeth removal and an additional surgery for abdominal hernia repair.

The subject reported one previous case of orthodontic treatment, lasting about 1 ½ years, taken off within the past few years. Upon examination of oral cavity, the researcher observed a normal occlusion, though there were areas of a very mild open bite on the lateral sides, as well as a high, vaulted palate with defined rugae. Habitual tongue rest posture reported to be pressed against the lower, anterior teeth. The subject also reported to have a consistent lip open rest posture. Upon further observation of lips, the subject appeared to have a short, everted upper lip with a prominent cupid's bow, suggesting chronic open mouth posture. The researcher also noted, and the subject reported, significant tension in the neck in all trials of solid and liquid food. Subject reported to be a slow, messy eater, requiring liquid to wash down food frequently. When asked to elevate the tongue tip within the oral cavity, the subject used the lower jaw to facilitate the movement, though she did not present with any signs of tongue-tie, or ankyloglossia. She reported difficulty gargling liquids, but did not give an explanation as to why.

Prior to the initiation of the STTP swallow trials, subject reported a history of heartburn. During the STTP, the subject was observed to meet the presentation with the tongue when using the straw with the water trials and with the puree given with a spoon. She reported that her back teeth were apart in all of the liquid and solid trials presented to her. Sucking in of the lips for closure was observed only during the regular solid Triscuit trial. In several trials with the pudding, the subject demonstrated slow depression of the larynx, observed by the researcher through palpation of the laryngeal area. The swallow was audible throughout all of the liquid and solids trials. The subject also reported to be a slow eater, though the researcher observed chewing and swallowing to be rushed with limited chewing during the Triscuit trials.

Table 3.5 Indicators of OMD for Subject 2

OMD Indicators	**Results**
Use liquid to wash food down/difficulty swallowing dry foods	Requires liquids to wash down food during meals/snacks due to difficulty with

	swallowing without liquid to wash down.
Fast/slow eater	Reports that eating is slow.
Messy eater	Yes. Reported needing few napkins each meal.
Noxious oral habits	Used a pacifier until 2-3; sucked thumb as a young child following pacifier use. Subject was unsure on the length of time thumb sucking was done.
Open bite	Yes. Mild lateral open bite.
Malocclusion	Class I malocclusion.
Orthodontic treatment	Received treatment once, lasting for 1 ½ years.
Tongue elevation	Used jaw to move the tip of the tongue to the incisive papilla area.
Tongue rest posture	Rests in the floor of the mouth with the tip resting against the lower, anterior teeth.
Palate	High, vaulted palate with defined rugae.
Difficulty gargling	Yes.
Lip rest posture	Subject reported closed lip rest posture, though open lip posture was observed occasionally throughout study.
Mouth breather	Yes.
Allergies	Reported seasonal allergies
Sinus and upper airway issues	Yes. Reported that upon getting sick, sinus congestion is always the main symptom.
Speech	No audible frontal lisping or interdental productions of speech sounds noted.
Tongue protrusion	Yes. Observed tongue protrusion with presentation of liquid through a straw, and the puree trials.
Chewing	Demonstrated limited chewing on regular solid trials.
Back teeth apart	Yes. Reported back teeth were apart during the swallow across food and liquid trials.
Pursing lips	Only observed during the regular solid trial.
Audible swallow	Yes. Observed during all swallow trials.
Swallow timing	Initiation of swallow was observed to be mildly slower during the regular solid and saliva trials upon palpation of the larynx.
History of GERD	Yes. Subject reported history of heartburn.

Table 3.6 Instrumental and Observational Data for Subject 2. Normative Data based on Female Age Group 15-19.

	Normative Mean	**Std Dev**	**Observed Score**	**# of SD from the mean**	**SD above or below the mean**	**t-score**	**p-value**
iopitipavg	45.04	12.23	31.00	2	below	38.52	ns
iopidorsavg	41.44	13.38	34.67	1	below	27.06	ns
iopilipsavg	33.09	14.21	6.33	2+	below	31.17	ns
mcbARMSav	115.38	98.87	125.15	1	above		
mcbBRMSav	107.31	96.34	95.21	1	below		
mcpud1ARMS	34.61	35.94	23.20	1	below		
mcpud1BRMS	40.80	47.78	21.21	1	below		
mcpud2ARMS	37.28	27.16	33.56	1	below		
mcpud2BRMS	65.93	80.42	27.84	1	below		
mc10ccARMS	112.75	307.34	15.56	1	below		
mc10ccBRMS	200.28	340.03	18.73	1	below		
mccrackARMS	108.13	117.34	80.09	1	below		
mccrackBRMS	128.76	171.57	57.76	1	below		
stcpud1avg	0.98	0.29	1.21	1	above	57.93	$p < 0.05$
stcpud2avg	0.98	0.39	1.22	1	above	56.15	$p < 0.05$
stc10ccavg	1.00	0.32	1.09	1	above	52.81	ns
stccrackavg	0.98	0.33	1.70	2+	above	71.82	$p < 0.01$
tppud1	0.83	0.92	3	2+	above		
tp10cc	1.22	1.06	3	2	above		
tpcrack	0.72	1.02	3	2+	above		
bolusres	2.24	1.12	3	1	above		
ope_p	0	0	1	2+	above		
ope_d	0.28	0.96	0	1	below		
cough	0.06	0.24	1	2+	above		
CB	0	0	0	0	n/a		
FP	0.06	0.24	0	1	below		
CTP	0	0	0	0	n/a		
NT	0	0	24	2+	above		
OMP	0	0	0	0	n/a		
TP	0.39	1.65	0	1	below		

***** Unable to calculate t-score from normative data

Table 3.6 summarizes the objective data taken through the EMG and IOPI, as well as several measures analyzing the behavioral data observed by the researcher throughout the evaluation. IOPI results did not prove to be statistically significant, though they did demonstrate a decrease in the strength of the tongue tip, tongue dorsum, and lips, though the baselines for EMG contraction varied in comparison to the averages of the norms, both left and right masseter contraction during swallow trials were decreased throughout consistencies. EMG data for the swallow timing indicated some variation, with the pudding trials and the Triscuit trials being statistically significant in their increased time compared to the norm. No significant differences were found in the water trial.

During trials in which the researcher utilized the lip pull down method to assess the presence/absence of tongue protrusion, the subject's tongue was visible through the lateral open bite in all of the tongue protrusion trials, which far exceeds the averages seen in the norms. Following the EMG laryngeal elevation swallow trials, the subject was asked to open her mouth for the researcher to observe the level of residue. The amount of residue was consistent following each trial, with some evidence of residue left on the tongue and surrounding the lower teeth, which did not appear to be much over the norms for this age group. The subject demonstrated consistent neck tension in all 24 trials of food and liquid for the EMG measures. In one instance, the subject did cough strongly following a water trial. The frequency of the tongue protrusions through the teeth, remaining residue, as well as other factors on the STTP indicate an OMD. The variation in swallow timing could also be a possible indication of OPD.

Subject 3

Subject 3 was a 27-year-old male recruited through another thesis being performed at Idaho State University. Data for the EMG and IOPI measures were received from the researcher, who precisely followed the same protocol as seen in this study. Participation included one-hour session at the Idaho State University Speech, Language, and Hearing Clinic. The subject completed the medical history and consent forms to participate in the study, followed by the completion of the STTP to confirm suspected tongue thrust. Following the STTP, the subject was finished with data collection due to the remaining EMG and IOPI measures being received from another researcher.

Table 3.7 summarizes the information received from the STTP, indicating that the tongue thrust is secondary to ankyloglossia, another oromyofunctional disorder. While there were not textures that he avoided due to difficulty chewing, the subject did mention many texture aversions, including: pudding, mayonnaise, cottage cheese, and cream cheese. Therefore, for this subject, pudding was replaced with applesauce, another puree texture. The subject did not report any presence of allergies, sinus conditions, noxious oral habits, or other structure altering problems.

The subject reported previous orthodontic treatment for a two-year period between the ages of 15-17. Occlusion of the teeth appeared to be normal, with only a mild open bite laterally on both sides. The palate appeared high and vaulted, with clearly defined rugae at the alveolar ridge. Lip structure was within normal limits; however, when asked to consecutively move between retracted and pursed lips, the subject revealed a large amount of neck tension. Habitual tongue rest posture reported to be pressed against the lower, anterior teeth, but with closed lip posture, which was consistent with the behavior seen during evaluation. Due to the ankyloglossia, or tongue-tie, the subject had difficulty with tongue tip elevation, using the lower jaw to compensate the movement. The lateral edges of the tongue also revealed reduced mobility, possibly an effect of the tongue-tie. Subject reported an extremely sensitive gag reflex, which is most evident with certain textures of food, and frequently when brushing his teeth. Because of the hypersensitivity of the gag reflex, the researcher was not able to view the tonsils.

Before the initiation of the swallow trials for the STTP, subject reported a history of heartburn, which can be typical of individuals with tongue-tie. Throughout the swallow trials, the tongue protruded to the presentation except with the water through a straw and the regular solid Triscuit trial. The subject reported to be a fast eater, and demonstrated limited chewing during the regular solid Triscuit trial. He reported that his back teeth were apart in most of the trials, aside from the regular solid. Sucking in of the lips for closure was observed across food and liquid trials, except the regular solid Triscuit and saliva trials. The swallow was audible only through the liquid trials. The researcher observed multiple swallows during the soft and regular solid trials.

Table 3.7 Indicators of OMD for Subject 3.

OMD Indicators	**Results**
Food avoidances	Puree foods with a thicker consistency: pudding, mayonnaise, cottage cheese, and cream cheese. Has gagging episodes upon these foods entering the oral cavity.
Noxious oral habits	Used a pacifier, though felt sure that it wasn't past the age of 2.
Open bite	Yes. Slightly lateral open bite noted bilaterally.
Malocclusion	Class I.
Orthodontic treatment	Braces for a two year period between the ages 15-17.
Tongue elevation	Yes. Relied on mandible to move the tongue upwards to the incisive papilla area.

Tongue weakness	Yes. Weakness noted in the lateral borders of the tongue.
Tongue rest posture	Tongue rests in the floor of the mouth with the tip of the tongue touching the lower front teeth.
Ankyloglossia	Yes. Has not undergone surgery to release the tongue-tie.
Palate	High and vaulted with defined rugae
Gag reflex	Hypersensitive.
Lip rest posture	Lips closed.
Lip coordination/movement	Demonstrated tension in neck during movement between retracted and protruded lip placements.
Mouth breather	No.
Tonsils	Still present; was not able to view them due to hyper active gag reflex.
Speech	No audible frontal lisping or interdental productions of speech sounds noted.
Tongue protrusion	Protruded to presentation of cup or spoon (not straw) to mouth in water, applesauce, and peach trials.
Back teeth apart	Yes. Subject reported back teeth were apart during all trials, except the regular solid trial.
Pursing lips	Observed during liquid, puree, and soft trials.
Chewing	Limited chewing was observed during regular solid trial.
Audible swallow	Yes. Only observed during the liquid trials.
Multiple swallows	Yes. Required multiple swallows following the soft and regular trials.
History of GERD	Reported a history of heartburn.

Table 3.8 Instrumental and Observational Data for Subject 3. Normative Data based on Male Age Group 25-29

	Normative Mean	**Std Dev**	**Observed Score**	**# of SD from the mean**	**SD above or below the mean**	**t-score**	**p-value**
iopitipavg	55.01	12.89	46.67	1	below	43.53	ns
iopidorsavg	50.54	12.00	48.67	1	below	48.44	ns

iopilipsavg	22.53	10.72	19.00	1	below	46.71	ns
mcbARMSav	317.62	120.10	84.94	2	below		
mcbBRMSav	523.11	415.93	174.09	1	below		
mcpud1ARMS	37.92	24.48	21.62	1	below		
mcpud1BRMS	68.79	71.43	61.05	1	below		
mcpud2ARMS	40.09	26.67	27.07	1	below		
mcpud2BRMS	90.82	123.48	24.29	1	below		
mc10ccARMS	20.87	14.72	67.82	2+	above		
mc10ccBRMS	51.27	57.96	56.94	1	above		
mccrackARMS	99.38	60.78	112.15	1	above		
mccrackBRMS	141.00	76.40	237.05	2	above		
stcpud1avg	1.13	0.54	1.71	2	above	60.74	$p < 0.01$
stcpud2avg	1.16	0.54	2.13	2	above	67.96	$p < 0.01$
stc10ccavg	0.86	0.33	1.90	2+	above	81.82	$p < 0.01$
stccrackavg	1.04	0.34	2.07	2+	above	80.29	$p < 0.01$
tppud1	0.33	0.87	3	2+	above		
tp10cc	0.96	1.12	1	1	above		
tpcrack	0.25	0.44	2	2+	above		
bolusres	1.33	0.66	2.33	2	above		
ope_p	0.29	0.46	1	2	above		
ope_d	0.83	1.31	1	1	above		
cough	0.08	0.28	0	1	below		
CB	0.00	0.00	0	0	n/a		
FP	0.04	0.20	0	1	below		
CTP	0.00	0.00	0	0	n/a		
NT	0.00	0.00	2	2+	above		
OMP	0.04	0.20	0	1	below		
TP	0.50	1.41	0	1	below		

***** Unable to calculate t-score from normative data

The above table details the differences in the subjective and objective findings to the normative data presented by Holzer (2011). Tongue tip strength, tongue dorsum strength, and lip strength all demonstrated a decrease as compared to the norms for males in the 25-29 year age group, though none were statistically significant. Baselines for masseter contraction, as well as scores during pudding swallow trials, indicated a decrease of masseter contraction, but scores for water and cracker trials demonstrated that this subject rose above the norm for those specific trials. In all cases of the EMG data for the swallow timing, subject 3 demonstrated longer transit times for all boluses, which proved to be statistically significant in comparison to the norms.

Following the assessment of the laryngeal elevation, the researcher asked the subject to prepare food and then allow the researcher to pull downward on the subject's lower lip. This was done to assess the presence/absence of tongue protrusion during varying food trials. Data was collected for applesauce and water trials, but was not initially completed for the Triscuit trial. This information was obtained later and added to the data. Tongue protrusion was evident all three trials of the applesauce and Triscuit, indicating a high prevalence as compared to the norm, but only once during the water trials, which was very close the norm.

The level of residue observed by the researcher varied through trials, though overall the amount of residue that remained following the swallow exceeded the average of the norms in the subject's age group. The subject did demonstrate some behavioral characteristics, though they were brief and inconsistent. In two cases, the researcher observed neck tension, particularly around the sternocleidomastoid. Due to the tongue-tie, tongue rest posture, and small, lateral space between the upper and lower teeth, the subject has strong evidence of an OMD. The consistency of the lengthened oropharyngeal transit times may be an indicator of current, or future, OPD.

Subject 4

Subject 4 was a 20-year-old female recruited through personal contact with the researcher. Participation included one two-hour session at the Idaho State University Speech, Language, and Hearing Clinic. Upon arriving at the clinic, the subject completed the medical history form, consent form, and was immediately assessed using the STTP for the presence of tongue thrust. Once tongue thrust was diagnosed and confirmed, the researcher obtained EMG and IOPI measures. EMG measures included masseter contraction and oropharyngeal swallow timing, while the IOPI measured tongue tip, tongue dorsum, and lip strength. All necessary information and data was collected in the aforementioned session.

Table 3.9 summarizes the information received from the STTP for Subject 4. Based on the STTP and other subjective observations, tongue thrust may be a result of the previously reported class II malocclusion (overbite) causing abnormal tongue rest posture. There was no evidence suggesting airway obstruction, such as allergies, reoccurring illnesses/medical conditions, or noxious oral habits that persisted past the age of 2. The subject did report a mild head injury sustained several years ago resulting in a concussion, though she never lost consciousness. She reports that she is a fast eater and frequently requires liquid to wash food down, suggesting that it is sometimes difficult to swallow dry foods without the assistance of liquid.

The subject has received previous orthodontic treatment, several years ago, for a period of three years. Upon examination of oral cavity, the researcher observed the subject to have a class III malocclusion (underbite), which may be the result of the orthodontic work to remedy the class II malocclusion. While the underbite is not significant, or even crossing the lower teeth, the molar relationship suggests the upper jaw is further posterior than typically desired. This results in the upper and lower anterior teeth being directly in line with one another. Several teeth were missing aside from the 3rd molars, including two teeth from the upper jaw and two teeth from the lower jaw. Habitual tongue rest posture reported to be pressed against the lower, anterior teeth. Tongue strength also appeared to be mildly decreased in the lateral borders. The subject reported to have an open lip rest posture during the day, and especially at night while sleeping, resulting in oral/mouth breathing. The palate was observed to be high and vaulted, with easily definable rugae on the anterior portion of the gum.

Presentation of the bolus by the researcher resulted in the tongue meeting the bolus only during the puree trial. She reported that her back teeth were apart in most of the trials, aside from the regular solid trial. The subject sucked in the lips against the teeth only once during the puree trial; however, upon review of the video, the subject was seen during the STTP and EMG swallow trials to demonstrate a large amount of lip tension for all bolus types. Several times, including the liquid trials and the saliva trial, the swallow the audible to the researcher. Multiple swallows were necessary for the subject following the presentation of the puree and regular solid trials. Throughout the solid trials of the study, both the STTP and EMG measures, the subject was observed to clean out teeth and buccal cavities with her tongue on occasion. The subject also reported to be a fast eater, and was observed to chew for a smaller amount of time than what is typical during the soft and regular solid trials.

Table 3.9 Indicators of OMD for Subject 4.

OMD Indicators	Results
Use liquid to wash food down/difficulty swallowing dry foods	Yes. Finds it difficult to swallow dry food without liquid; uses liquid frequently

	during meals/snacks.
Fast/slow eater	Reports that subject is a fast eater, often taking large bites.
Noxious oral habits	Yes. Reported that a pacifier was used and was a thumb sucker, though the subject was unsure on the length of time for either of those habits.
Open bite	Yes. Very mild lateral open bite, more prominent on the left side.
Malocclusion	Class III. Upper and lower dentition are directly on top of each other.
Missing teeth	Yes. Aside from all four third molars missing, subject reported that four others had been previously pulled.
Orthodontic treatment	Yes. Reported braces one time for a total of three years in high school ages 14-17.
Tongue weakness	Yes. Observed weakness of the lateral borders of the tongue.
Tongue rest posture	Reported that tongue rests in the floor of the mouth, with the tip touching the anterior lower teeth.
Palate	High, vaulted palate with defined rugae.
Gag reflex	Hypersensitive.
Lip rest posture	Lips apart. Both reported and observed.
Mouth breather	Yes. Though she is able to breath through her mouth.
Tonsils	Tonsils have not been removed, though was not able to view them due to hyperactive gag reflex.
Speech	No audible frontal lisping or interdental productions of speech sounds noted.
Tongue protrusion	Tongue was noted to protrude only during the puree trial when fed by the researcher with a spoon.
Back teeth apart	Yes. Reported back teeth were apart during the swallow across food and liquid trials, except for the regular solid trial.
Chewing	Limited chewing was observed with the soft and regular solid swallow trials.
Pursing lips	Yes. Tension in lips was observed during all trials aside from the liquid trials.
Audible swallow	Yes. Swallow was audible in liquid and saliva trials.
Multiple swallows	Yes. Subject was observed to take multiple swallows during puree and regular solid trials.

The following table, Table 3.10, summarizes in detail the measures taken both subjectively and objectively, using the EMG and IOPI for subject 4. The IOPI was the first measure taken, measuring the strength of the tongue tip, tongue dorsum, and lips, which resulted in very high numbers for the tongue tip and tongue dorsum strength as compared to the norms. The lip strength did not follow that pattern, and was decreased in comparison to the norms for this subject's age group. Lip strength was not significant, but tongue tip and tongue dorsum scores proved to be statistically significant, although it was due to the numbers being so much higher than the norms rather than demonstrating a decrease as expected. Masseter contraction was consistently less for the baseline and each of the trials than the scores observed in the normative data. This suggests decreased strength of the masseter in comparison to the norms, and decreased use of the masseter while swallowing, regardless of the consistency of the food. Lastly, the data provided by the EMG for the timing of the swallow demonstrated a statistically significant increase in the swallow times for all of the swallow trials aside from the ½ teaspoon of pudding.

Table 3.10 Instrumental and Observational Data for Subject 4. Normative Data based on Female Age Group 20-24

	Normative Mean	**Std Dev**	**Observed Score**	**# of SD from the mean**	**SD above or below the mean**	**t-score**	**p-value**
iopitipavg	37.18	15.75	73.00	2+	above	72.74	$p < 0.01$
iopidorsavg	33.75	10.60	50.67	2	above	65.96	$p < 0.01$
iopilipsavg	23.33	13.66	14.33	1	below	43.41	ns
mcbARMSav	152.86	107.29	138.10	1	below		
mcbBRMSav	168.38	108.95	129.50	1	below		
mcpud1ARMS	29.12	15.85	14.48	1	below		
mcpud1BRMS	55.92	77.29	22.61	1	below		

mcpud2ARMS	44.66	36.30	24.54	1	below		
mcpud2BRMS	49.62	82.78	42.84	1	below		
mc10ccARMS	22.44	8.73	10.30	2	below		
mc10ccBRMS	30.73	30.06	15.55	1	below		
mccrackARMS	108.90	79.56	70.26	1	below		
mccrackBRMS	151.99	140.59	56.43	1	below		
stcpud1avg	1.39	0.48	1.61	1	above	54.58	ns
stcpud2avg	1.32	0.37	1.81	2	above	63.24	p < 0.01
stc10ccavg	1.03	0.20	1.35	2	above	66.00	p < 0.01
stccrackavg	1.20	0.28	1.83	2+	above	72.50	p < 0.01
tppud1	0.20	0.70	3	2+	above		
tp10cc	1.00	1.30	3	2	above		
tpcrack	0.35	0.81	3	2+	above		
bolusres	1.27	0.55	3.67	2+	above		
ope_p	0.20	0.41	1	2	above		
ope_d	0.70	1.53	3	2	above		
cough	0	0	6	2+	above		
CB	0	0	0	0	n/a		
FP	0	0	0	0	n/a		
CTP	0.05	0.22	0	1	below		
NT	0	0	0	0	n/a		
OMP	0	0	0	0	n/a		
TP	0	0	0	0	n/a		

***** Unable to calculate t-score from normative data

As with previous subjects, the lip pull down method was used to assess the frequency of tongue protrusion through the teeth during three swallows per bolus type. In each trial for all of the food consistencies, the subject's tongue was mildly visible only through the left lateral opening of the teeth, particularly around the area of the lateral incisors. Residue was assessed during the masseter contraction portion of the evaluation. Following each swallow of a Triscuit trial, the subject would open her mouth for the researcher to assess the amount of remaining residue in her mouth. The amount of residue exceeded the amount presented in the normative data. The researcher noted on several occasions throughout the EMG swallow trials that the laryngeal movement was minimal, to the point where palpation was difficult. Based on the reduced laryngeal activity, remaining residue, tongue protrusion, and weakened lips and masseter, the subject demonstrates compensatory strategies for the swallow, which may result in symptoms similar to OPD.

Subject 5

Subject 5 was an 18-year-old female, recruited through the poster that was hung in a public building on campus. Participation included one two-hour session at the Idaho State University Speech, Language, and Hearing Clinic. Upon arriving at the clinic, the medical history form and consent form were completed, and the subject was assessed using the STTP for tongue thrust. She had previously been in therapy for tongue thrust, as well as a frontal lisp, and did not find success in the therapy, as was demonstrated in the persistent presence of the tongue thrust. Following the STTP, the IOPI and EMG instruments were used to assess the function of the following structure: masseter contraction, oropharyngeal transit time, tongue tip strength, tongue dorsum strength, and lip strength. All data was completed at the finish of the evaluation.

Indicators for tongue thrust are represented in Table 3.11, which summarizes the information received from the STTP. Based on these findings, Subject 5 was confirmed to have a prominent tongue thrust. Due to the 5 mm space between the upper and lower anterior teeth, the thrust was relatively easy to identify. The subject reported cheek biting as the only noxious oral habit that may have been present, though it was not mentioned whether this was a previous or current habit. Seasonal allergies were reported to be present and impacting the ability to breath through the nose with relatively consistent congestion. Subject reported the removal of her wisdom teeth within the last two years. Liquid is used to wash food down, such as at mealtime, but liquid is not required to have a successful swallow when dealing with drier foods.

Orthodontic treatment has been completed, within the last two years, for a 20-month period. Upon examination of oral cavity, several observations were made by the researcher: normal (molar) occlusion with a significant open bite, short upper lip, upper teeth tipped labially, flat cupid's bow, and tension in the lateral areas of the lips during a swallow. Habitual tongue rest posture reported to be pressed against the upper, anterior teeth, particularly resting on the upper arch permanent retainer. The palate was high and vaulted with clearly defined rugae. The subject reported to have open mouth rest posture, though the researcher observed moments of closed lip/mouth rest posture during the evaluation as well. When the lips are closed, the face appears long and mildly flaccid in the cheek area, directly next to the lips and nose. There was also tension visible in the orbicularis oris and mentalis muscles during swallowing and any activity in which the lips made contact. When asked about mouth breathing, subject denied breathing through the mouth and instead reported that she typically breathed through the nose; however, the researcher observed both modes of breathing throughout the evaluation.

During the STTP, the subject was observed to have a large presentation of the bolus during the cup presentation of liquid, as well as the puree and soft solid trials. Trials of liquid reported to be lateralized in the oral cavity. Upon drinking from the cup, there were two instances in which there was anterior leakage from the right side of the mouth. She reported that her back teeth were apart during the straw presentation of the liquid, as well as the soft solid trial. However, the subject's responses were variable concerning the separation of the back teeth as multiple trials of each of the consistencies were presented. During the regular solid trial, a rotational style of chewing was not utilized; it was similar to munching, but with the use of the back molars. The swallow was audible in all trials except the soft and regular solid consistencies. The researcher observed multiple swallows for all of the solid consistency trials, including the puree, soft, and regular solid.

Throughout the solid trials of the study, both the STTP and EMG measures, the subject was observed to clean out teeth and buccal cavities following each trial, with clear evidence of residue through consistent use of lip licking while chewing and after a swallow. The subject also reported to be a fast eater, demonstrating limited chewing for the soft and regular solid trials.

Table 3.11 Indicators of OMD for Subject 5.

OMD Indicators	Results
Use liquid to wash food down/difficult to swallow dry foods without liquid	Yes. Reported that liquid is frequently used to wash food down, but not that it is difficult without liquids when eating dry foods.
Fast/slow eater	Subject reports she is a fast eater.
Noxious oral habits	Reported that neither a pacifier was used nor thumb sucking utilized.
Open bite	Yes. Central with lips tipped labially, with approximately 5 mm between the upper and lower central incisors.
Malocclusion	Class I. Molars typical; central and lateral incisors labially tipped.
Orthodontic treatment	Yes. Received braces one time for approximately 20 months.
Tongue rest posture	Reports that tip of tongue rests on upper teeth, about where her permanent retainer is.
Palate	High, vaulted palate with defined rugae.
Gag reflex	Hypersensitive.
Lip rest posture	Subject reported lips apart. Though lips were observed both open and closed at rest throughout time together.
Mouth breather	Subject reported that she was not a mouth breather; however, mouth breathing was occasionally observed.
Allergies	Allergies include hay, dust, and other unknown environmental allergens. Experiences allergy attacks.
Sinus and upper airway issues	Can breath through nose, though she is frequently congested from seasonal

	allergies.
Speech	A frontal lisp was observed throughout speech. Subject has previously been in speech therapy for the frontal lisp and tongue thrust for a little over a year, though the tongue thrust is still present.
Large presentation	Yes. Observed large bite/stuffing of all trials aside from the regular solid.
Back teeth apart	Yes. Reported during liquid trial with straw presentation and the soft solid. The remaining trials were with the back teeth together.
Lateralization of bolus	Yes. Reported during liquid trials.
Chewing	Observed during soft and regular solid trials.
Audible swallow	Yes. Observed liquid, puree, and saliva trials.
Multiple swallows	Yes. Observed during puree, soft, and regular solid trials.
Head tilt back	Observed only when researcher pulled back lower lip to look for tongue protrusion. Could not swallow without tilting head back.

Table 3.12 Instrumental and Observational Data for Subject 5. Normative Data based on Female Age Group 15-19

	Normative Mean	**Std Dev**	**Observed Score**	**# of SD from the mean**	**SD above or below the mean**	**t-score**	**p-value**
iopitipavg	45.04	12.23	28.67	2	below	36.61	ns
iopidorsavg	41.44	13.38	30.00	1	below	41.45	ns
iopilipsavg	33.09	14.21	8.33	2	below	32.58	ns
mcbARMSav	115.38	98.87	125.30	1	above		
mcbBRMSav	107.31	96.34	168.79	1	above		
mcpud1ARMS	34.61	35.94	43.10	1	above		
mcpud1BRMS	40.80	47.78	40.10	1	below		
mcpud2ARMS	37.28	27.16	34.00	1	below		
mcpud2BRMS	65.93	80.42	43.19	1	below		
mc10ccARMS	112.75	307.34	20.24	1	below		
mc10ccBRMS	200.28	340.03	19.33	1	below		
mccrackARMS	108.13	117.34	58.80	1	below		
mccrackBRMS	128.76	171.57	76.33	1	below		
stcpud1avg	0.98	0.29	1.53	2	above	68.97	p < 0.01

stcpud2avg	0.98	0.39	1.31	1	above	58.46	p < 0.05
stc10ccavg	1.00	0.32	1.24	1	above	57.50	p < 0.05
stccrackavg	0.98	0.33	1.72	2+	above	72.42	p < 0.01
tppud1	0.83	0.92	0	1	below		
tp10cc	1.22	1.06	1	1	below		
tpcrack	0.72	1.02	3	2+	above		
bolusres	2.24	1.12	3.67	2	above		
ope_p	0	0	1	2+	above		
ope_d	0.28	0.96	4	2+	above		
cough	0.06	0.24	0	1	below		
CB	0	0	0	0	n/a		
FP	0.06	0.24	24	2+	above		
CTP	0	0	0	0	n/a		
NT	0	0	23	2+	above		
OMP	0	0	0	0	n/a		
TP	0.39	1.65	0	1	below		

***** Unable to calculate t-score from normative data

Table 3.12 summarizes the objective data taken through the EMG and IOPI, as well as the behavioral measures as reported by researcher. The IOPI measures demonstrated weakness in the strength of the tongue tip, tongue dorsum, and lips, all of which were decreased, as compared to the normative means for those measures. However, the IOPI measures were not statistically significant, as seen in Table 3.12. Baseline data for this subject was calculated by averaging two trials: the second and third trial. This was due to invalid data from an inaccurate reading by the EMG for the first trial. Scores for the EMG masseter contraction began with high scores, starting with the baselines, and decreased further from the norms as the trials continued, starting with the 1 ½ teaspoon trials. This demonstrates that masseter contraction and use was limited and would tire as demand increases. This was evident throughout the evaluation, as the effort to swallow each bolus became more of a struggle. In almost all of the trials, including both masseter contraction and laryngeal elevation, the subject demonstrated a forward and upward movement of the head to facilitate each swallow. Swallow timing indicated an increase for each of the bolus types, which was statistically significant in comparison to the normative data.

During trials in which the researcher utilized the lip pull down method to assess the presence/absence of tongue protrusion, the subject's tongue was visible through the central open bite, but only with certain consistencies. For example, with the pudding and water trials, the consistency was too thin, so the subject compensated by leaning her head back, which allowed gravity and a downward movement of the tongue to move the bolus towards the back of the oral cavity. Without that compensation, the bolus would leak out through the anterior open bite. The obvious protrusion was only seen during the Triscuit trials when the consistency was thicker and not as easy to lose control of the bolus. Residue following the Triscuit trials far exceeded the norms for her age group, indicating that the tongue is not properly clearing the oral cavity. The subject demonstrated the aforementioned forward posture and neck tension with almost all of the swallow trials, which surpassed the norms for such behavioral observations. Several factors indicate the presence of an OMD. The OMD is affecting the efficiency of the swallow, and causing her to present with significant deficits that could later demonstrate as OPD.

Group Results

Following the individual examination of each subject's data, the data were combined in the following charts to determine if there were overall trends in comparison to the normative data, as mentioned in Holzer (2011). Aside from one subject during the ½ teaspoon of pudding in which the trial score was less than the normative score, there was a consistent trend of increased oral pharyngeal transit times for these individuals with tongue thrust. Graphs were created for each bolus type: ½ teaspoon, 1 ½ teaspoon, 10 cc water, and a Triscuit cracker. Each compares the observed oral pharyngeal transit time of each subject to the oral pharyngeal transit times listed in the norms by age group. Participants are listed by age, ranging from youngest to oldest, and represented on the x-axis. The length of the transit time is represented on the y-axis.

Figure 3.1 Oropharyngeal Transit Time – ½ teaspoon of pudding

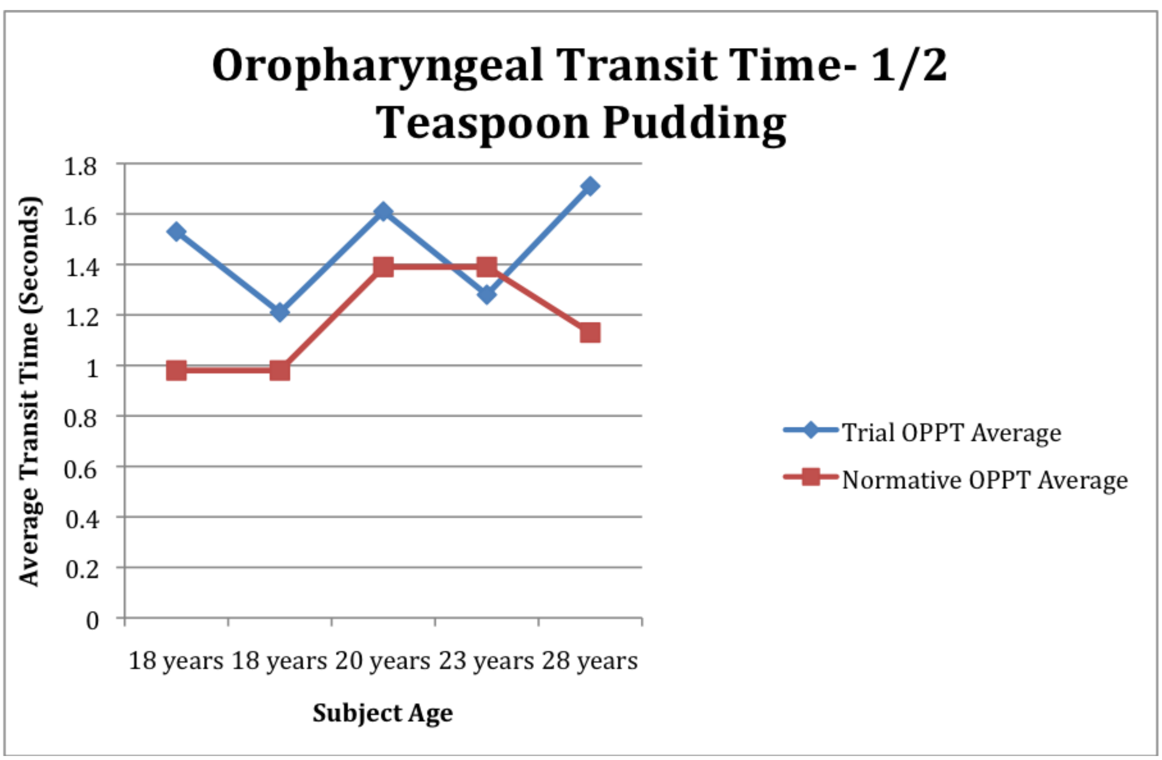


Figure 3.2 Oropharyngeal Transit Time – 1 ½ teaspoon of pudding

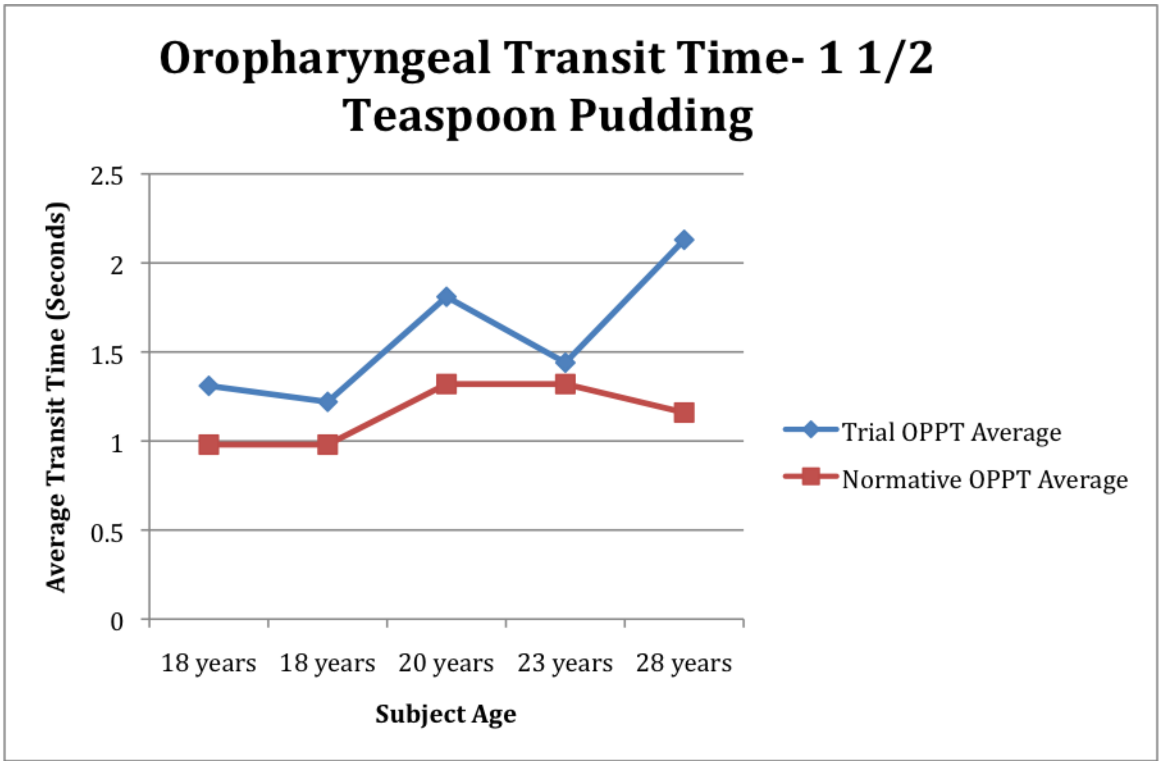


Figure 3.3 Oropharyngeal Transit Time – 10 cc water

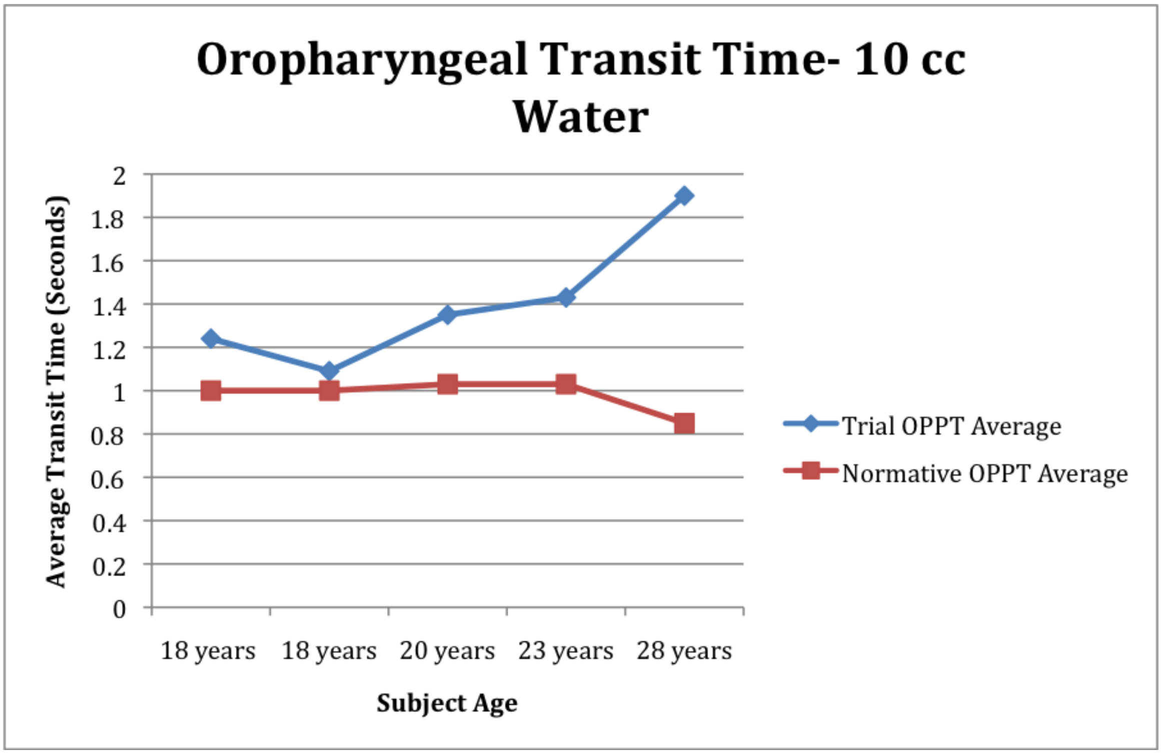
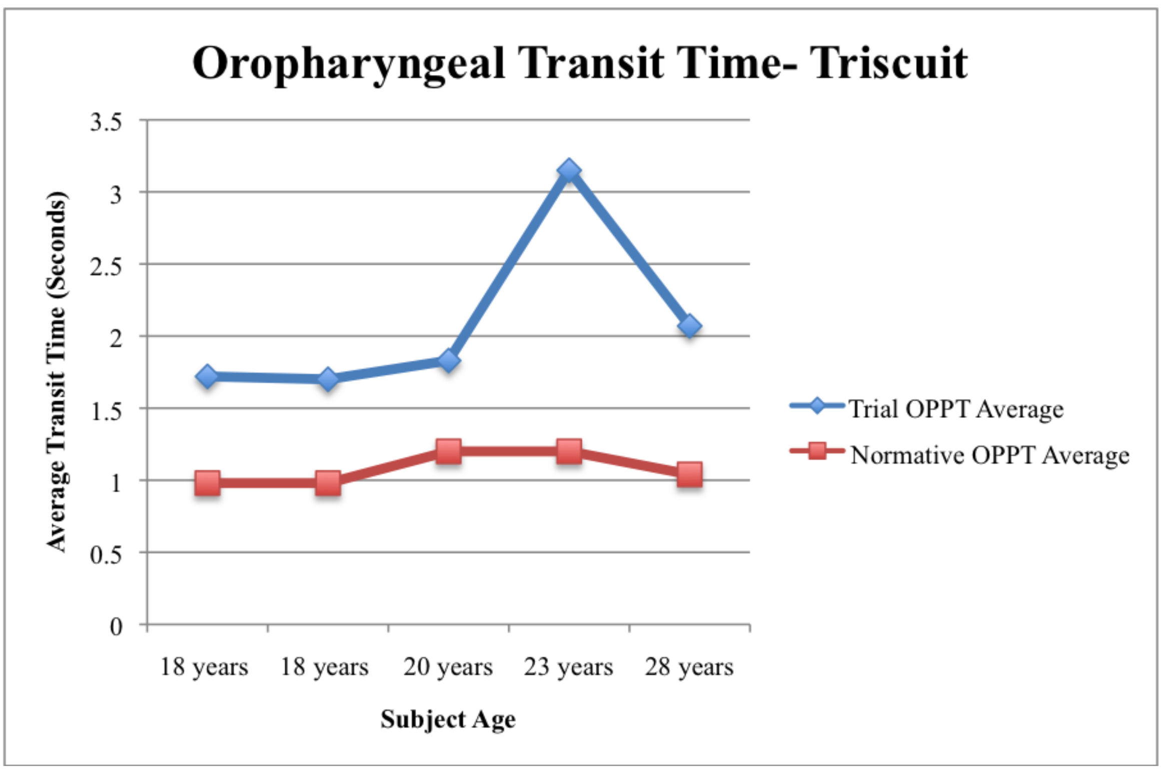


Figure 3.4 Oropharyngeal Transit Time – Triscuit



Reliability

Inter-judge reliability: inter-judge reliability was ensured through the use of consensus coding. The researcher, and a colleague trained in the tests, examined all subjects' oropharyngeal transit time data, including all EMG oropharyngeal transit time graphs, together. Both researchers came to a consensus for each trial of oropharyngeal transit time.

Intra-judge reliability: to safeguard intra-judge reliability the researcher re-measured all EMG oropharyngeal transit time graphs for 20% of trials.

Summary

All of the raw scores from the data were grouped together by consistency and averaged to get a single number. For EMG oral pharyngeal transit times and IOPI measures, these averages were then compared to the normative data from Holzer (2011) and converted into t-scores and p-values to determine statistical significance. If the p-value was 0.05 or smaller when compared to the norms, the data was considered statistically significant. Regardless of t-score and p-value, all observed scores were compared to the means from the normative data and was marked to be within one or two standard deviations from the mean. This particularly beneficial for masseter contraction scores where inferential statistics were not available. These results are represented in Table 3.13.

Inferential statistics were only calculated for IOPI measures and EMG oral pharyngeal transit times. These statistics demonstrated significance for oral pharyngeal transit times across subjects and bolus types. These bolus types included: ½ teaspoon pudding, 1 ½ teaspoon pudding, 1 cc water, and subject determined bite of Triscuit cracker. Although statistics were not calculated for the subjective behaviors, results from the data demonstrate that the occurrence for several of the behaviors were largely increased in comparison to the normative data found in Holzer (2011). These subjective behaviors included: tongue protrusion, bolus cohesion, bolus residue, coughing, clavicular breathing, forward posture, chin tuck position, neck tension, and open mouth posture, and were observed during: ½ teaspoon pudding, 1 ½ teaspoon pudding, 10 cc water, and subject determined bite of Triscuit cracker.

Table 3.13. Number of subjects deviating from the norm, by degree of deviation.

# of Standard Deviations from the Norm, separated by measurement and participant					
	1	**2**	**3**	**4**	**5**
iopitipavg	1 above	2 below	1 below	2+ above	2 below
iopidorsavg	1 above	1 below	1 below	2 above	1 below
iopilipsavg	2 below	2 below	1 below	1 below	2 below
mcbARMSav	2 below	1 above	2 below	1 below	1 above
mcbBRMSav	1 below	1 below	1 below	1 below	1 above
mcpud1ARMS	2 above	1 below	1 below	1 below	1 above
mcpud1BRMS	1 above	1 below	1 below	1 below	1 below
mcpud2ARMS	1 below	1 below	1 below	1 below	1 below
mcpud2BRMS	1 below	1 below	1 below	1 below	1 below
mc10ccARMS	2+ above	1 below	2+ above	2 below	1 below
mc10ccBRMS	1 below	1 below	1 above	1 below	1 below
mccrackARMS	1 below	1 below	1 above	1 below	1 below
mccrackBRMS	1 below	1 below	2 above	1 below	1 below
stcpud1avg	1 below	1 above	2 above	1 above	2 above
stcpud2avg	1 above	1 above	2 above	2 above	1 above
stc10ccavg	2 above	1 above	2+ above	2 above	1 above
stccrackavg	2+ above	2+ above	2+ above	2+ above	2+ above
tppud1	2+ above	2+ above	2+ above	2+ above	1 below
tp10cc	2 above	2 above	1 above	2 above	1 below
tpcrack	2+ above	2+ above	2+ above	2+ above	2+ above
bolusres	2+ above	1 above	2 above	2+ above	2 above
ope_p	2 above	2+ above	2 above	2 above	2+ above
ope_d	1 above	1 below	1 above	2 above	2+ above

cough	0 n/a	2+ above	1 below	2+ above	1 below
CB	0 n/a	0 n/a	0 n/a	0 n/a	0 n/a
FP	0 n/a	1 below	1 below	0 n/a	2+ above
CTP	1 below	0 n/a	0 n/a	1 below	0 n/a
NT	0 n/a	2+ above	2+ above	0 n/a	2+ above
OMP	0 n/a	0 n/a	1 below	0 n/a	0 n/a
TP	0 n/a	1 below	1 below	0 n/a	1 below

Chapter 4: Discussion

The purpose of this study was to collect data on various OPD measures to determine if there are diagnostic indicators of OPD in individuals with tongue thrust. This study included five subjects, one male and four females, all ranging in age from 18-27. Tongue thrust is found to be opportunistic and demonstrates itself secondary to other behavioral and clinical indicators of OMD. This was consistent with all of the subjects presented in this study; all of the subjects had tongue thrust secondary to other factors of OMD. OPD measurements that were observed were tongue tip strength, tongue dorsum strength, lip strength, masseter contraction, and oropharyngeal transit time, as measured using the IOPI and EMG. Behavioral data was also observed and measured through clinical observations made by the researcher. Raw data of the previously mentioned measurements were compared to the normative data of individuals without tongue thrust to assess for significant differences between individuals with tongue thrust and individuals without tongue thrust. 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 has been found to be limited in individuals with tongue thrust, which is a reason why masseter function was included as a measurement in this study. Masseter contraction was measured using the EMG at baseline and during swallow trials of the following boluses: ½ tsp pudding, 1 ½ tsp pudding, 10 cc water, and Triscuit cracker. Upon palpation of one subject's masseter for electrode placement, the researcher noted that the subject had difficulty maintaining closure of back molars, and therefore maintaining masseter contraction for baseline. Results from the masseter contraction demonstrated inconsistency throughout subjects and bolus types. While inferential statistics were not calculated at this time, the observed scores demonstrated such fluctuation in results that no direct correlation could be assumed.

Based on these findings, the null hypothesis is accepted. In comparing the raw data to the normative data, there were not consistent differences between the two groups.

However, while there were mild variations, the overall measurements did demonstrate an overall decrease in the contraction of the masseter among the subjects with tongue thrust. This continues to support the existing knowledge that masseter contraction is affected in individuals with tongue thrust. As seen in the charts represented the normative and raw data under each subject in chapter 3, many of the standard deviations for the masseter contraction measurements were exceptionally high, resulting in little opportunity for significant differences to be made. However, this may be due to the measurements being based upon EMG amplitudes, which can be affected by electrode impedance in the normative data (Holzer, 2011) and in the current study.

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?*

As with masseter contraction, a decrease in tongue tip strength, tongue dorsum strength, and lip strength are indicators for OMD, due to their high level of involvement in a typical swallow. Such variables were measured in the present study with the IOPI. Results from the study revealed differences 1-2 standard deviations or greater for tongue tip strength and lip strength for two subjects. However, one of the subjects scores for the tongue tip and tongue dorsum strength were two or more standard deviations above the mean, rather than below the mean as expected. The remaining of the scores taken with the IOPI for the rest of the subjects revealed lower scores in all areas. Of the three variables assessed via the IOPI, lip strength was most consistent in being negatively affected, demonstrated by a decreased score for all of the subjects in comparison to the normative data. However, observed scores were converted into t-scores and p-values, which revealed that although the observed scores were decreased in comparison to the norms, they were not statistically significant. Based on these findings, the null hypothesis is accepted.

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 most closely associated with indicators for OPD. As seen in the graphs presented in Figure 3.1-3.4, all of the oral pharyngeal transit times recorded for this study were longer than the normative data. The only exception is Subject 1 with the ½ teaspoon of pudding. Overall, significant differences were found for oral pharyngeal transit time across bolus types and across subjects. Of the twenty scores reported, only four of those were found to not be significant. Of those four that were not statistically significant, three of those scores still demonstrated in increase in time in comparison to the normative data. Based on these findings, the null hypothesis is rejected.

As mentioned in the chapter 3 results, several subjects were noted to need multiple swallows, though the space in between the initial swallow and the secondary swallow was large enough that the data was not affected. Extraneous movements, such as pumping or false starts, were also frequently observed when attempting to palpate for the initiation of the swallow. Best clinical judgment was used by the researcher to indicate in the onset and offset of each swallow upon palpation, which was marked by event markers on the EMG graphs, indicating the "true swallow."

"Pre-swallow activity" was also observed on the EMG graphs upon review of the data. The researcher did not include this activity in the oral pharyngeal transit times due to the activity returning near baseline before the initiation of the swallow. This varies from previous studies performed by Evans (2015) who included the pre-swallow activity. The initiation of the swallow in the subjects presented in this current study was typically simple to mark, typically beginning ½ of a second before the event marker for the initiation of the swallow was made.

Additional Findings

For one of the subjects, subject 5, there appeared to be a familial connection. The subject reported one other sibling in her family that demonstrated symptoms of tongue thrust similar to her, including altered speech. The question could be raised as to whether tongue thrust is hereditary. However, upon further research into OMDs, changes in structure and function as seen in a tongue thrust are not directly hereditary. Rather, parent-to-child, or siblings, are exposed to similar lifestyles, allergens, and environments that may affect the airway or immune system, which then affects breathing, rest posture of the tongue and lips, and the rest of the structure and function of the oral cavity. The only OMD that has been directly related to genetics is ankyloglossia, or tongue-tie, which can also be a contributor to tongue thrust.

Another trend that the researcher noticed was the lack of self-awareness of their tongue thrust. Prior to evaluation with the researcher, four out of the five subjects were unaware of their tongue thrust and all five of the subjects were unaware of the implications of a tongue thrust. This may be due to their young age and not yet having had any awareness of difficulties.

Clinical Applications

The field of oromyofunctional disorders was a larger field in the past before several cases of malpractice were recognized, at which time the field seemed to die off.

However, in recent years, the need for oromyofunctional therapy is beginning to grow once again, though still not widely. Particularly in the field of speech-language pathology, there has not been much attention given to the environment of the oral cavity. However, as seen in many of the subjects involved in this study, there are many consequences related to OMDs. These include, but are not limited to: improper dental development and growth, misarticulation of speech sounds, negative impacts on facial structure, and negative impacts on management of salivary secretions (American Speech-Language-Hearing Association, n.d.; Hanson & Mason 2003). OPD, as well, can have life-altering consequences and may lead to several risk factors, such as aspiration pneumonia, lack of proper nutritional intake, or dehydration, all of which are potentially life threatening (Logemann, 1998). The structural and functional differences demonstrated in individuals with OMD, may also be a causal factor for difficulties in OPD, particularly in the increased oropharyngeal transit times. This is supported based on the results from the current study, as well as the previous findings of Evans (2015) and Evers (2013). These findings suggest that the impact of OMDs, specifically tongue thrust, is larger than commonly recognized by professionals, particularly on the function of the swallow.

If there is in fact a link between tongue thrust and OPD, identification and treatment of underlying causes of tongue thrust are warranted. Professionals of late have viewed tongue thrust, and other OMDs, as cosmetic, rather than a disorder with multiple domino effects surrounding more than just cosmetics. Education of professionals, such as dentists, orthodontists, dental hygienists, pediatricians, and general physicians, is necessary for recognition of the severity and potential harmful implications for tongue thrust if left untreated. It is the hope of the researcher that more speech-language pathologists, and other previously mentioned related professionals, will seek knowledge on the negative impacts of tongue thrust, and therefore increase screenings in clients for differences on structure and function of the oral cavity, particularly tongue thrust, and encourage referrals and interdisciplinary work for the benefit to the individuals struggling with tongue thrust.

Limitations

Potentially the biggest limitation to the present study is that it does not address the underlying cause of each subject's tongue thrust. Tongue thrust has been found to be opportunistic, or to fill in and compensate for errors in the oral cavity for appropriate speech and swallowing. Therefore, if the cause of the tongue thrust was identified and remedied, would the tongue thrust persist or decline from removing the source? Future studies could evaluate the swallow function following intervention to remove the underlying cause of tongue thrust to assess if the tongue thrust was still present.

Another limitation to the study found by the researcher was the limited variation in age and gender. 80% of the subjects were female, with only one male. All of the subjects were within a ten-year gap, giving limited information on how the swallow might change as age increases. The group of five subjects also lacked ethnic background diversity. A larger, more diverse in age, gender, and ethnic background, would be recommended for future studies.

Although the data from the present study support and add new evidence to previous findings of Evers (2013) and Evans (2015), the sample size of five participants is a limitation. Four 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. In continuing research done on the current research question, "*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,"* including individuals across a wider variety of ages and ethnic backgrounds, relevant findings could then be applied to the general population rather than smaller subgroups of the general population.

Implications for Future Research

OMD and OPD have previously been seen as two separate disorders, and therefore are treated separately and use different methods. However, data from previous studies, as well as the current study, recognize that there are similarities in the signs and symptoms of OMD and OPD. The data obtained supports the notion that individuals with tongue thrust differ from the norms in oral pharyngeal transit times, as seen in individuals with OPD. Although these findings support previous findings (Evans, 2015; Evers, 2013), there has been little other research to further demonstrate the relationship of OPD and OMD. Therefore, further research is warranted to determine if a relationship does in fact exist between tongue thrust and OPD.

As mentioned previously, furthered research examining this same research questions should focus on including a larger variety of subjects, ranging more widely in amount of participants, as well as age, gender, and ethnic background, particularly those that have not yet been explored in previous studies. In addition to expanding the subject pool, looking at a holistic picture of tongue thrust, beginning with identifying the cause, assessing measures of strength and transit time, treating the causal factor of tongue thrust, and then following through in later months with re-evaluating the same measures to assess an increase or decrease in function, would further the understanding of tongue thrust and it's relationship to the swallow function.

Conclusions

The present study investigated the question of: "*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?"* to further understand the hypothesized relationship between tongue thrust and OPD. Participants included four females and one male, with a total of five participants, ranging from 18-27 years of age. All participants were identified with the STTP as having tongue thrust. The following measures were gathered using EMG, IOPI, and clinical observations: tongue dorsum strength, tongue tip strength, lip strength, masseter contraction, and oropharyngeal transit time. Results of all subjects were analyzed and averaged, compared to the normative data provided in Holzer (2011) based on age groups separated by gender. Observed scores were converted into t-scores and p-values, and marked as statistically significant if the p-value was less then 0.05.

Lip strength was found to be decreased in all of the subjects with tongue thrust, though did not prove to be statistically significant. No significant differences were found for masseter contraction at baseline or for the remainder of the swallow trials due to inconsistent results across subjects and bolus type. Significant differences were found for increased oral pharyngeal transit time. There were four instances where the swallow time was not significant, though the observed score continued to be less than the norm averages. The Triscuit trial was consistently significant across all subjects and bolus types. Increased oral pharyngeal transit time is a potential indicator of OPD, indicating that the findings from this study should encourage speech-language pathologists, OMD professionals, orthodontists, dentists, and other health professionals in increasing their knowledge surrounding the identification and treatment of tongue thrust and it's underlying causes. In doing so, cases and incidences of OPD may potentially decrease.

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Appendix A

Recruitment Poster

This was posted in multiple campus buildings at ISU and on social media sources.

Do you have tongue thrust?!

What is tongue thrust?

Tongue thrust is the forward movement of the tongue during swallowing, eating, and/or speech. A typical swallow consists of the up and back movement of the tongue. But how do you know if you have it? As a quick screener, answer the following questions while swallowing food or liquid:

1. Did your tongue push forward against your teeth?
2. Was your tongue up in your palate? Or low in your mouth?
3. Did you need to make extra effort to close your lips when you swallowed?

Common causes include the following, which may be current or past conditions: malocclusions of the teeth, open mouth while breathing, tongue in the bottom of your mouth while at rest, allergies/airway obstruction, and current or past oral habits (sucking on objects-thumb, pens, etc).

If any of these apply to you, I would love to assess your swallow for tongue thrust. If you do have tongue thrust, you would qualify to be in my thesis study. I would really appreciate any and all participation in my study. If you're not sure, or you have questions, feel free to call or email me. Thank you!

Lisa Ellgen ellglisa@isu.edu; 970-629-3892

Appendix B

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 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

(10 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 (Appendix D)	"Please answer the following questions to the best of your knowledge. Please make sure to answer all of the questions. If you have any questions, please do not hesitate to ask me. This information will remain confidential. Here is a consent form for you to	Give subject the medical history form and consent form.	

	read as well. You do not need to sign it. It is strictly for your knowledge."		
<u>3. Stone Tongue Thrust Protocol: Oral Evaluation</u>			
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 say /a/"	Push "reset"	
IOPI Dorsum		Look for the peak of the tongue dorsum when subject says /a/.	
IOPI Dorsum		Place the tip of the bulb at the peak.	
IOPI Dorsum – Trial 1	"Close your mouth and push as hard as you can against the bulb."	Have subject press until IOPI number stabilizes	
IOPI Dorsum – Trial 1	"Stop"		
IOPI Dorsum – Trial 1			_______Record reading
		Wipe bulb with tissue, reposition bulb & repeat Push "reset"	
IOPI Dorsum – Trial 2	"Go"		
IOPI Dorsum – Trial 2	"Stop"		
IOPI Dorsum – Trial 2			_______Record reading
		Wipe bulb with tissue, reposition bulb & repeat Push "reset"	
IOPI Dorsum – Trial 3	"Go"		
IOPI Dorsum – Trial 3	"Stop"		
IOPI Dorsum – Trial 3		Wipe bulb	_______Record reading

7. IOPI Lip strength		Push “reset”	
IOPI Lip Strength	“Bite down and clench your teeth together. Now I’m going to place this between your lips but be sure not bite the bulb directly”		
IOPI Lip Strength		Place bulb between lips (parallel with lips), but not between teeth.	
IOPI Lip Strength	“When I say go press your lips together”	Have subject press until IOPI number stabilizes	
IOPI Lip Strength – Trial 1	“Go”		
IOPI Lip Strength – Trial 1	“Stop”		
IOPI Lip Strength – Trial 1			______Record reading
		Reposition bulb between lips parallel with lips & Repeat Push “reset”	
IOPI Lip Strength – Trial 2	“Go”		
IOPI Lip Strength – Trial 2	“Stop”		______Record reading
		Reposition bulb between lips parallel with lips & Repeat Push “reset”	
IOPI Lip Strength – Trial 3	“Go”		
IOPI Lip Strength – Trial 3	“Stop”		______Record reading
8. Masseter baseline			
Masseter Baseline		Select “start open display session” on computer. Add new client by number. Define new session and select “skeletal muscle rehab.” Choose screen M1revw-2ch open display screen. Then turn on the encoder.	

Masseter Baseline	"Clench your back teeth"	Palpate the Masseter, Feel for belly of masseter during contraction.	
Masseter Baseline	"Do you have skin allergies?" **(If subject has skin allergies don't use Nuprep, use alcohol swabs).**	Use Nuprep to exfoliate skin (masseter and clavicle). Rub for 30 seconds on location of electrode placement. Remove excess Nuprep with alcohol. **(If subject has skin allergies don't use Nuprep, use alcohol swabs).**	
Masseter Baseline	"Clench your back teeth"	Palpate masseter again and mark placement for electrodes with marker.	
Masseter Baseline	"Bite down for me while I place these electrodes on your muscle."	**Put conductive gel on electrodes**. Place EMG electrodes bilaterally on masseter belly in a vertical plane, **Channel A is on the subject's right masseter (yellow on superior/blue inferior) & Channel B is on the subject's left masseter (yellow superior/blue inferior). Place the ground electrode (black) on the subject's collar bone.** (Reference Figure 1 for	

		specific placement). Clip electrode cables to subject's sleeve if needed.	
Masseter Baseline		Select record	
Masseter Baseline – Trial 1 (max contraction)	"Clamp down with your back teeth as hard as possible until I say stop and then relax."	Wait 3 seconds	
Masseter Baseline – Trial 1 (max contraction)	"Stop"		_____Check for EMG reading of contraction
Masseter Baseline – Trial 2 (max contraction)	"Clamp down with your back teeth as hard as possible until I say stop and then relax."	Wait 3 seconds	
Masseter Baseline – Trial2 (max contraction)	"Stop"		_____Check for EMG reading of contraction
Masseter Baseline – Trial 3 (max contraction)	"Clamp down with your back teeth as hard as possible until I say stop and then relax."	Wait 3 seconds	
Masseter Baseline – Trial 3 (max contraction)	"Stop"		_____Check for EMG reading of contraction
		Stop recording and save without reviewing in non compressed format and start new session with same client.	
9. Masseter Activity			
Masseter Activity		Electrodes will remain in the same placement. Select record	
Masseter Activity – Trial 1 (1/2 tsp pudding)		Measure ½ teaspoon of pudding with syringe and place on spoon.	
Masseter Activity – Trial 1		Have subject	

(1/2 tsp pudding)		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 ½ 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 ½ teaspoon of pudding with syringe and place on spoon.	
Masseter Activity – Trial 3 (1/2 tsp pudding)		Have subject place the pudding in their mouth	
Masseter Activity – Trial 3 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Watch for swallow initiation and press space bar to mark swallow time.	______ Cough (+/-) ______ Clavicle breathing (+/-) ______ Forward posture (+/-) ______ Chin tuck posture (+/-) ______ Neck tension (+/-) ______ Open-mouth posture (+/-)

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

	I say swallow"	swallow time.	______ 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 udding)			______Check EMG for completion of task ______ Swallow initiation time
Masseter Activity – Trial 1 (10 cc water)		Stop recording and save without reviewing in non compressed format and start new session with same client.	
Masseter Activity – Trial 1 (10 cc water)		Measure 10 cc of water, to line marked on the syringe and squirt into cup.	
Masseter Activity – Trial 1 (10 cc water)	"I'm going to give you a small amount of water in a cup."	Press record	
Masseter Activity – Trial 1 (10 cc water)	"Drink the water from the cup but don't swallow until I say swallow."	Watch for swallow initiation and press space bar to mark swallow time.	______ Cough (+/-) ______ Clavicle breathing (+/-) ______ Forward posture (+/-) ______ Chin tuck posture (+/-) ______ Neck tension (+/-) ______ Open-mouth posture (+/-)

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

Masseter Activity – Trial 1 (Triscuit)		Give subject whole Triscuit	
Masseter Activity – Trial 1 (Triscuit)	"Take a normal bite, chew it and open your 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 parts of residue) / Some evidence of residue / Significant amount of residue
Masseter Activity – Trial 2 (Triscuit)	"We are going to repeat the process 2 more times"		
Masseter Activity – Trial 2 (Triscuit)	"Take another bite & open your mouth when you are ready to swallow. Signal to me when you	Press record.	

	are ready to swallow."		
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 3 5 Minimal/No residue (few to no parts of residue) / Some evidence of residue / 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 3 5 Organized in ball or tube in middle of / Some evidence of cohesion, / Disorganized or scattered on tongue

			tongue some scattering
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 (1/2 tsp pudding)		Measure ½ teaspoon of pudding with syringe and place on spoon	
		Press record	
LE – Trial 1 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Have subject place the pudding in their mouth	
LE – Trial 1 (1/2 tsp pudding)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	_______ Cough (+/-) _______ Clavicle breathing (+/-) _______ Forward posture (+/-) _______ Chin tuck posture (+/-) _______ Neck tension (+/-) _______ Open-mouth posture (+/-) _______ Tongue protrusion (+/-) Additional notes:
LE – Trial 1 (1/2 tsp pudding)		Press pause	_______Check EMG for completion of task _______ Swallow initiation time
LE – Trial 1 (1/2 tsp pudding)	"Say ah"		_______ Gurgly voice (+/-)
LE – Trial 2 (1/2 tsp pudding)		Measure ½ 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 ½ teaspoon of pudding with syringe and place on spoon	
LE – Trial 3 (1/2 tsp pudding)		Press record	
LE – Trial 3 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"	Have subject place the pudding in their mouth	
LE – Trial 3 (1/2 tsp pudding)	"Swallow"	Feel for swallow initiation and press space bar to mark laryngeal elevation and depression	______ Cough (+/-) ______ Clavicle breathing (+/-) ______ Forward posture (+/-) ______ Chin tuck posture (+/-) ______ Neck tension (+/-) ______ Open-mouth posture (+/-) ______ Tongue protrusion (+/-) Additional notes:
LE – Trial 3 (1/2 tsp pudding)		Press pause	______Check EMG for completion of task ______ Swallow initiation time
LE – Trial 3 (1/2 tsp pudding)	"Say ah"		______ Gurgly voice (+/-)
LE – Trial 3 (1/2 tsp pudding)		Stop recording and save without reviewing in non compressed format and start new session with same client.	
LE – protrusion	"I'm going to pull down your lip when you swallow."		

LE/protrusion – Trial 1 (1/2 tsp pudding)		Measure ½ 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 ½ 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 ½ teaspoon of pudding with syringe and place on spoon	
LE/protrusion – Trial 3 (1/2 tsp pudding)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when ready"	Have subject place the pudding in their mouth Pull down lip while swallowing and watch for protrusion of tongue.	_______ Tongue protrusion (+/-)
LE – Trial 1 (1 ½ tsp pudding)		Measure 1 ½ teaspoons of pudding with syringe and place on spoon	
LE – Trial 1 (1 ½ tsp pudding)		Press record	

LE – Trial 1 (1 ½ tsp pushing)	"Place the pudding in your mouth, cleaning the whole spoon, & swallow when I say swallow"		
LE – Trial 1 (1 ½ tsp pushing)	"Swallow"	Feel for swallow initiation and press space 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 (1 ½ tsp pudding)	"Say ah"		_______ Gurgly voice (+/-)
LE – Trial 3 (1 ½ tsp pudding)		Measure 1 ½ teaspoons of pudding with syringe and place on spoon	
LE – Trial 3 (1 ½ tsp pudding)		Press record	
LE – Trial 3	"Place the		

(1 ½ tsp pudding)	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	"Say ah"		______ Gurgly voice (+/-)

(10 cc water)			
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

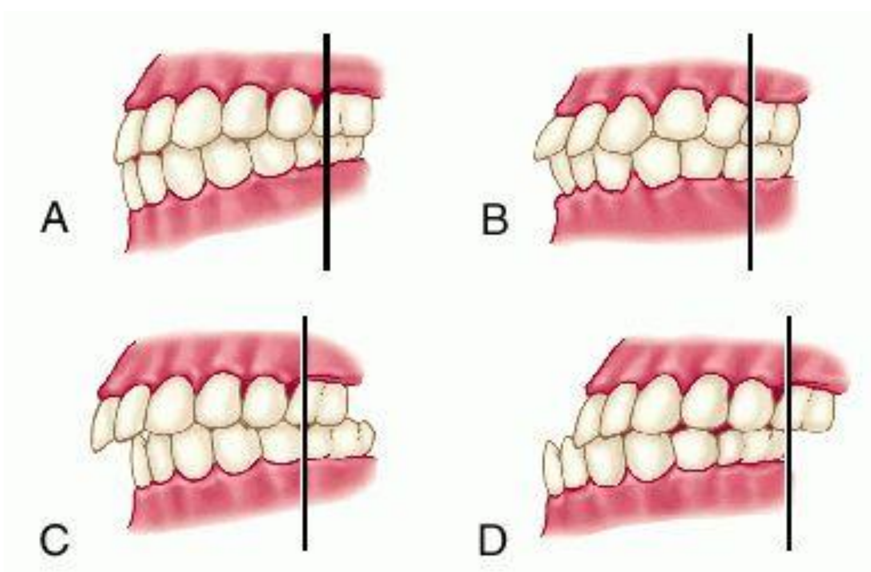
LE – Trial 3 (10 cc water)	"Say ah"		_______ Gurgly voice (+/-)
LE		Stop recording and save without reviewing in non compressed format and start new session with same client.	
LE/protrusion	"I'm going to pull down your lip when you swallow."		
LE/protrusion – Trial 1 (10 cc water)		Measure 10 cc of water, 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 ready"	Pull down lip while swallowing and watch for protrusion of tongue.	_______ Tongue protrusion (+/-)
LE – Trial 1 (Triscuit)		Give subject Triscuit	
LE – Trial 1 (Triscuit)	"Take a normal bite of the cracker & signal to me when you are ready to swallow."	Press record	
LE – Trial 1		Participant	_______ Cough (+/-)

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

- 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 or Variable Name	**Description/Criteria**
Iopitipavg	iopi tongue tip average
Iopidorsavg	iopi dorsum average
Iopilipsavg	iopi lips average
mcbARMSav	masseter contraction baseline ARMS av.
mcbBRMSav	masseter contraction baseline BRMS av.
mcpud1ARMS	masseter contraction ½ tsp ARMS
mcpud1BRMS	masseter contraction ½ tsp BRMS
mcpud2ARMS	masseter contraction 1 ½ tsp ARMS
mcpud2BRMS	masseter contraction 1 ½ tsp BRMS
mc10ccARMS	masseter contraction 10 cc ARMS
mc10ccBRMS	masseter contraction 10 cc BRMS
mccrackARMS	masseter contraction cracker ARMS
mccrackBRMS	masseter contraction cracker BRMS
stcpud1avg	Swallow timing w/ contraction ½ tsp av.
stcpud2avg	Swallow timing w/ contraction 1 ½ tsp av.
stc10ccavg	Swallow timing w/ contraction 10cc av.
stccrackavg	Swallow timing w/ contraction cracker av.
tppud1	tongue protrusion ½ tsp (lip pulled down, sum of 3 trials)
tp10cc	tongue protrusion 10 cc (lip pulled down, sum of 3 trials)
tpcrack	tongue protrusion cracker (lip pulled down, sum of 3 trials)
bolusres	bolus residue
ope_p	oral peripheral exam of palate
ope_d	oral peripheral exam of dentition: 0=normal; 1=type 1; 2=type 2; 3=type 3; 4=open bite; 5=other
cough	Cough
CB	clavicular breathing
FP	forward posture
CTP	chin tuck
NT	neck tension
OMP	open mouth posture
TP	tongue protrusion (on trials without pulling lip down)

Appendix F

Raw Data Charts by Measure

IOPI Measures

PARTICIPANT TT	TRIAL 1	TRIAL 2	TRIAL 3	AVERAGE	STD
1	35	43	36	38.00	4.36
2	29	31	33	31.00	2.00
3	40	48	52	46.67	6.11
4	75	69	75	73.00	3.46
5	22	33	31	28.67	5.86

PARTICIPANT TD	TRIAL 1	TRIAL 2	TRIAL 3	AVERAGE	STD
1	36	42	49	42.33	6.51
2	42	34	28	34.67	7.02
3	45	53	48	48.67	4.04
4	47	51	54	50.67	3.51
5	28	32	30	30.00	2.00

PARTICIPANT BL	TRIAL 1	TRIAL 2	TRIAL 3	AVERAGE	STD
1	9	10	9	9.33	4.93
2	6	5	8	6.33	1.53
3	19	21	17	19.00	2.00
4	13	15	15	14.33	1.15
5	9	8	8	8.33	0.58

EMG Masseter Contraction- Right Masseter

PARTICIPANT RIGHT MASSETER BASELINE (AVG)	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	20.8	21.97	24.38	22.38	1.83
2	107.39	127.88	140.17	125.15	16.56
3	84.7	88.19	81.94	84.94	3.13
4	145.14	118.79	150.38	138.10	16.93
5		120.26	130.33	125.30	7.12

PARTICIPANT RIGHT MASSETER 1/2	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	57.83	62.2	49.43	56.49	6.49
2	28.35	18.1	23.15	23.20	5.13
3	25.29	16.67	22.91	21.62	4.45
4	19.48	13.1	10.87	14.48	4.47
5	65.47	46.35	17.47	43.10	24.16

PARTICIPANT RIGHT MASSETER 1 1/2	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	43.03	37.18	35.62	38.61	3.91
2	24.12	25.55	51.02	33.56	15.13
3	19.79	16.66	44.77	27.07	15.41
4	27.19	25.47	20.96	24.54	3.22
5	25.17	34.44	42.39	34.00	8.62

PARTICIPANT RIGHT MASSETER WATER	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	272.51	46.75	35.47	118.24	133.72
2	16.66	11.71	18.32	15.56	3.44
3	75.64	58.09	69.74	67.82	8.93
4	9.79	11.22	9.9	10.30	0.80
5	20.91	20.03	19.77	20.24	0.60

PARTICIPANT RIGHT MASSETER TRISCUIT	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	56.65	37.25	50.11	48.00	9.87
2	52.81	151.01	36.46	80.09	61.96
3	87.15	158.58	90.71	112.15	40.25
4	167.35	12.91	30.52	70.26	84.54
5	25.19	28.19	123.02	58.80	55.64

*Subject 5 masseter baseline for trial 1 is not included due to it being invalid from an inaccurate EMG reading. Average was calculated based on trial 2 and trial 3.

EMG Masseter Contraction- Left Masseter

PARTICIPANT LEFT MASSETER BASELINE (AVG)	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	50.79	63.55	81.02	65.12	15.18
2	84.69	95.83	105.12	95.21	10.23
3	186.74	172.62	162.92	174.09	11.98
4	134.23	108.56	145.7	129.50	19.02
5		166.49	171.08	168.79	3.25

PARTICIPANT LEFT MASSETER 1/2	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	134.37	113.06	126.58	124.67	10.78
2	19.06	20.04	24.53	21.21	2.92
3	81.27	55.54	46.33	61.05	18.11
4	24.47	24.3	19.07	22.61	3.07
5	60.03	38.42	21.84	40.10	19.15

PARTICIPANT LEFT MASSETER 1 1/2	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	18.97	18.92	23.69	20.53	2.74
2	26.2	25.54	31.79	27.84	3.43
3	19.22	17.02	36.64	24.29	10.75
4	45.14	45.22	38.15	42.84	4.06
5	34.17	31.67	63.72	43.19	17.83

PARTICIPANT LEFT MASSETER WATER	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	15.89	19.18	18.29	17.79	1.70
2	14.36	14.46	27.37	18.73	7.48
3	49.36	52.73	68.74	56.94	10.35
4	15.37	15.45	15.84	15.55	0.25
5	21.72	21.74	14.54	19.33	4.15

PARTICIPANT LEFT MASSETER TRISCUIT	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	75.17	43.05	95.73	71.32	26.55
2	45.28	97.52	30.49	57.76	35.22
3	187.62	277.93	245.59	237.05	45.76
4	108.34	17.58	43.36	56.43	46.77
5	38.83	53.76	136.4	76.33	52.56

*Subject 5 masseter baseline for trial 1 is not included due to it being invalid from an inaccurate EMG reading. Average was calculated based on trial 2 and trial 3.

Laryngeal Elevation- Swallow Timing (Physiological Onset to Physiological Offset)

PARTICIPANT LE 1/2 PHYS DUR	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	1.44	1.24	1.16	1.28	0.14
2	1.21	1.16	1.25	1.21	0.05
3	1.53	1.72	1.88	1.71	0.18
4	1.67	1.55	1.61	1.61	0.06
5	1.78	1.23	1.59	1.53	0.28

PARTICIPANT LE 1 1/2 PHYS DUR	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	1.12	1.56	1.64	1.44	0.28
2	1.27	1.23	1.17	1.22	0.05
3	2.1	2.34	1.96	2.13	0.19
4	1.84	1.87	1.73	1.81	0.07
5	1.15	1.18	1.61	1.31	0.26

PARTICIPANT LE WATER PHYS DUR	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	1.34	1.55	1.4	1.43	0.11
2	1.05	1.26	0.97	1.09	0.15
3	2.1	2.02	1.57	1.90	0.29
4	1.27	1.5	1.27	1.35	0.13
5	1.03	1.42	1.28	1.24	0.20

PARTICIPANT LE TRISCUIT PHYS DUR	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	2.94	4.05	2.46	3.15	0.82
2	1.42	1.39	2.29	1.70	0.51
3	2.8	1.94	1.47	2.07	0.67
4	1.61	1.65	2.24	1.83	0.35
5	1.48	2.07	1.62	1.72	0.31

Laryngeal Elevation- Swallow Timing (Physiological Onset to Depression Tick Marker)

PARTICIPANT LE 1/2 PHYS DUR TO TICK	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	0.8	0.98	1	0.93	0.11
2	1.04	0.88	0.83	0.92	0.11
3	0.54	0.99	1.2	0.91	0.34
4	1.28	1.39	1.65	1.44	0.19
5	1.53	0.95	1.18	1.22	0.29

PARTICIPANT LE 1 1/2 PHYS DUR TO TICK	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	0.74	1.03	1.5	1.09	0.38
2	1.11	0.92	1.07	1.03	0.10
3	1.33	1.54	1.17	1.35	0.19
4	1.33	1.16	1.51	1.33	0.18
5	0.99	0.99	1.16	1.05	0.10

PARTICIPANT LE WATER PHYS DUR TO TICK	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	0.81	0.94	0.7	0.82	0.12
2	0.75	0.93	0.8	0.83	0.09
3	1.43	1.09	0.91	1.14	0.26
4	1.03	1.39	0.91	1.11	0.25
5	0.79	1	1.14	0.98	0.18

PARTICIPANT LE TRISCUIT PHYS DUR TO TICK	TRIAL 1	TRIAL 2	TRIAL 3	AVG	STD
1	2.83	3.88	2.09	2.93	0.90
2	1.36	1.37	2.09	1.61	0.42
3	1.89	1.68	1.46	1.68	0.22
4	1.51	1.78	2.27	1.85	0.39
5	1.34	2.19	1.54	1.69	0.44

Bolus, Residue, and Behavioral/Observational Data

PARTICIPANT BOLUS ORGANIZATION	TRIAL 1	TRIAL 2	TRIAL 3	AVG
1	3	5	3	3.67
2	5	3	3	3.67
3	1	1	3	1.67
4	3	3	3	3.00
5	5	5	5	5.00

PARTICIPANT RESIDUE	TRIAL 1	TRIAL 2	TRIAL 3	AVG
1	3	3	3	3.00
2	3	3	3	3.00
3	3	1	3	2.33
4	3	3	5	3.67
5	5	3	3	3.67

PARTICIPANT TONGUE PROTRUSION	PUDDING	WATER	TRISCUIT	AVG
1	3	3	3	3.00
2	3	3	3	3.00
3	3	1	2	2.00
4	3	3	3	3.00
5	0	1	3	1.33

PARTICIPANT OBSERVED BEHAVIORS	COUGH	CB	FP	CTP	NT	OMP	TP	GV
1	0	0	0	0	0	0	0	4
2	1	0	0	0	24	0	0	5
3	0	0	0	0	2	0	0	0
4	6	0	0	0	0	0	0	2
5	0	0	24	0	23	0	0	6

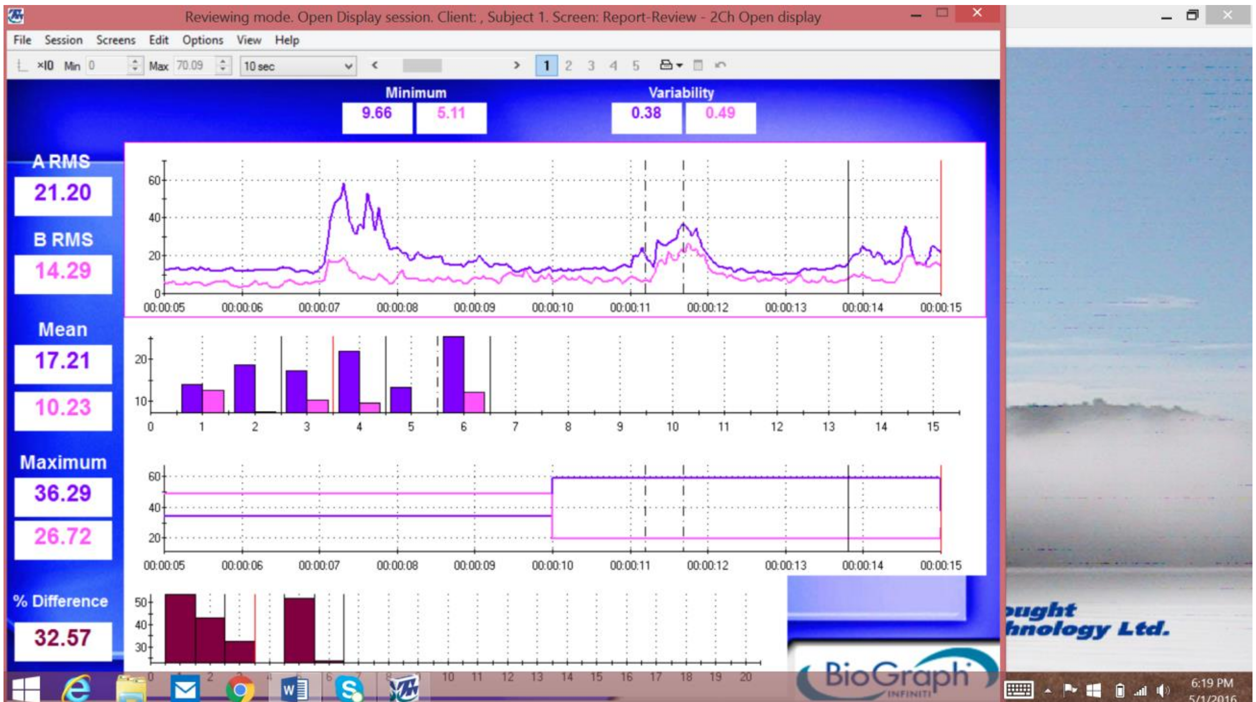
PARTICIPANT DATA	GENDER	AGE GROUP	AGE MONTHS	PROTOCOL
1	F	20	273.9	B
2	F	15	224.8	C
3	M	25	329.8	B
4	F	20	250.8	A
5	F	15	216.2	A

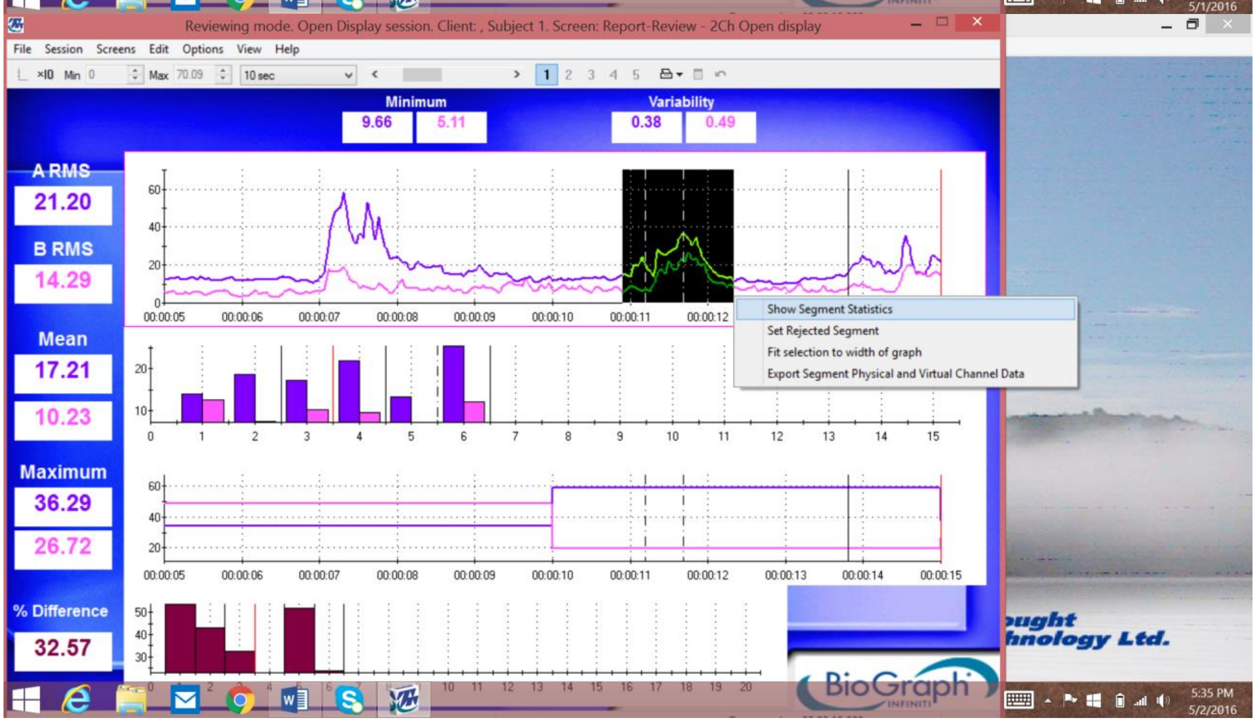
Appendix G
Screenshots of EMG recordings used to extract data
*Note: Subject 3 not included. Data received from another researcher.

Subject 1

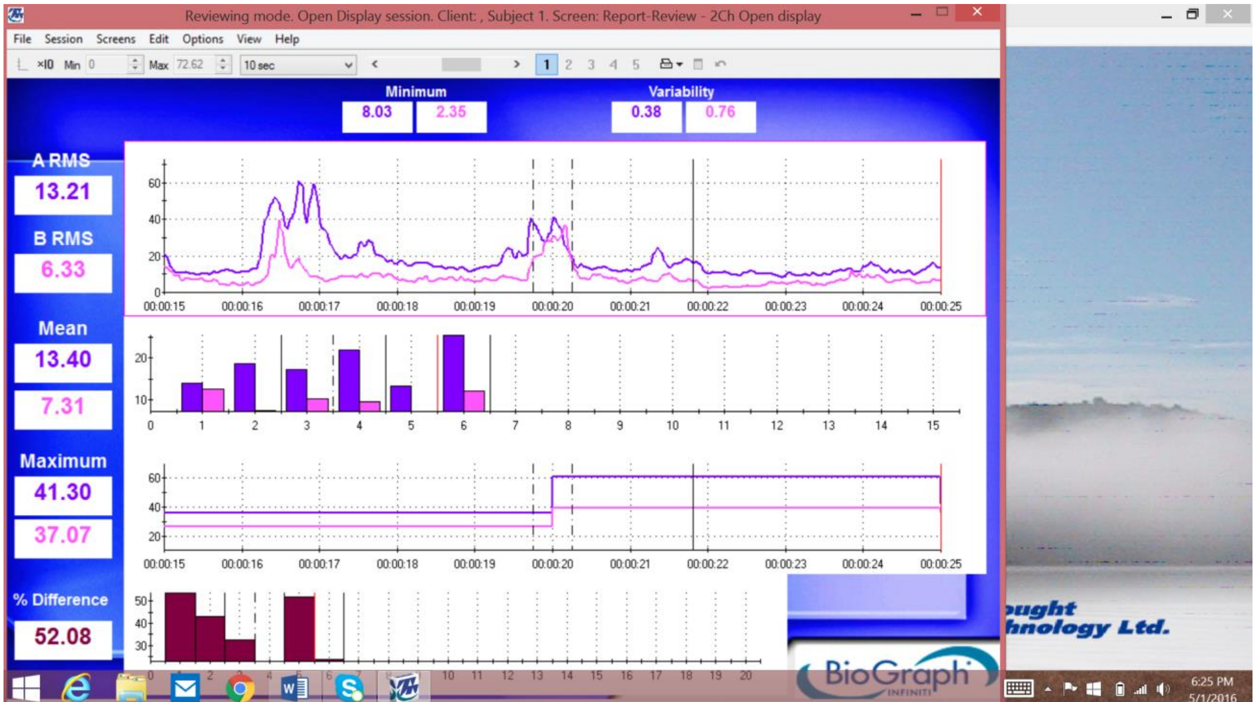
½ pudding

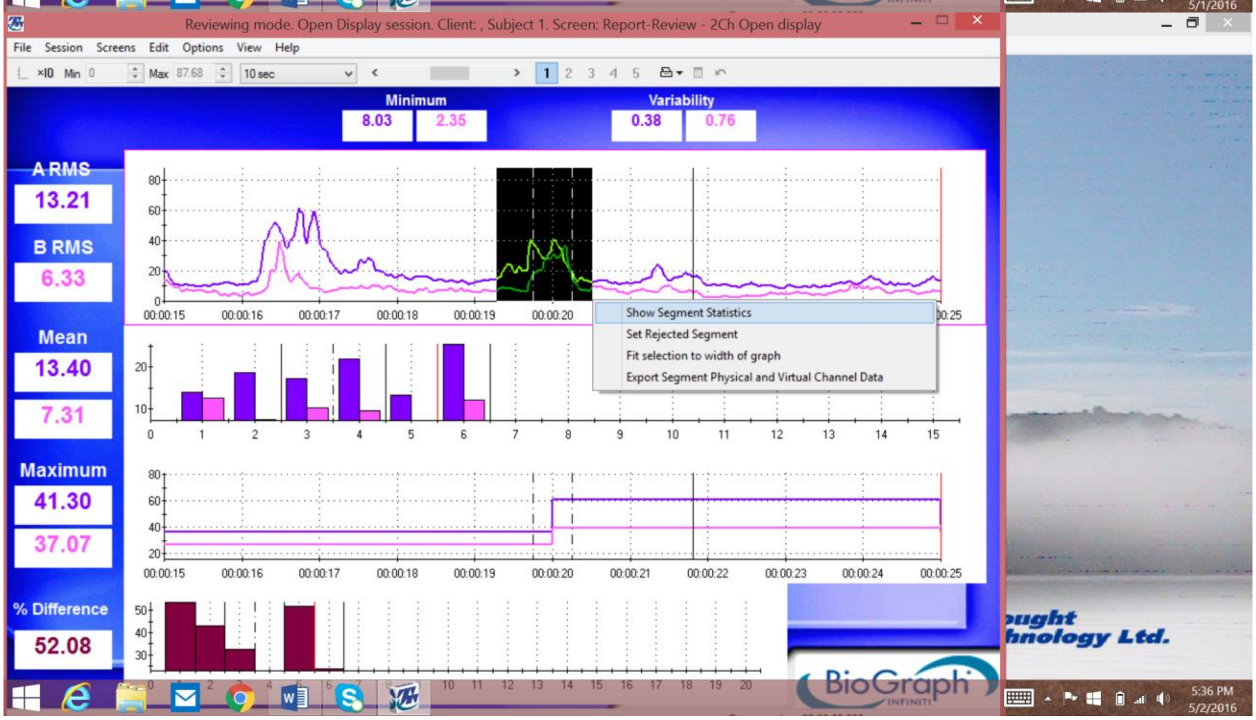
Trial 1



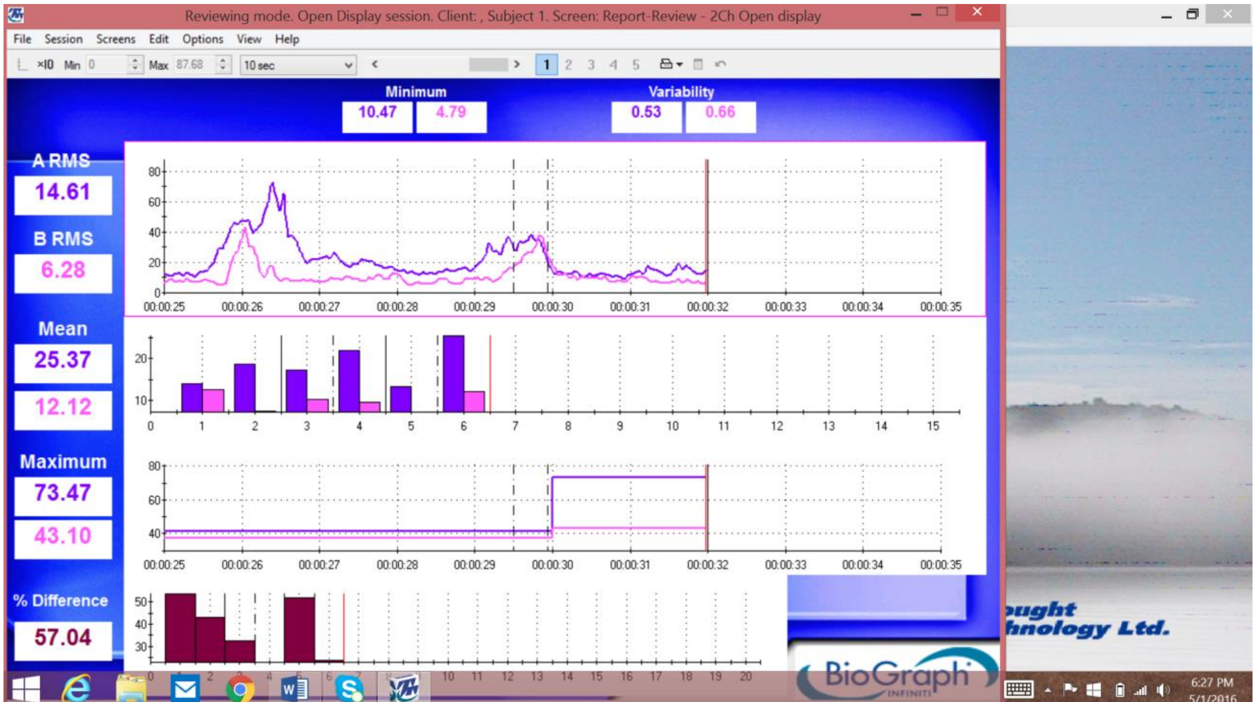


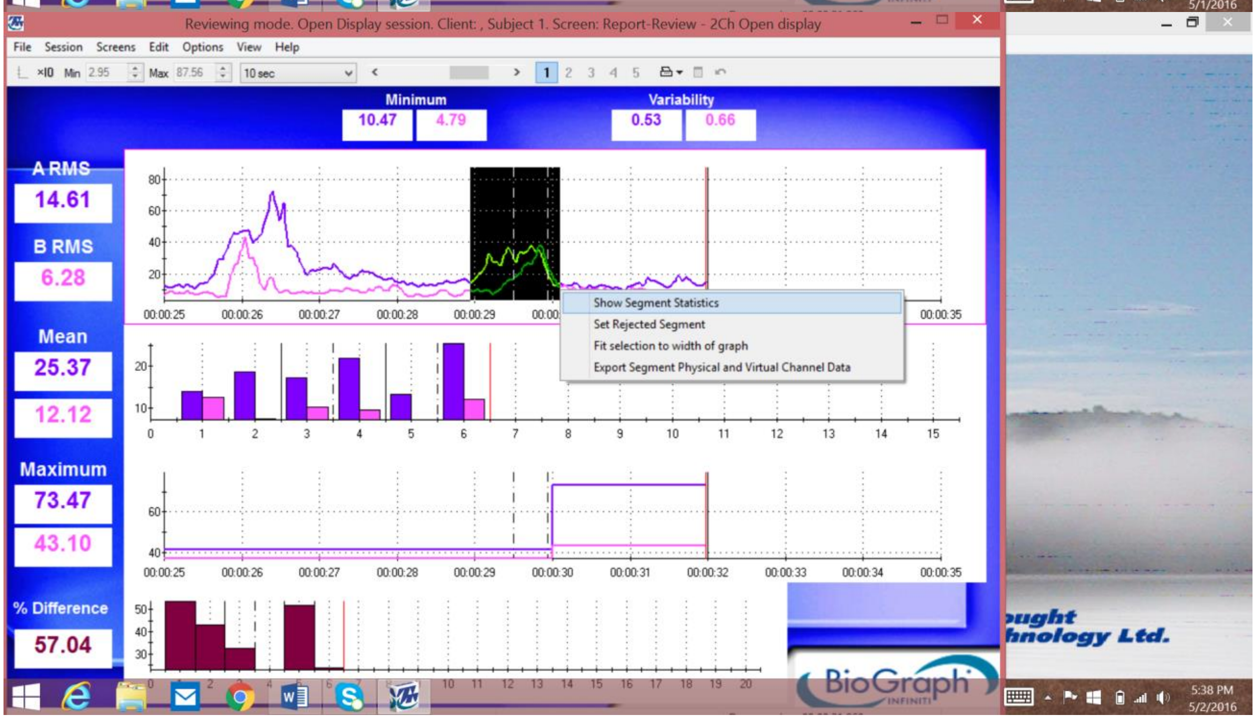
Trial 2


Reviewing mode. Open Display session. Client: , Subject 1. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
8.03
2.35
Variability
0.38
0.76
A RMS
13.21
B RMS
6.33
Mean
13.40
7.31
Maximum
41.30
37.07
% Difference
52.08
BioGraph INFINITI
6:25 PM
5/1/2016


Reviewing mode. Open Display session. Client: , Subject 1. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
8.03
2.35
Variability
0.38
0.76
A RMS
13.21
B RMS
6.33
Mean
13.40
7.31
Maximum
41.30
37.07
% Difference
52.08
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph INFINITI
5:36 PM
5/2/2016

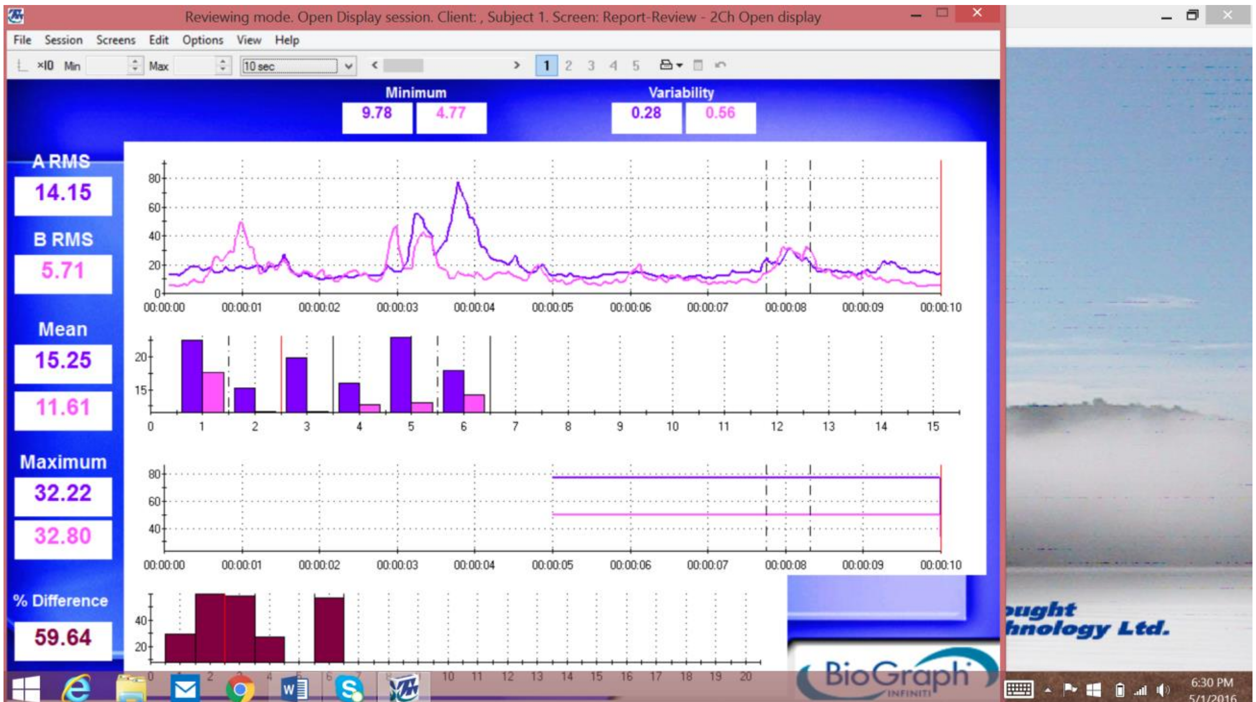
Trial 3

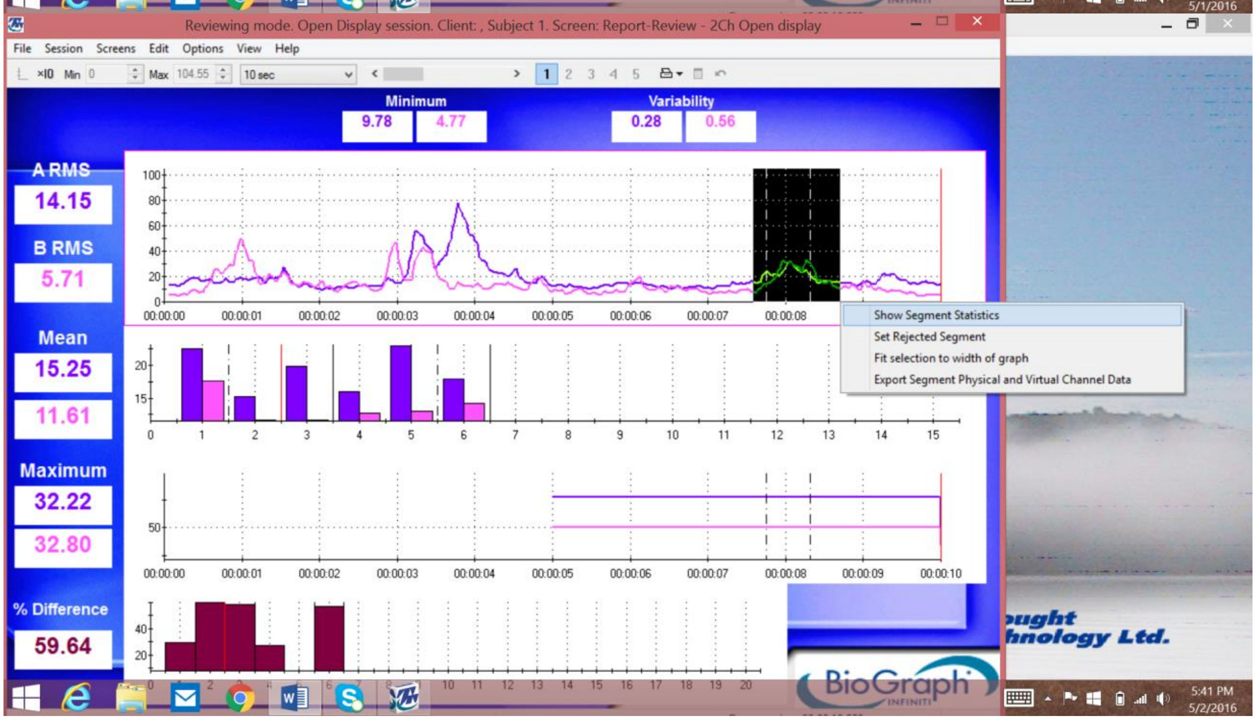

Reviewing mode. Open Display session. Client: , Subject 1. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
10.47
4.79
Variability
0.53
0.66
A RMS
14.61
B RMS
6.28
Mean
25.37
12.12
Maximum
73.47
43.10
% Difference
57.04
BioGraph INFINITI
6:27 PM
5/1/2016


Reviewing mode. Open Display session. Client: , Subject 1. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
10.47
4.79
Variability
0.53
0.66
A RMS
14.61
B RMS
6.28
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
Mean
25.37
12.12
Maximum
73.47
43.10
% Difference
57.04
BioGraph INFINITI
5:38 PM
5/2/2016

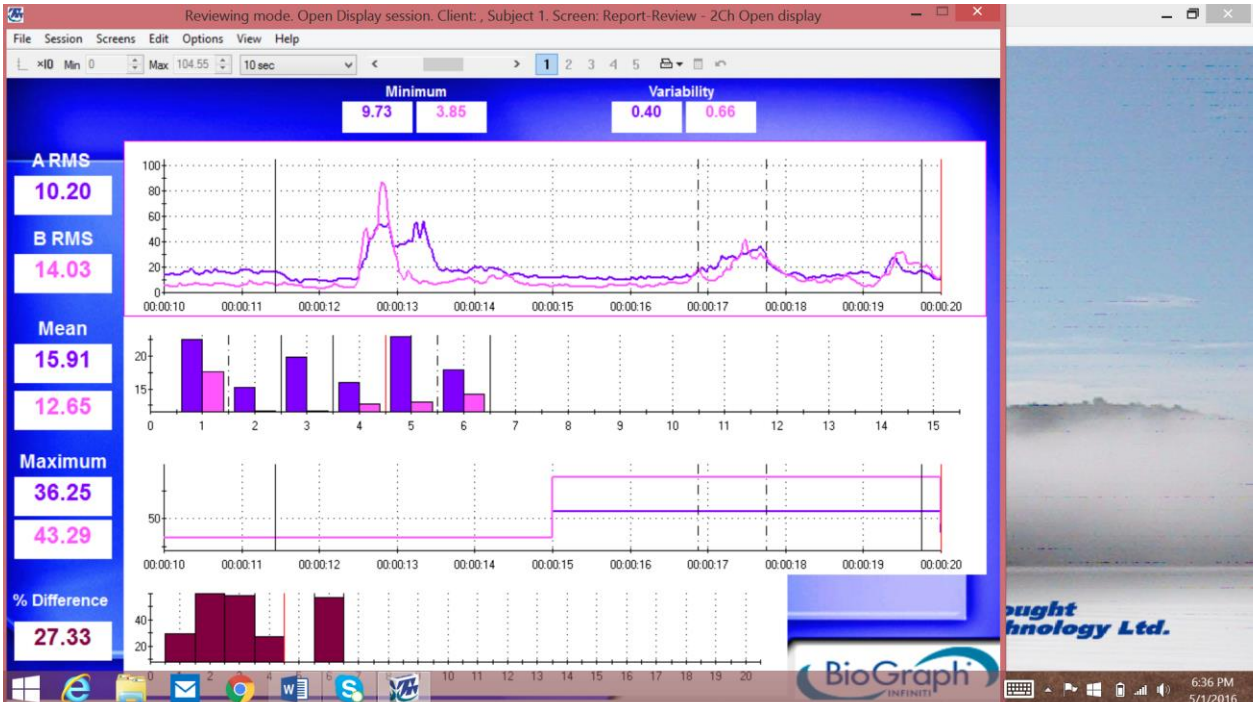
1 ½ pudding

Trial 1





Trial 2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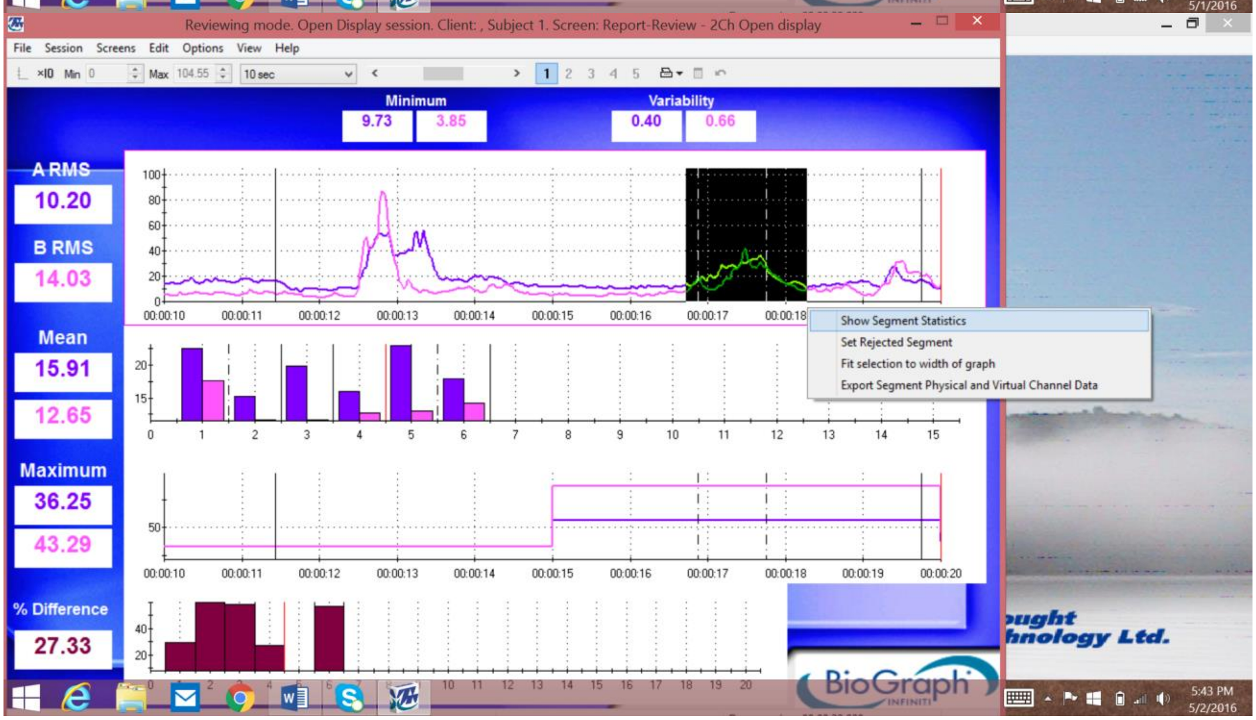
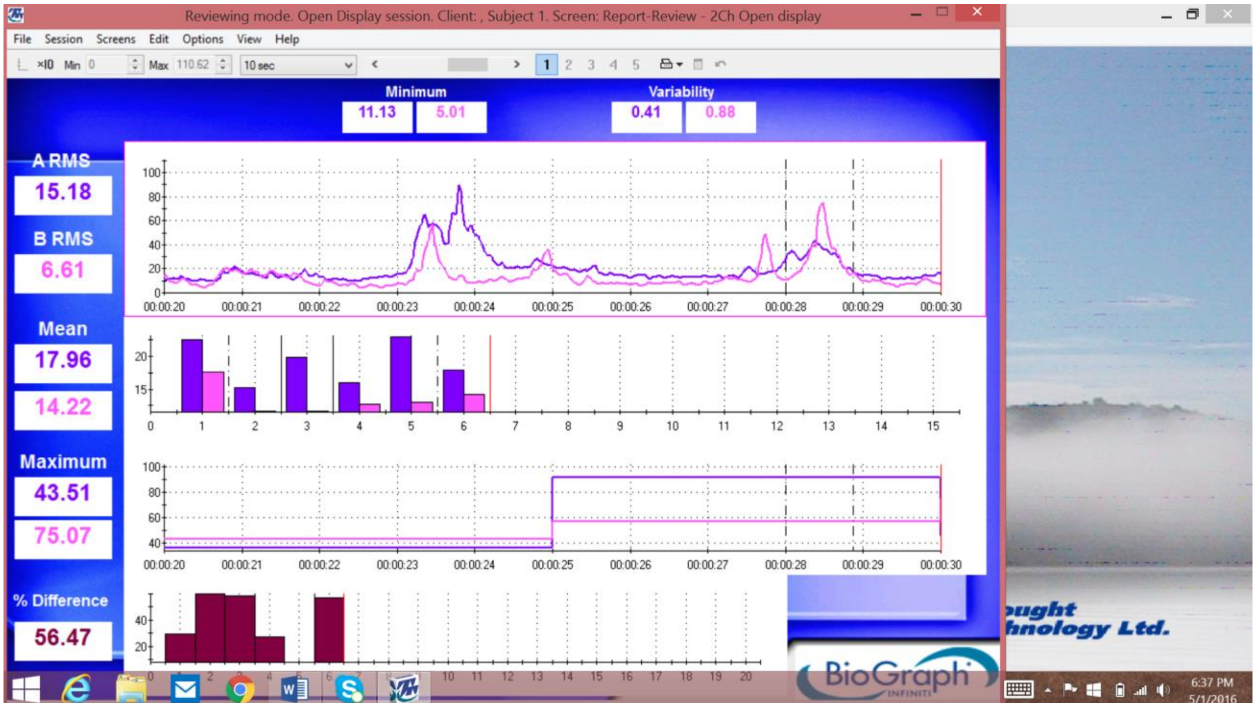
File Session Screens Edit Options View Help
Minimum
9.73
3.85
Variability
0.40
0.66
A RMS
10.20
B RMS
14.03
Mean
15.91
12.65
Maximum
36.25
43.29
% Difference
27.33
BioGraph
6:36 PM
5/1/2016


Reviewing mode. Open Display session. Client: , Subject 1. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
9.73
3.85
Variability
0.40
0.66
A RMS
10.20
B RMS
14.03
Mean
15.91
12.65
Maximum
36.25
43.29
% Difference
27.33
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph
5:43 PM
5/2/2016

Trial 3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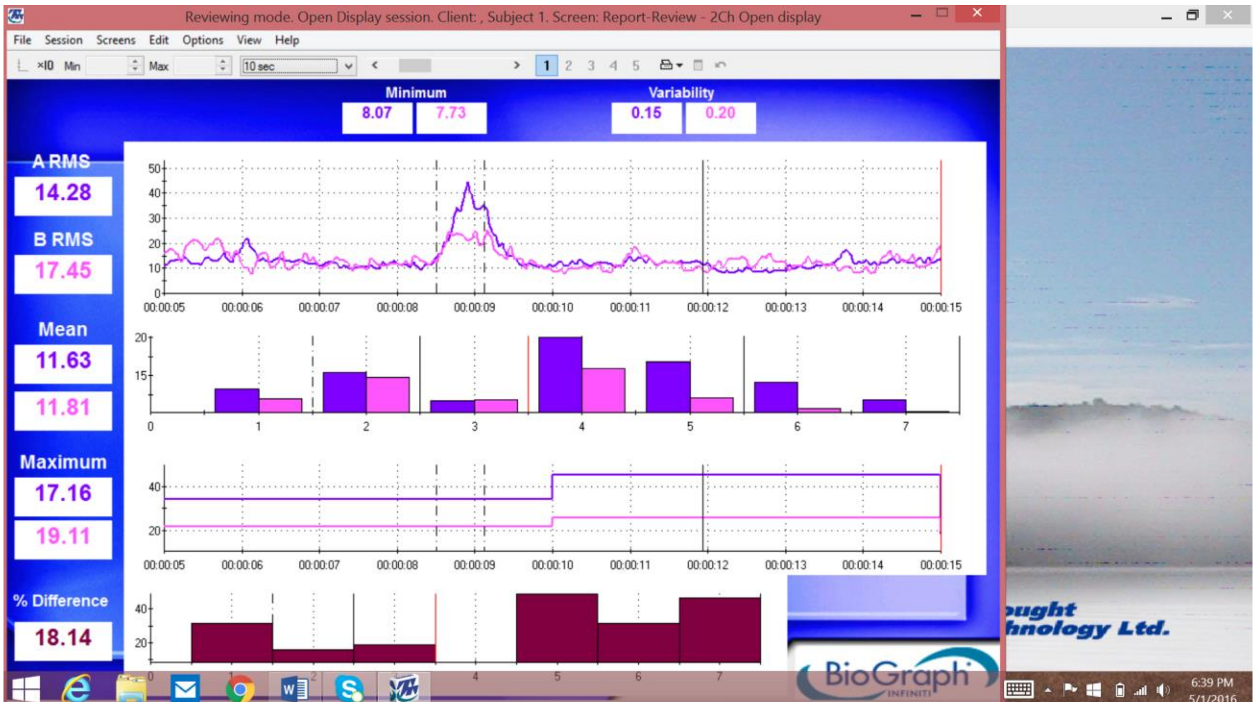
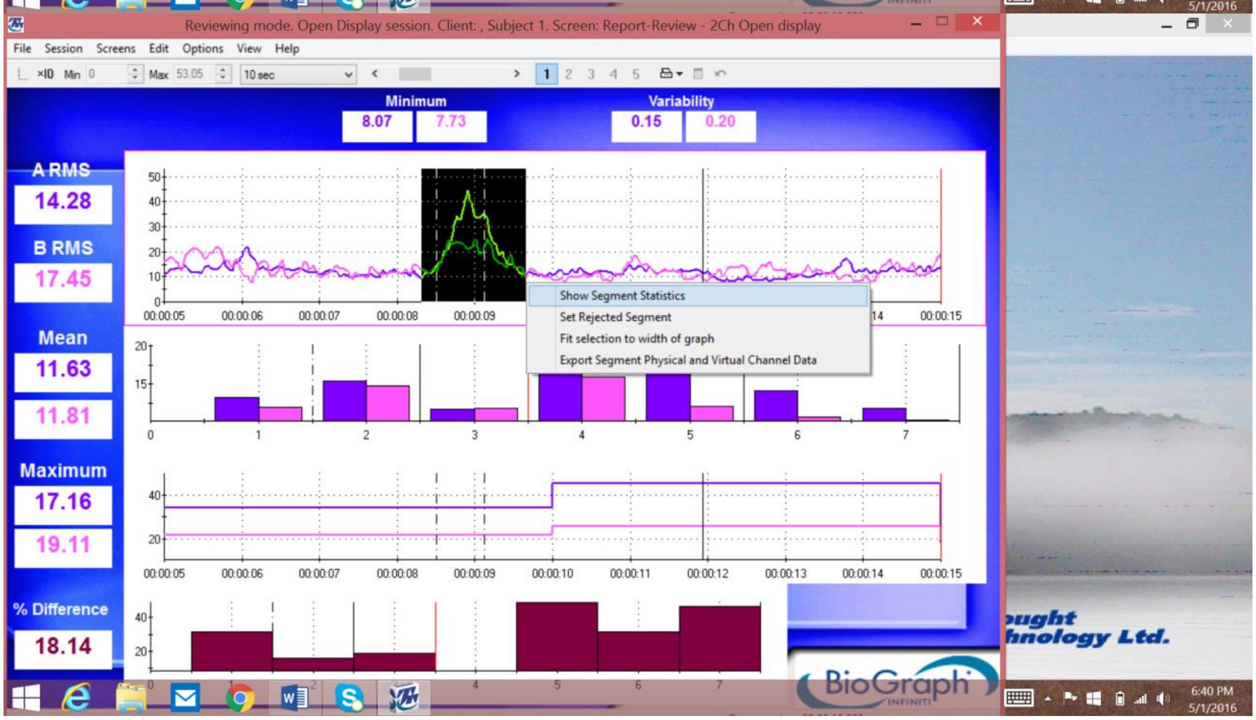
File Session Screens Edit Options View Help
Minimum
11.13
5.01
Variability
0.41
0.88
A RMS
15.18
B RMS
6.61
Mean
17.96
14.22
Maximum
43.51
75.07
% Difference
56.47
BioGraph INFINITI


Reviewing mode. Open Display session. Client: , Subject 1. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
11.13
5.01
Variability
0.41
0.88
A RMS
13.16
B RMS
5.72
Mean
17.96
14.22
Maximum
43.51
75.07
% Difference
56.57
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph INFINITI

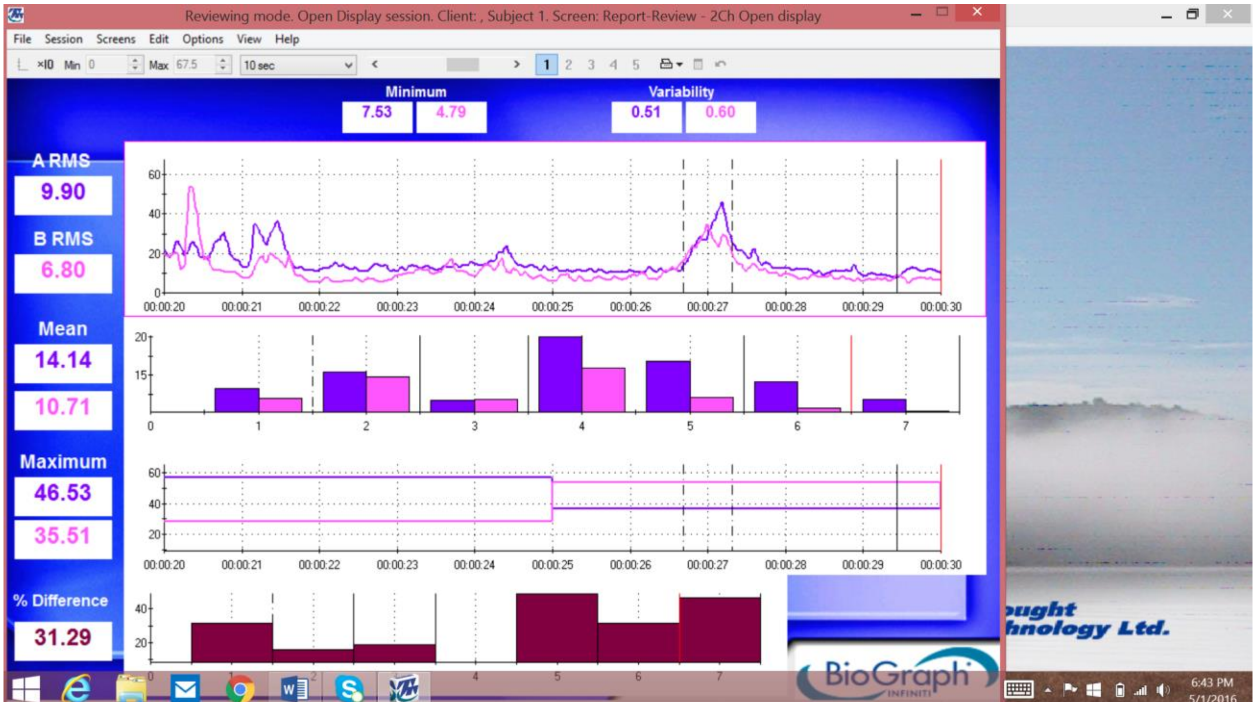
Water

Trial 1



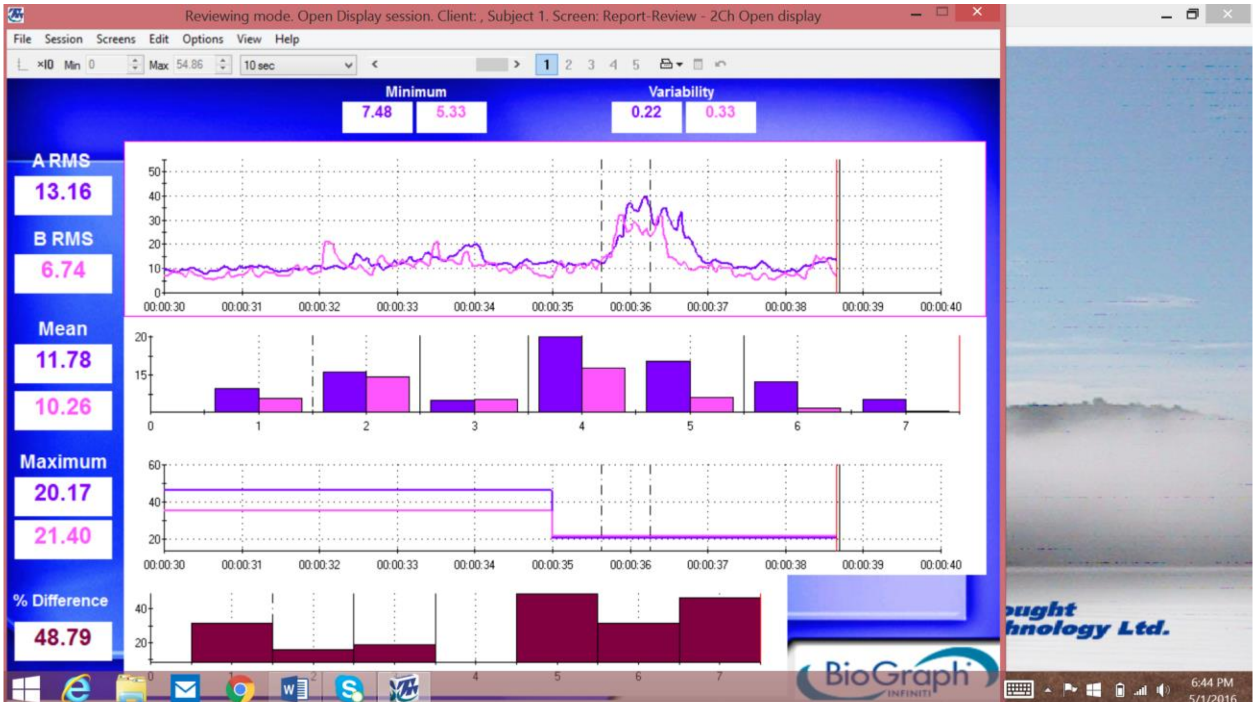


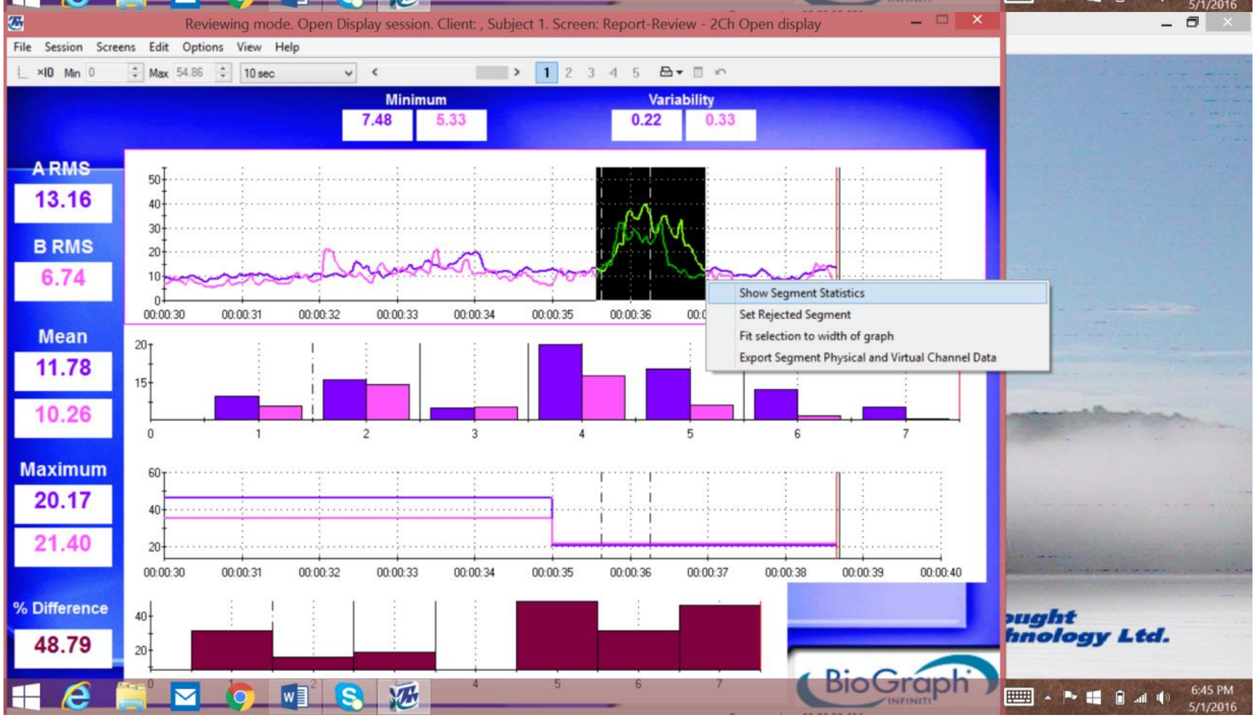
Trial 2


Reviewing mode. Open Display session. Client: , Subject 1. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
7.53 4.79
Variability
0.51 0.60
A RMS
9.90
B RMS
6.80
Mean
14.14
10.71
Maximum
46.53
35.51
% Difference
31.29
BioGraph INFINITI
6:43 PM
5/1/2016


Reviewing mode. Open Display session. Client: , Subject 1. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
7.53 4.79
Variability
0.51 0.60
A RMS
9.90
B RMS
6.80
Mean
14.14
10.71
Maximum
46.53
35.51
% Difference
31.29
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph INFINITI
6:43 PM
5/1/2016

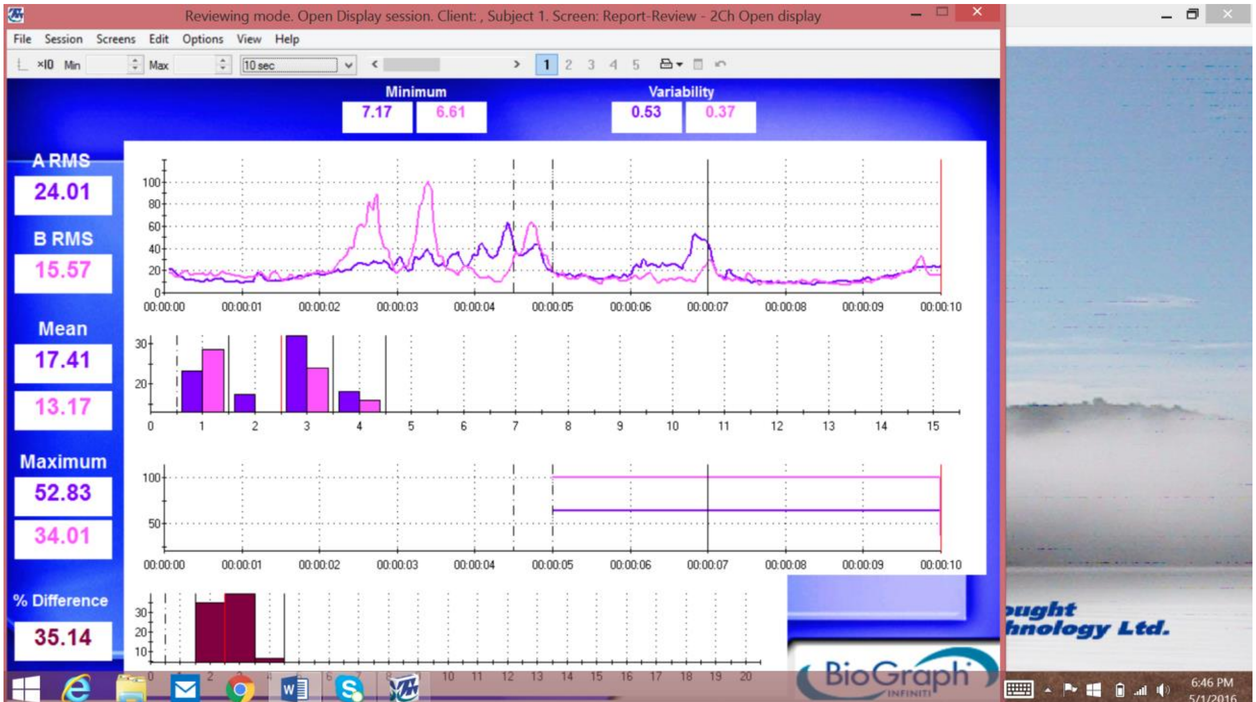
Trial 3

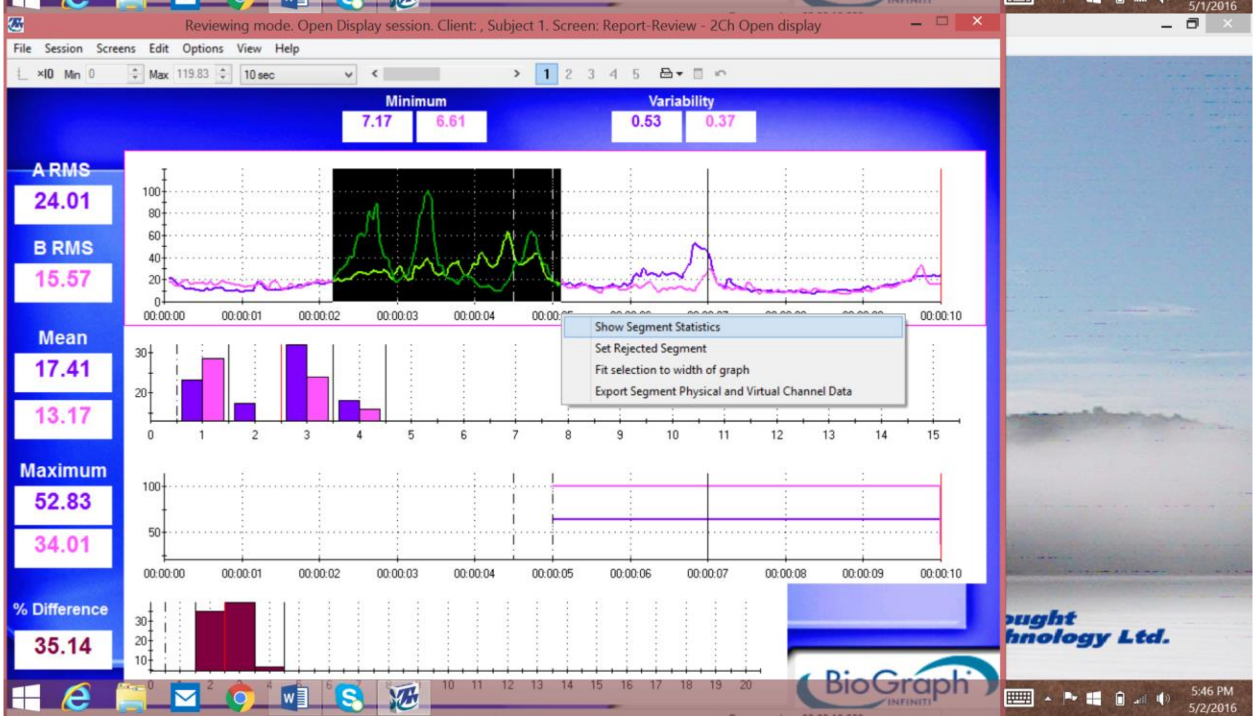

Reviewing mode. Open Display session. Client: , Subject 1. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
7.48
5.33
Variability
0.22
0.33
A RMS
13.16
B RMS
6.74
Mean
11.78
10.26
Maximum
20.17
21.40
% Difference
48.79
BioGraph
6:44 PM
5/1/2016


Reviewing mode. Open Display session. Client: , Subject 1. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
7.48
5.33
Variability
0.22
0.33
A RMS
13.16
B RMS
6.74
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
Mean
11.78
10.26
Maximum
20.17
21.40
% Difference
48.79
BioGraph
6:45 PM
5/1/2016

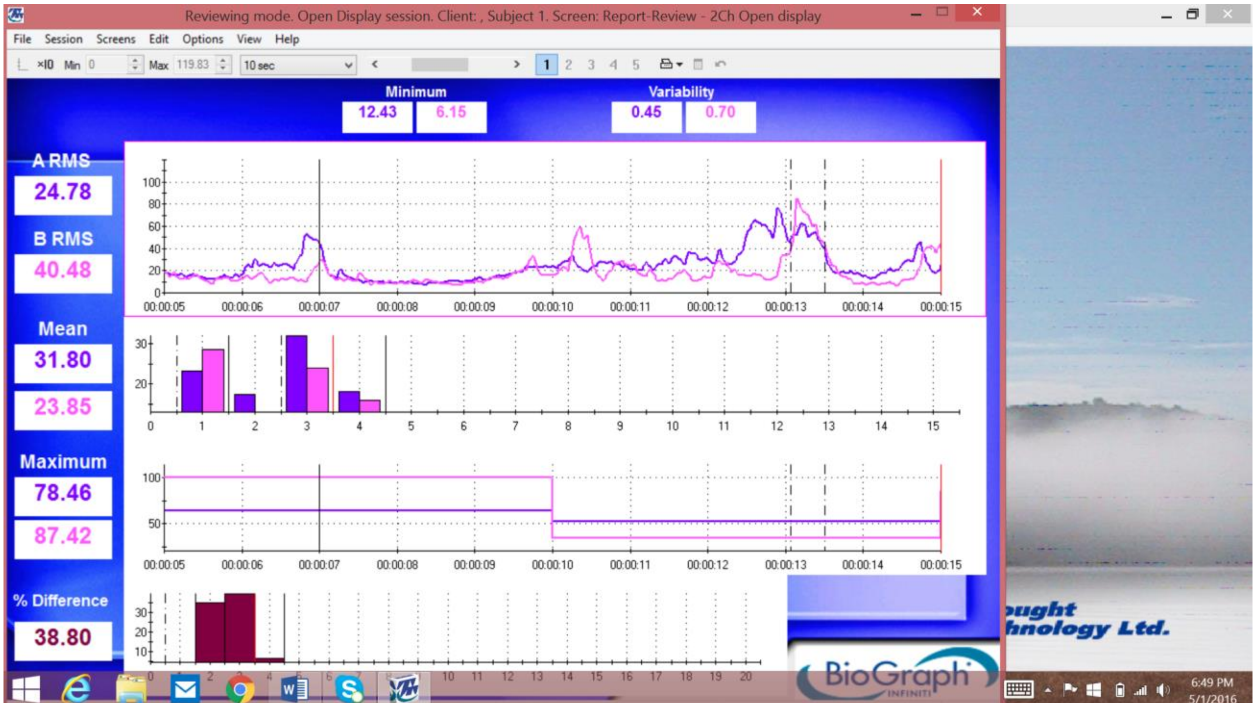
Triscuit

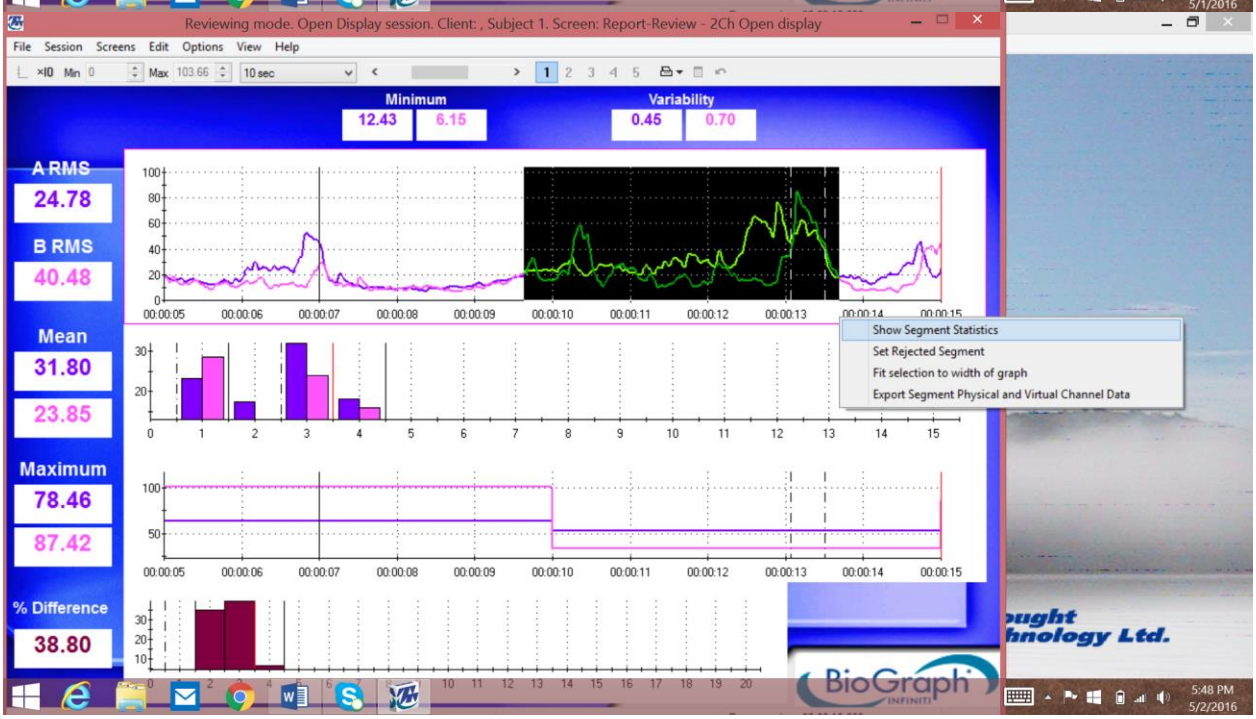
Trial 1



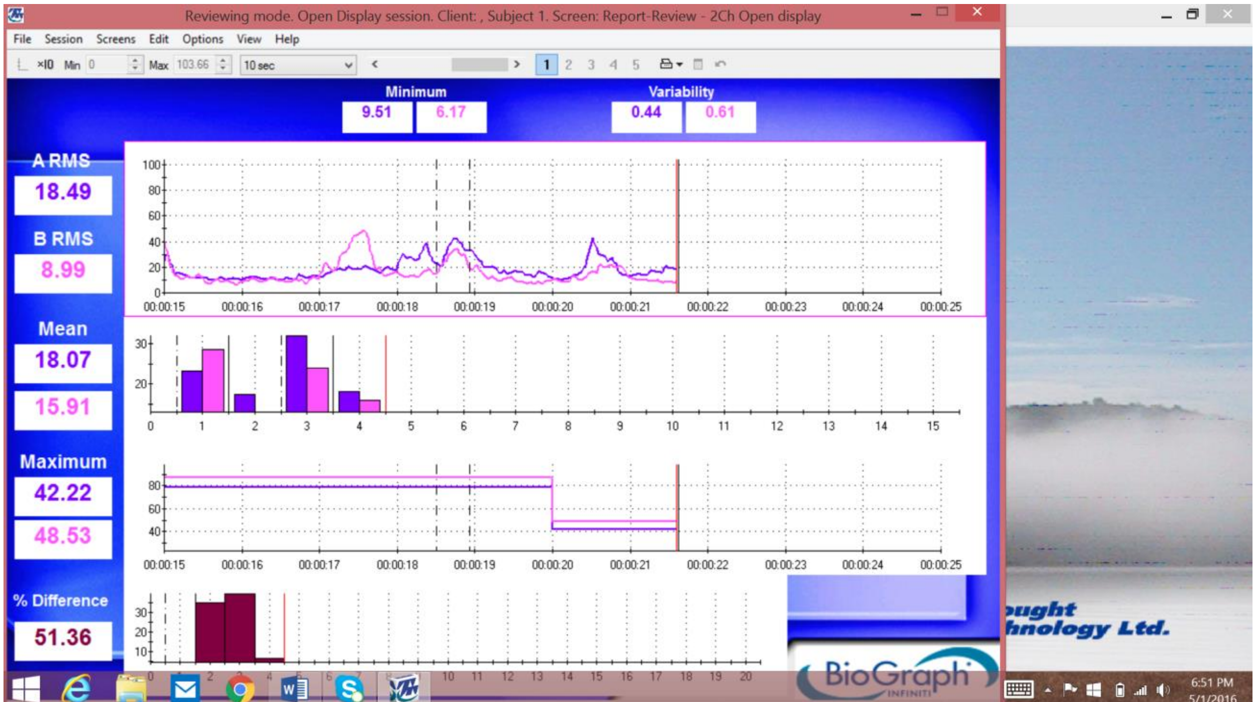


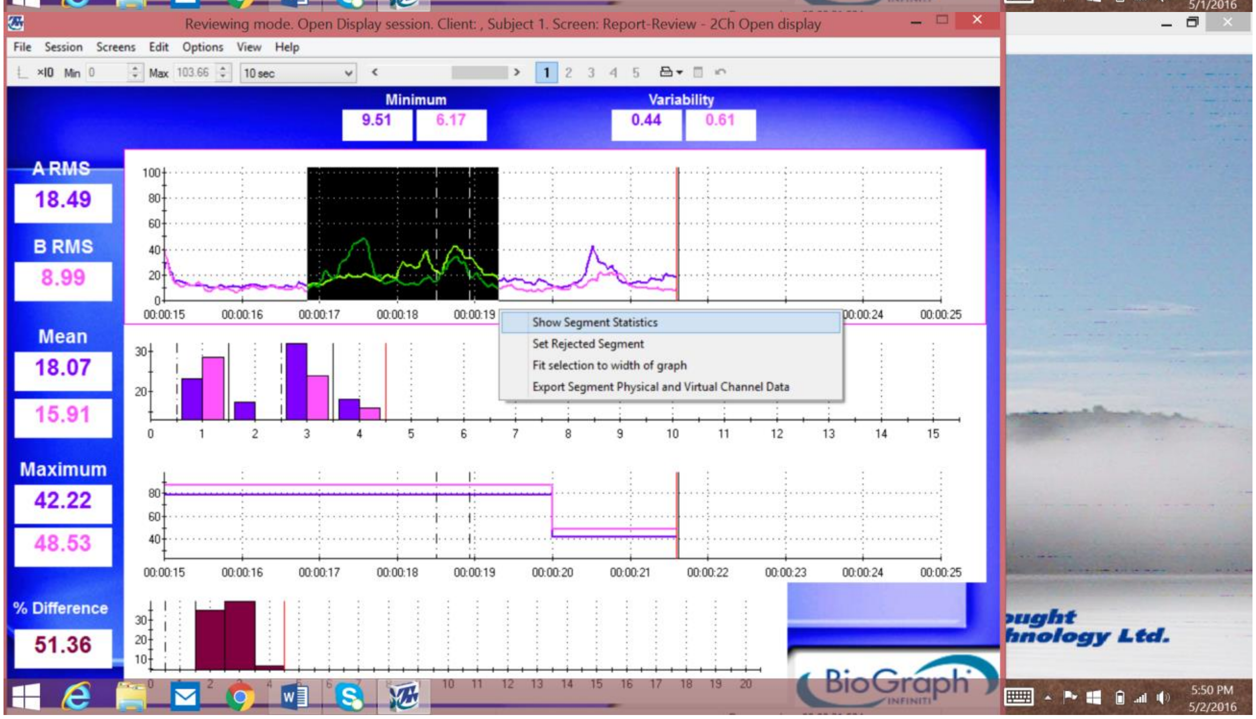
Trial 2


Reviewing mode. Open Display session. Client: , Subject 1. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
12.43
6.15
Variability
0.45
0.70
A RMS
24.78
B RMS
40.48
Mean
31.80
23.85
Maximum
78.46
87.42
% Difference
38.80
BioGraph INFINITI
6:49 PM
5/1/2016


Reviewing mode. Open Display session. Client: , Subject 1. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
12.43
6.15
Variability
0.45
0.70
A RMS
24.78
B RMS
40.48
Mean
31.80
23.85
Maximum
78.46
87.42
% Difference
38.80
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph INFINITI
5:48 PM
5/2/2016

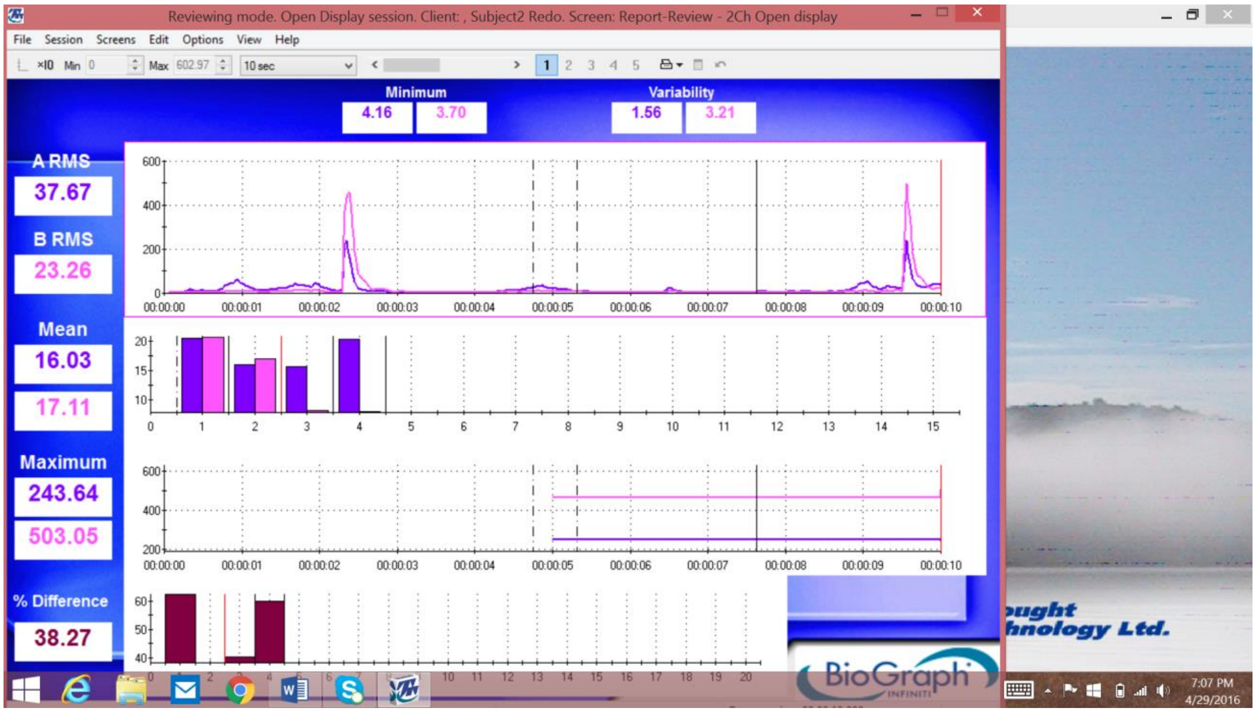
Trial 3


Reviewing mode. Open Display session. Client: , Subject 1. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
9.51
6.17
Variability
0.44
0.61
A RMS
18.49
B RMS
8.99
Mean
18.07
15.91
Maximum
42.22
48.53
% Difference
51.36
BioGraph
6:51 PM
5/1/2016


Reviewing mode. Open Display session. Client: , Subject 1. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
9.51
6.17
Variability
0.44
0.61
A RMS
18.49
B RMS
8.99
Mean
18.07
15.91
Maximum
42.22
48.53
% Difference
51.36
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph
5:50 PM
5/2/2016

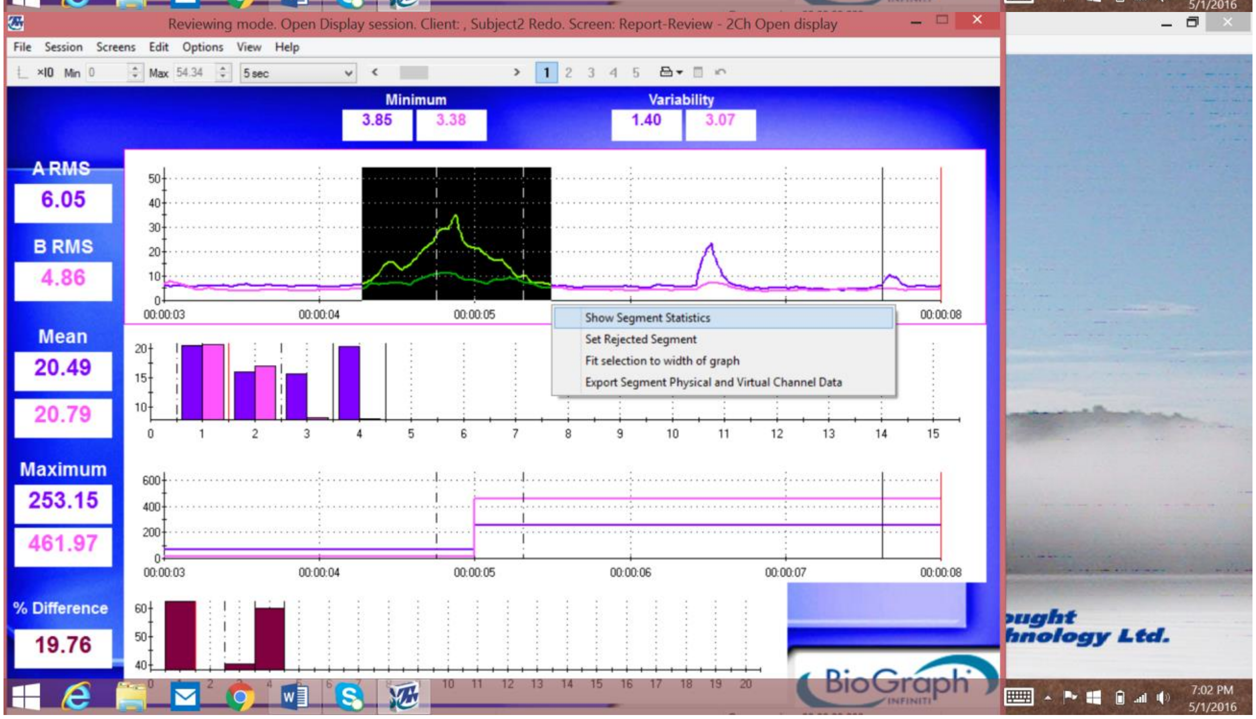
Subject 2
½ teaspoon pudding

Trial 1- Evidence that it was difficult to see (all trials looked like this at 10 sec interval)

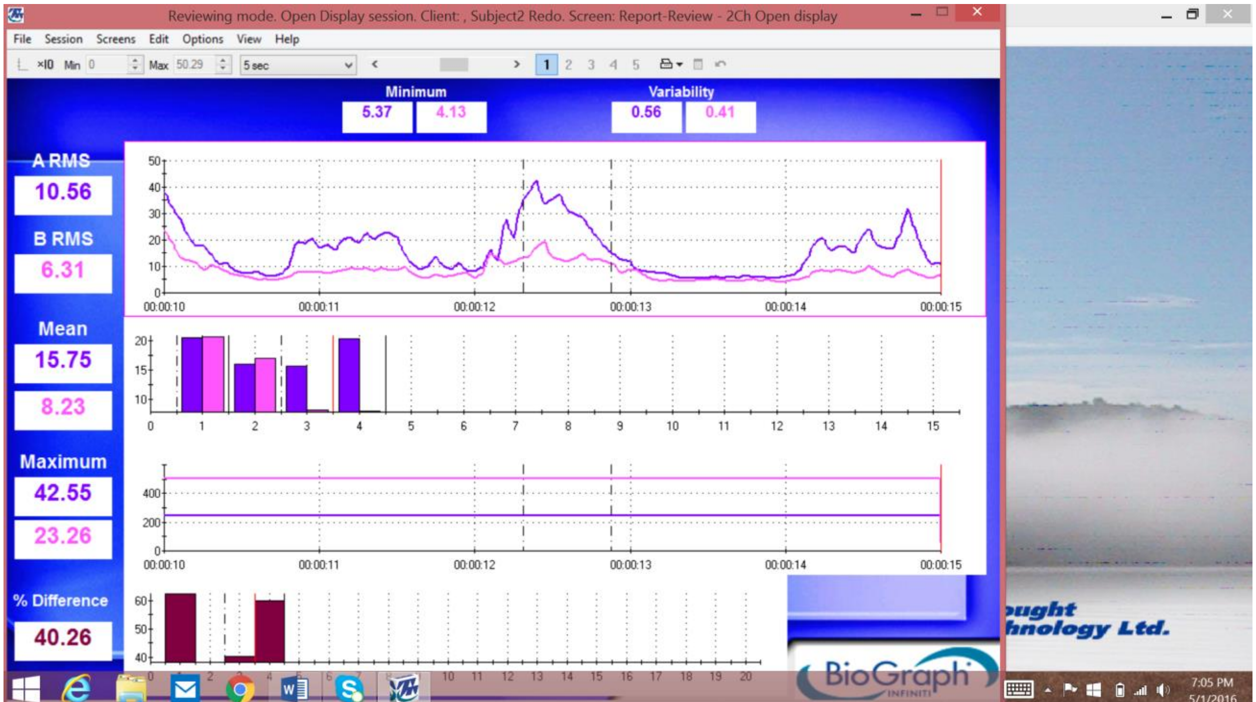


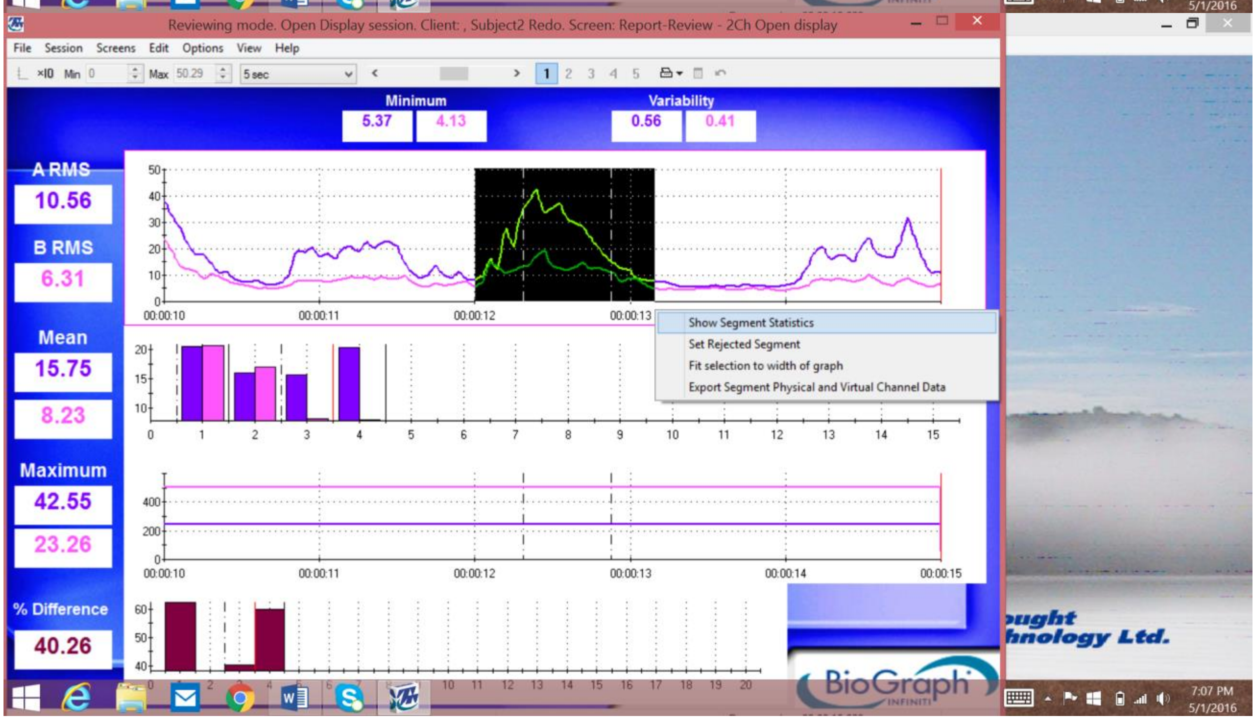
Trial 1 (zoomed into 5 sec)


Reviewing mode. Open Display session. Client: , Subject2 Redo. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Min 0
Max 54.34
5 sec
Minimum
3.85
3.38
Variability
1.40
3.07
A RMS
6.05
B RMS
4.86
Mean
20.49
20.79
Maximum
253.15
461.97
% Difference
19.76
00:00:03 00:00:04 00:00:05 00:00:06 00:00:07 00:00:08
BioGraph INFINITI
ught
hnology Ltd.
7:01 PM
5/1/2016

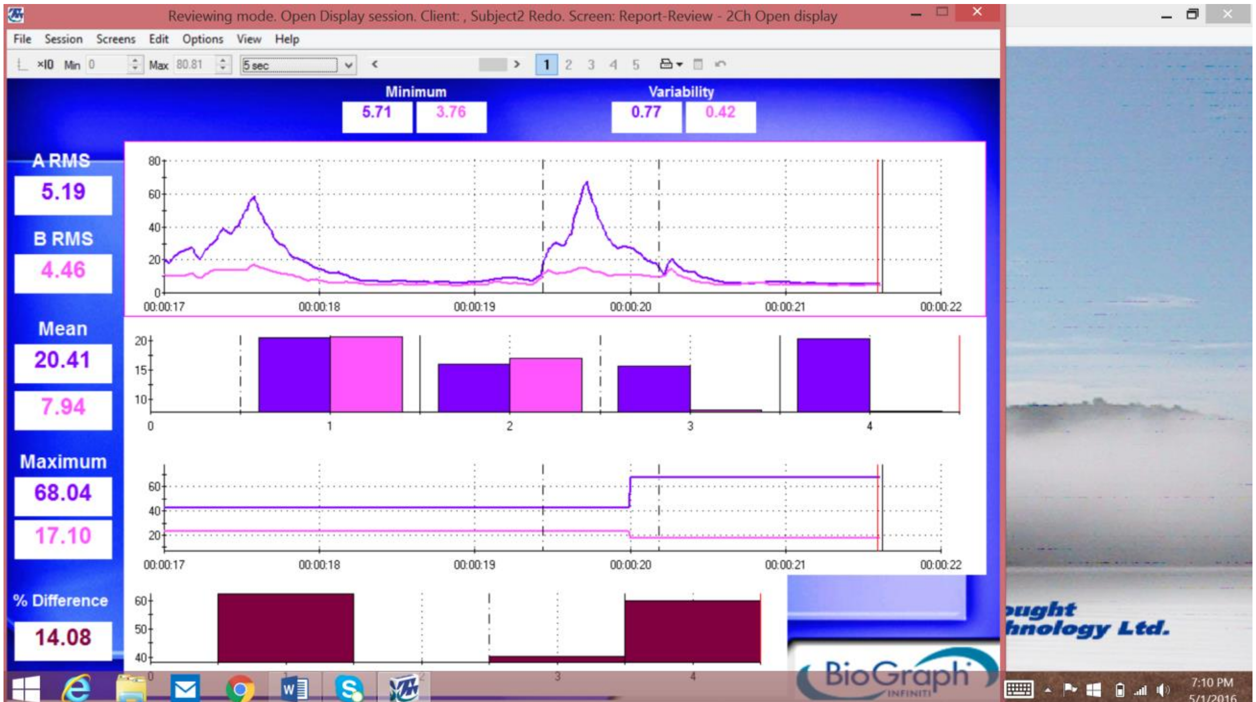

Reviewing mode. Open Display session. Client: , Subject2 Redo. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Min 0
Max 54.34
5 sec
Minimum
3.85
3.38
Variability
1.40
3.07
A RMS
6.05
B RMS
4.86
Mean
20.49
20.79
Maximum
253.15
461.97
% Difference
19.76
00:00:03 00:00:04 00:00:05 00:00:06 00:00:07 00:00:08
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph INFINITI
ught
hnology Ltd.
7:02 PM
5/1/2016

Trial 2 (zoomed into 5 sec)



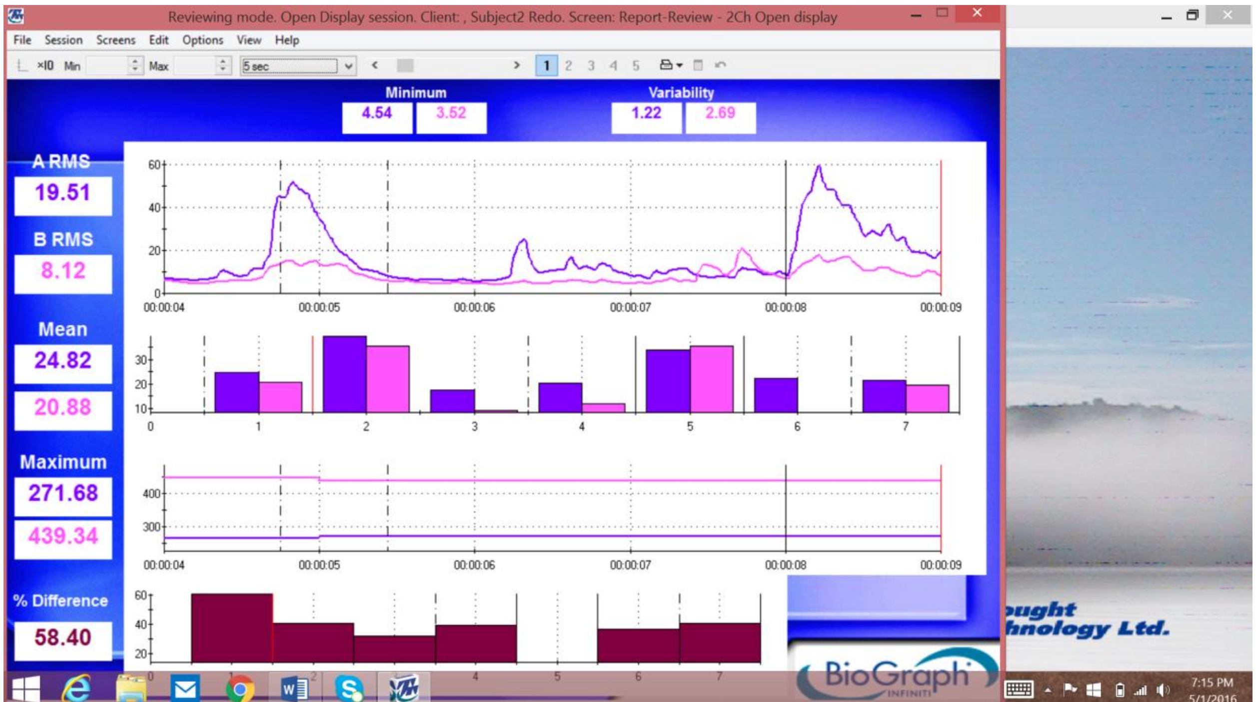


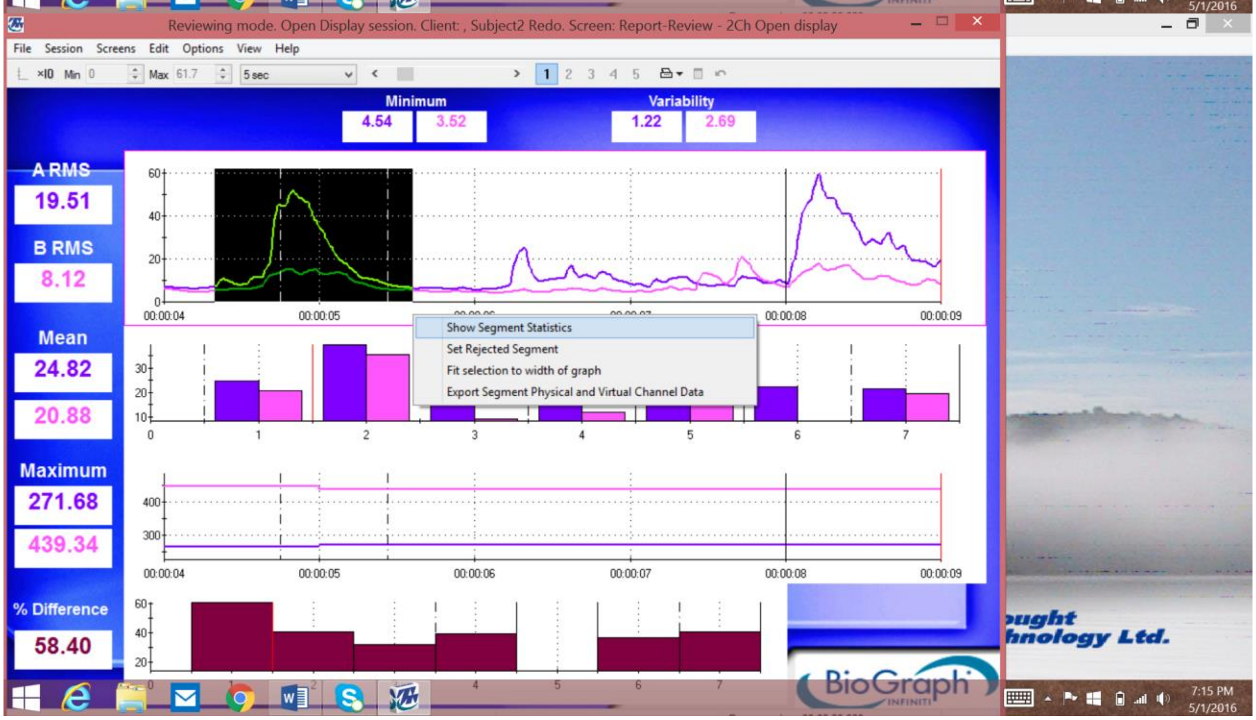
Trial 3 (zoomed into 5 sec)



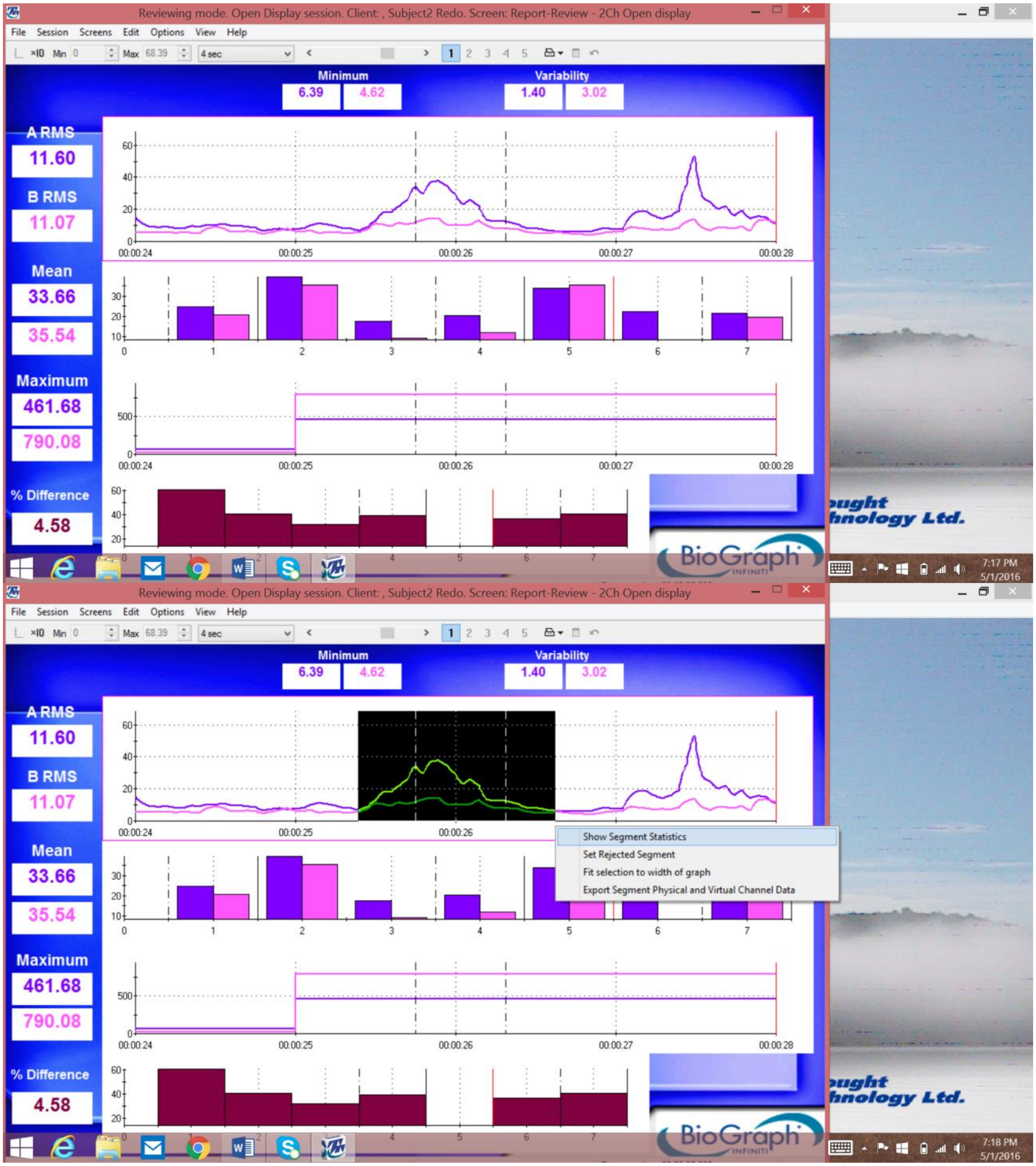
1 ½ pudding

Trial 1 (zoomed into 5 sec)

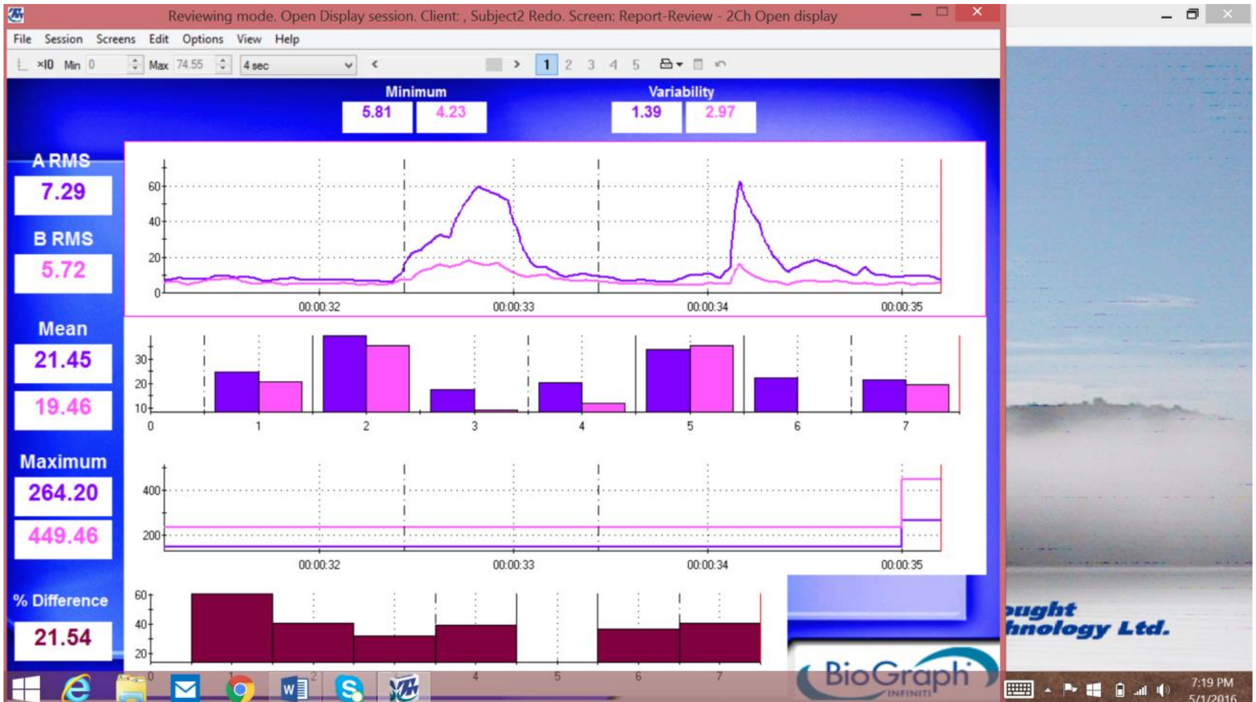




Trial 2 (zoomed into 4 sec)

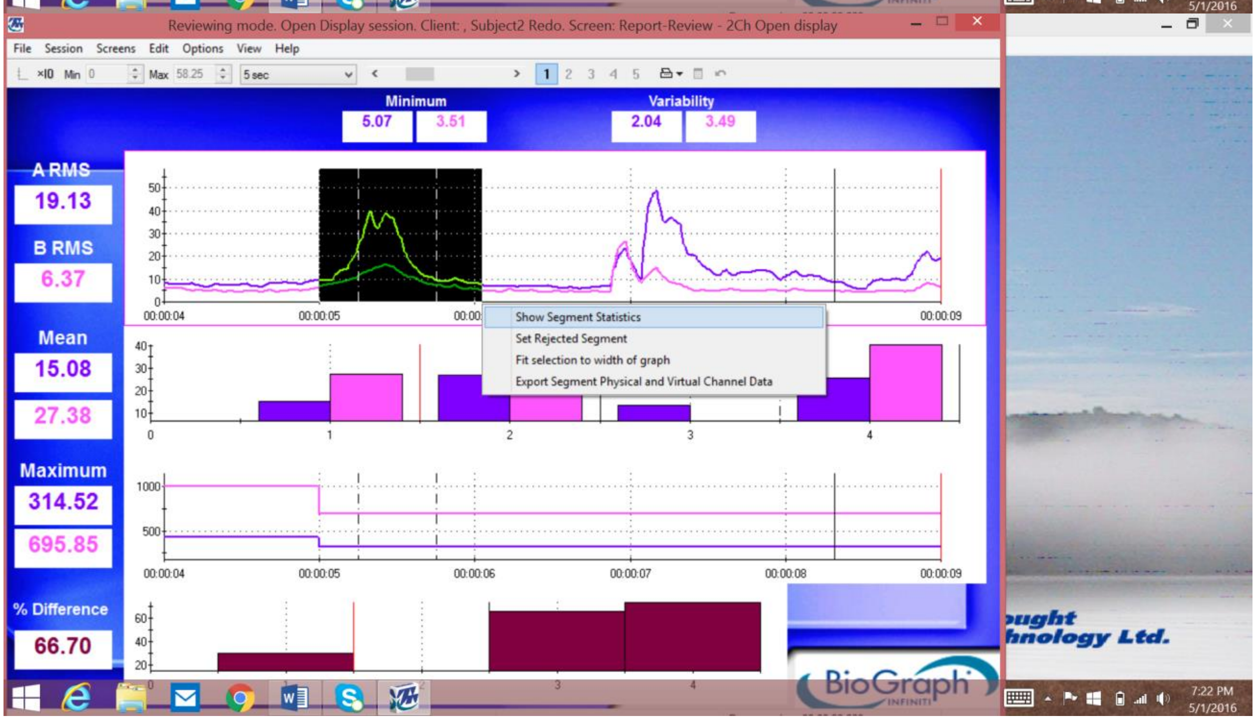


Trial 3 (zoomed into 4 sec)

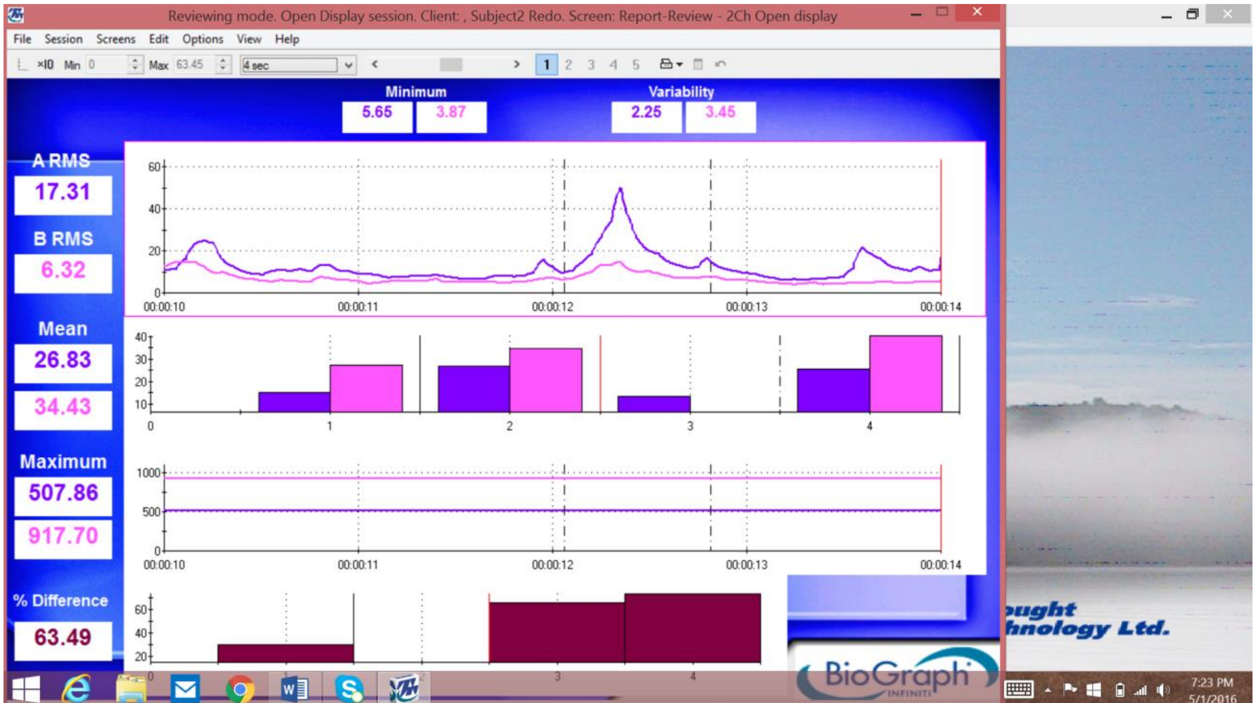


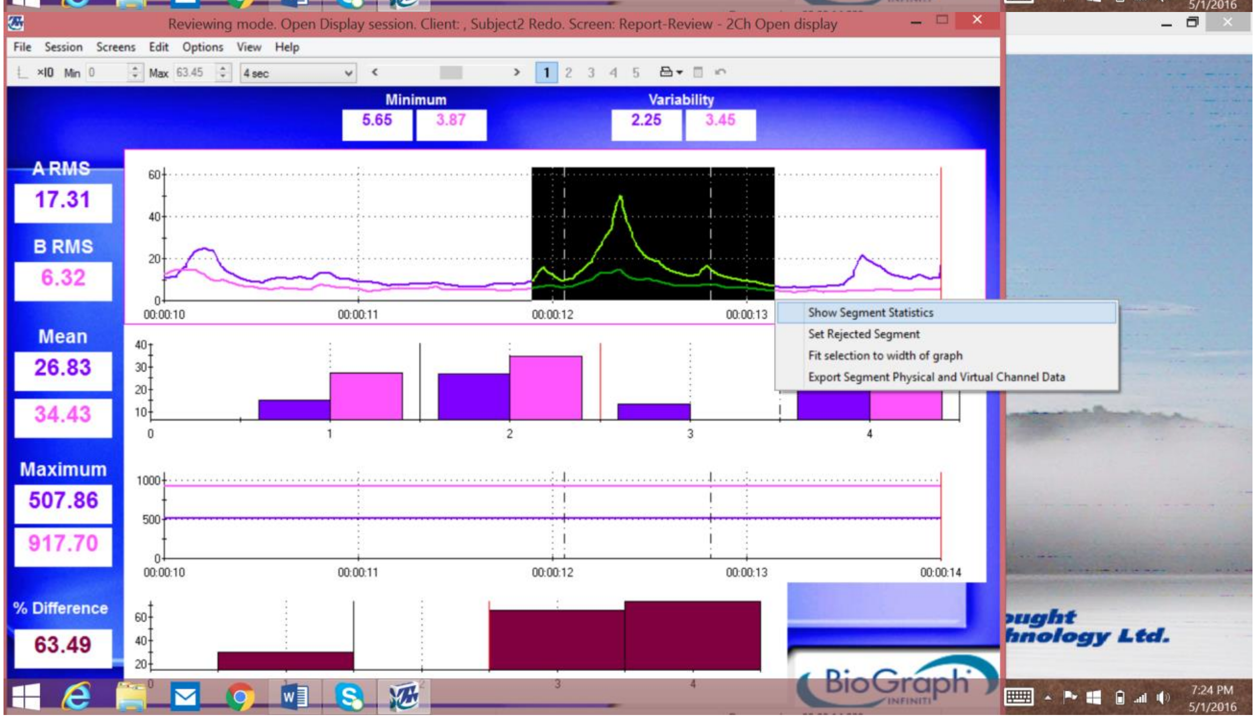
Water

Trial 1 (zoomed into 5 sec)

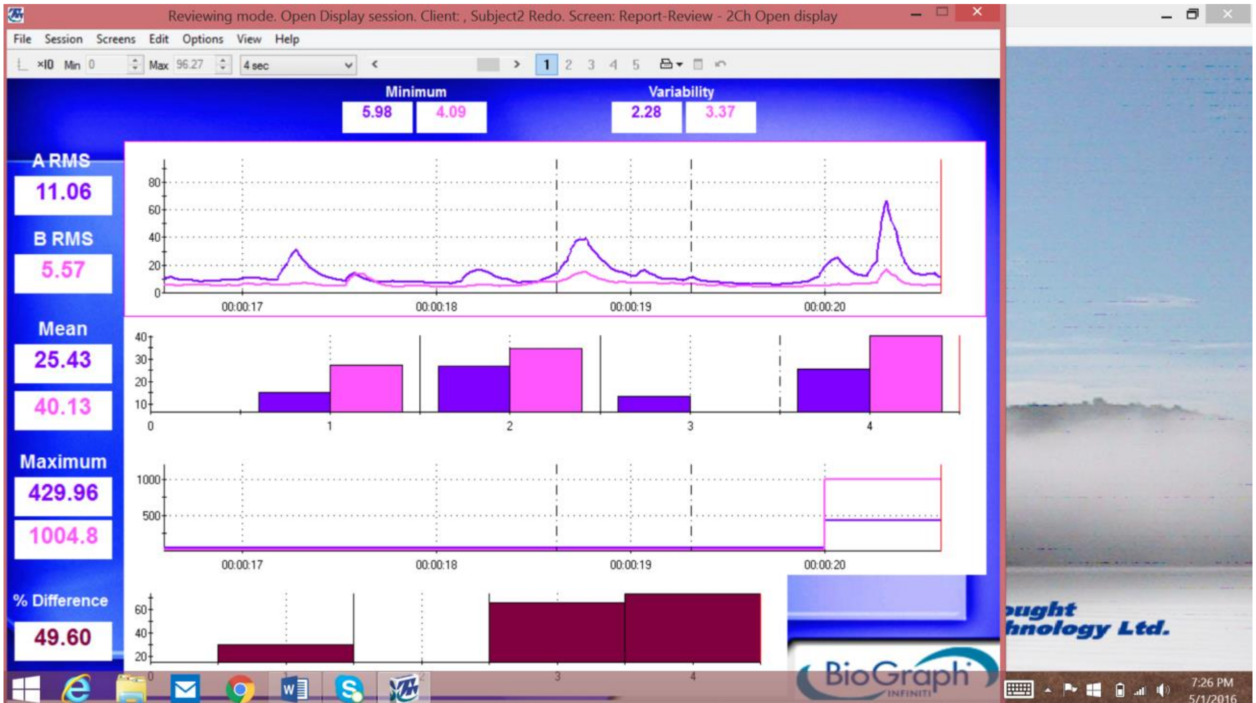


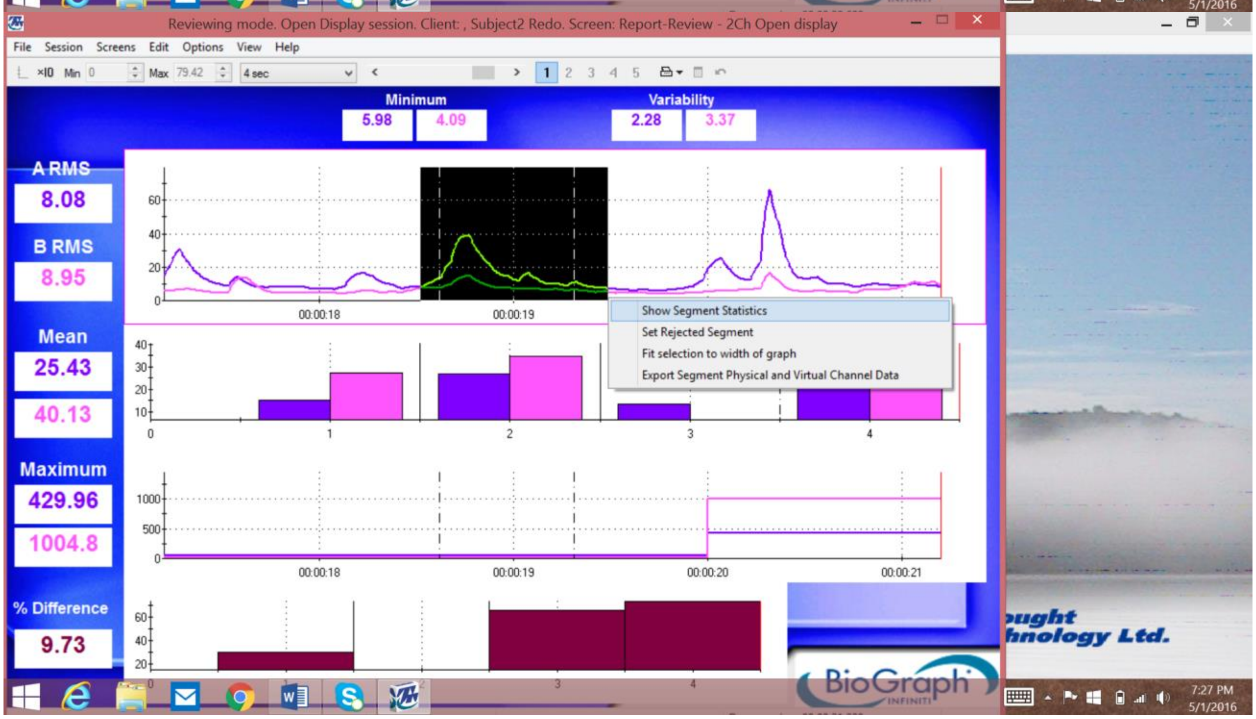
Trial 2 (zoomed into 4 sec)





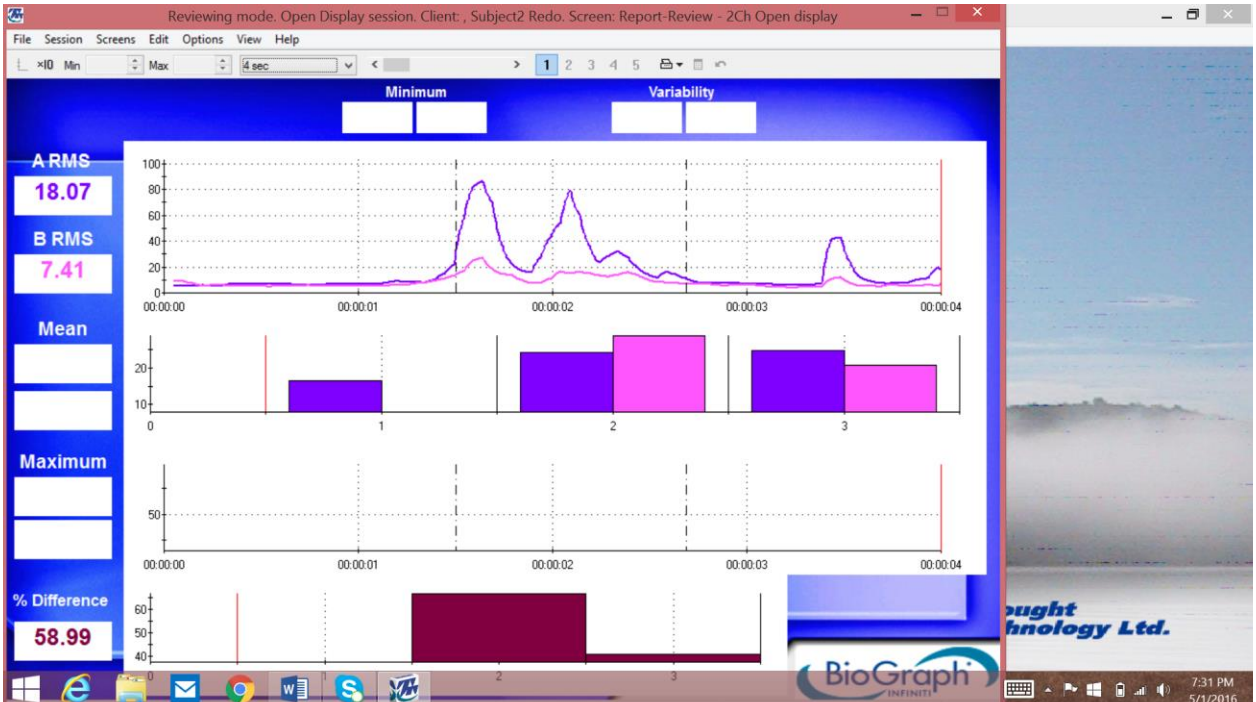
Trial 3 (zoomed into 4 seconds)

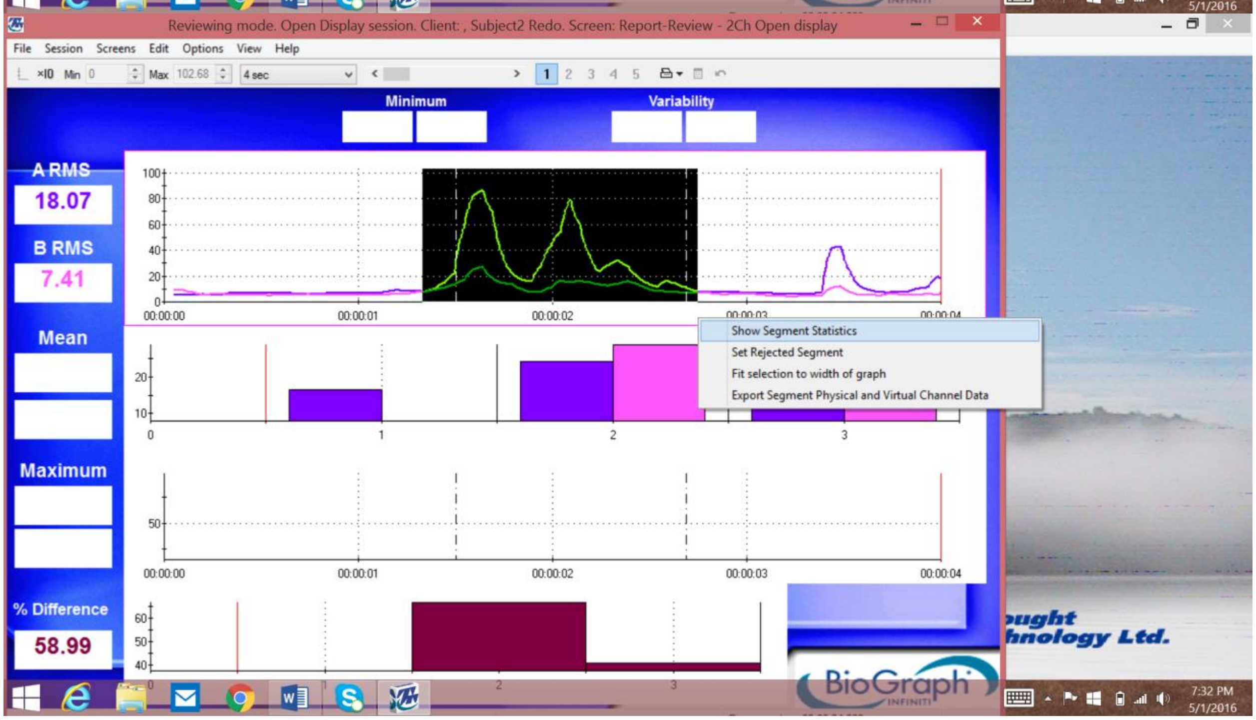




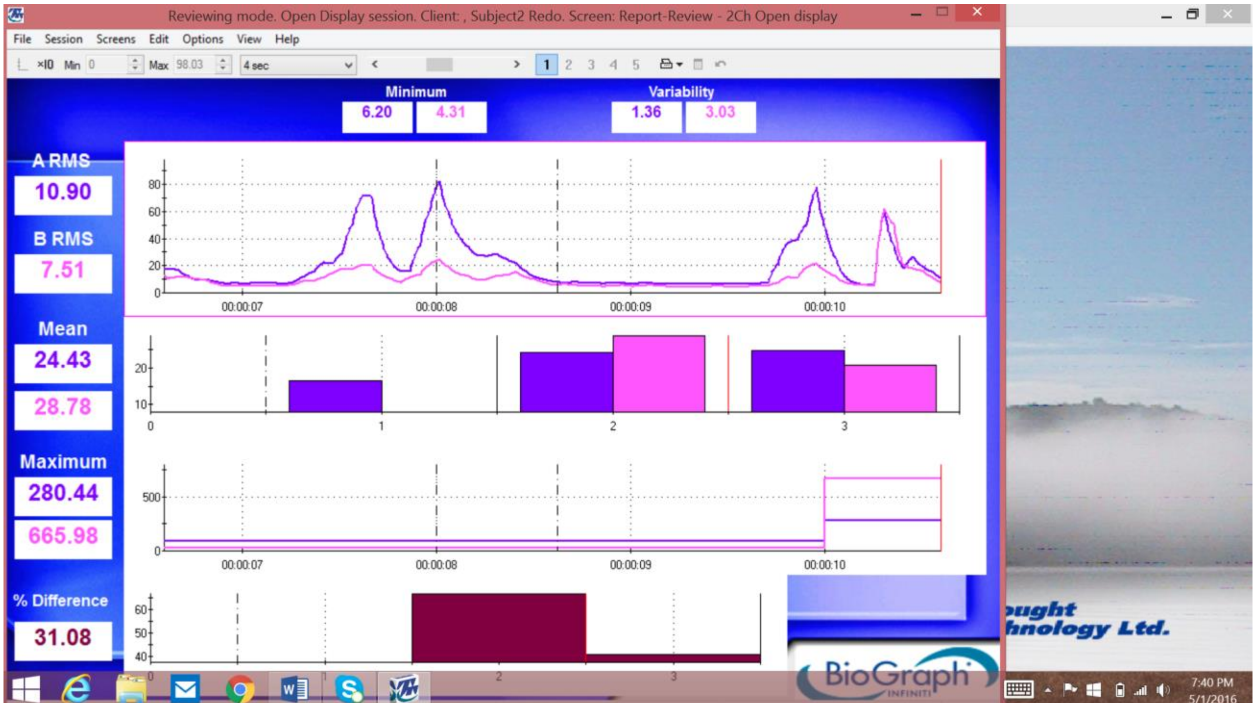
Triscuit

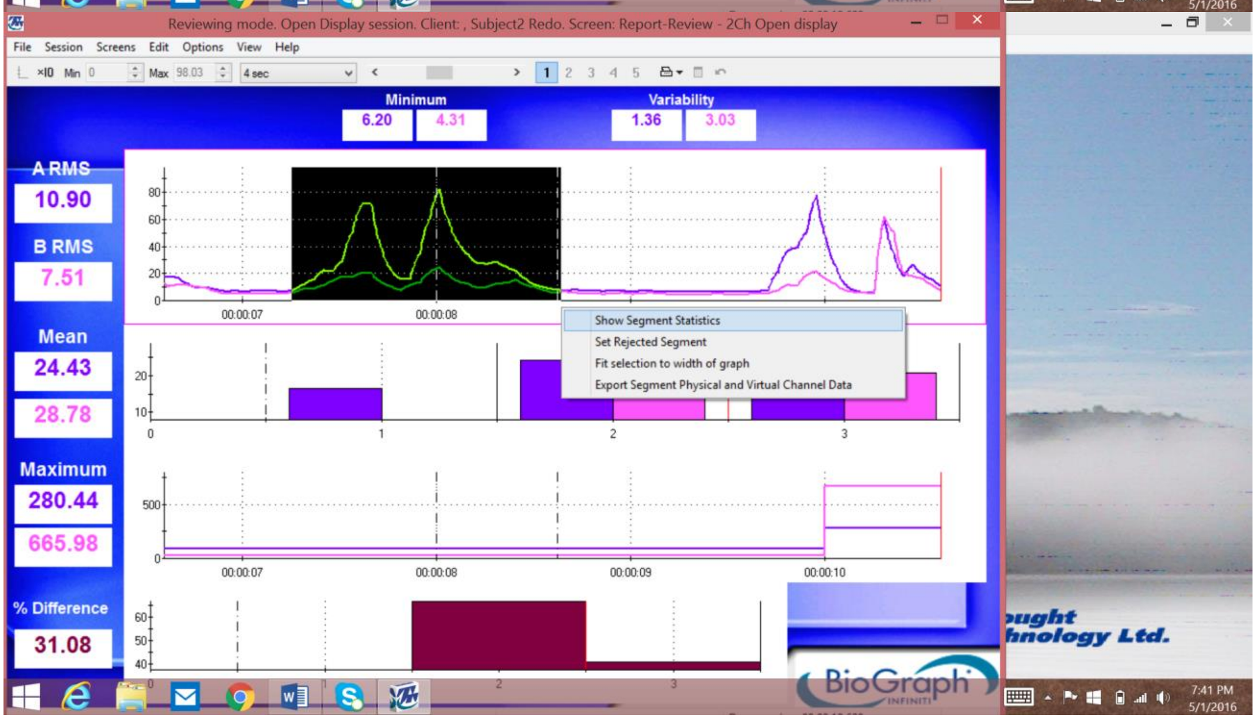
Trial 1 (zoomed into 4 sec)



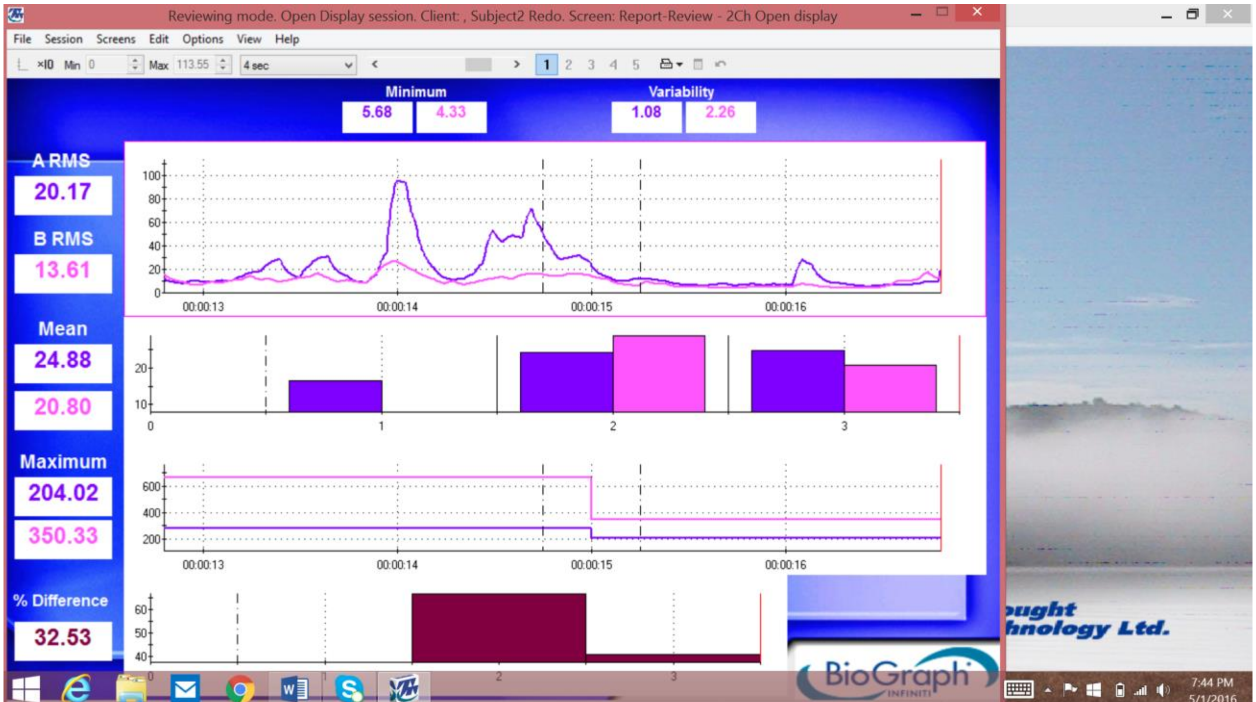


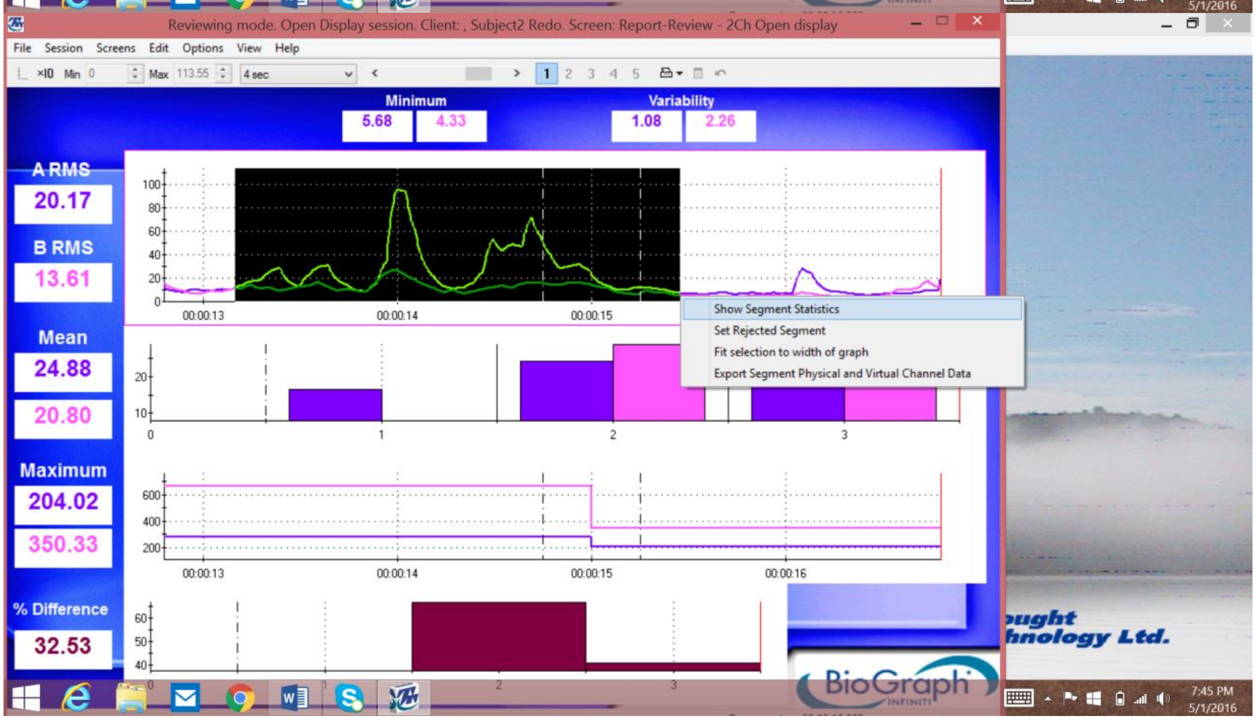
Trial 2 (zoomed into 4 sec)





Trial 3 (zoomed into 4 sec)

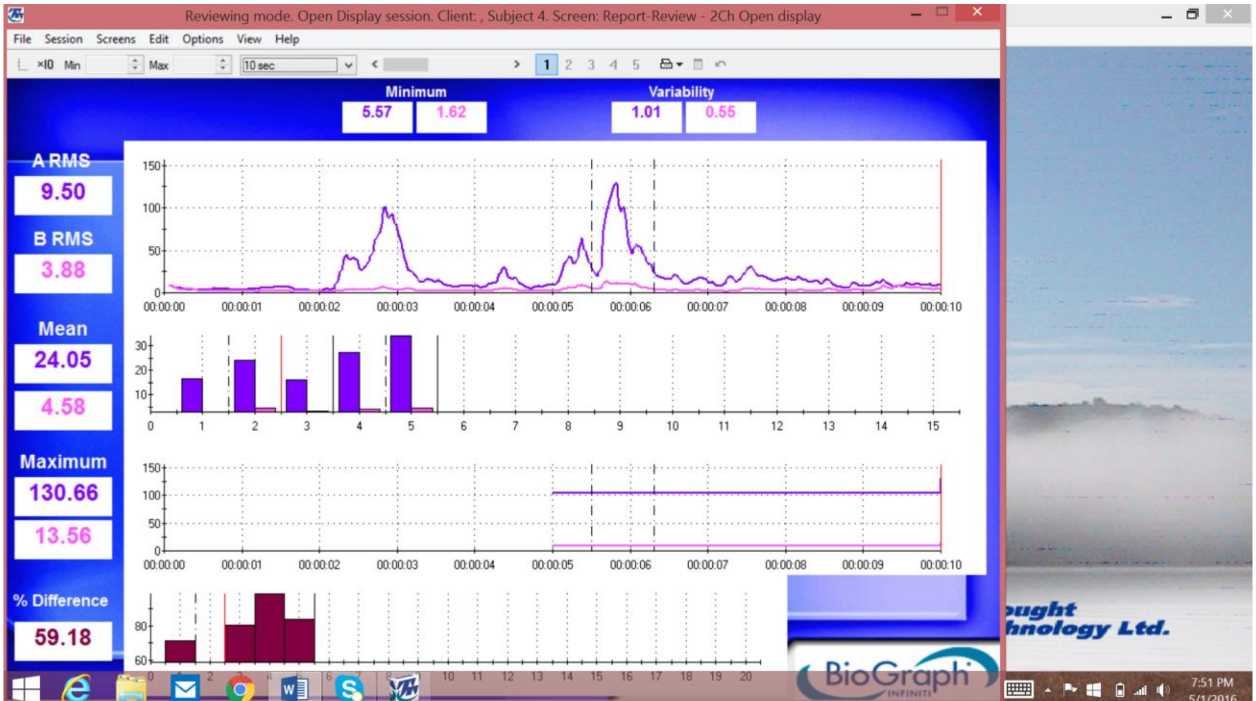


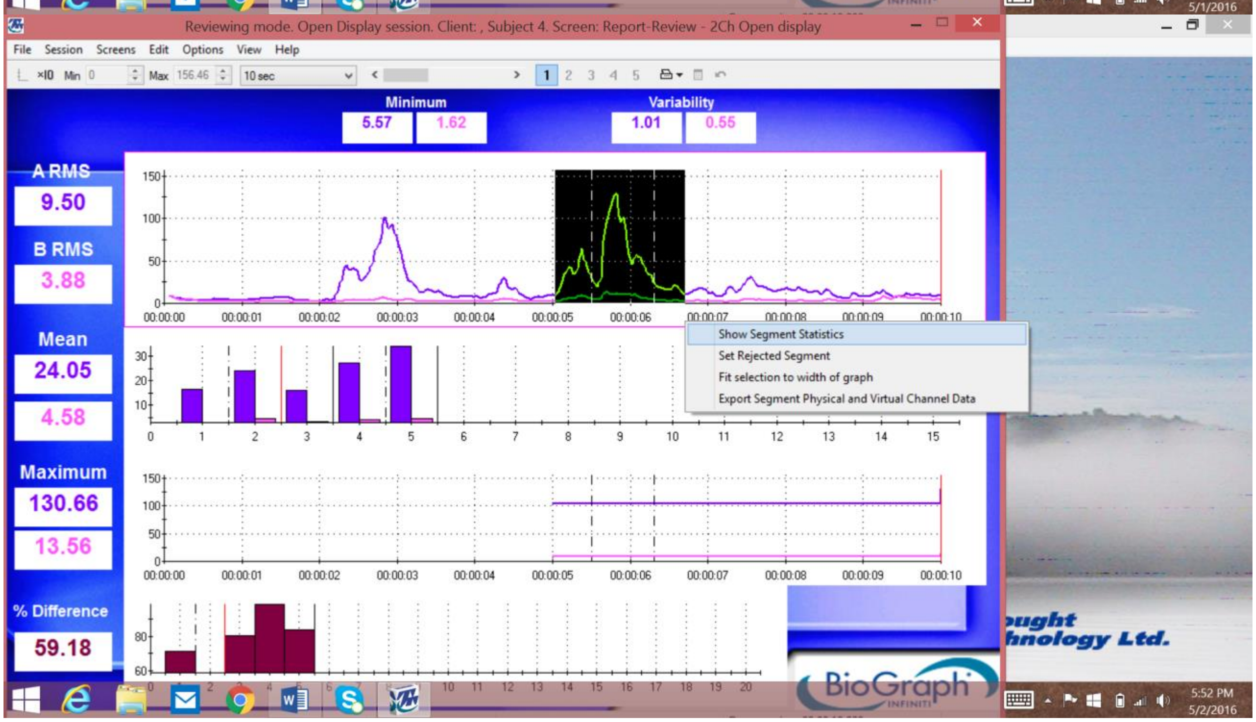


Subject 4

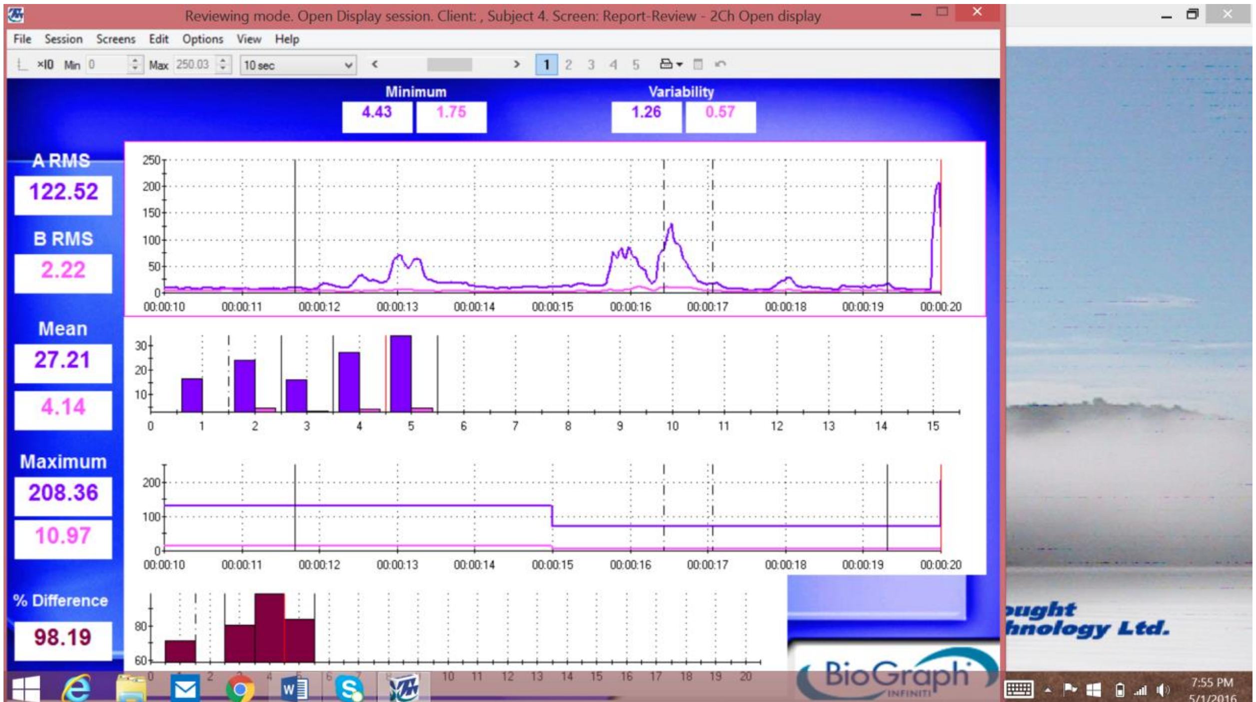
½ pudding

Trial 1



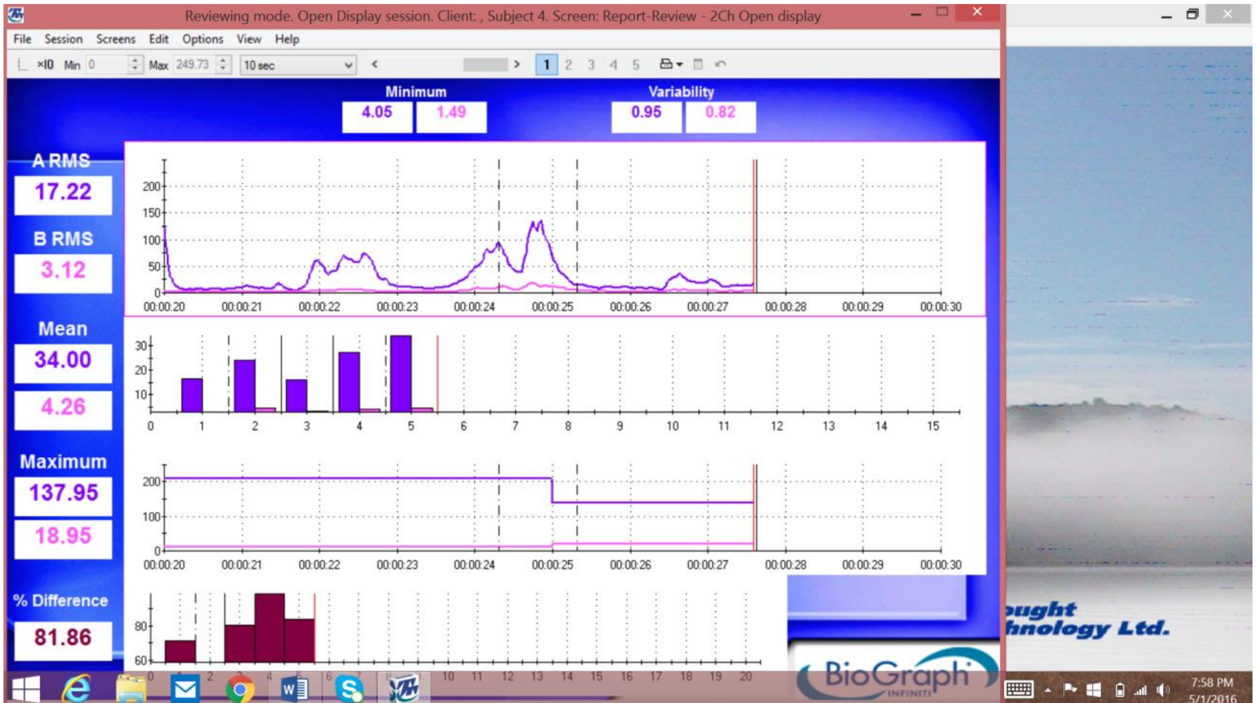


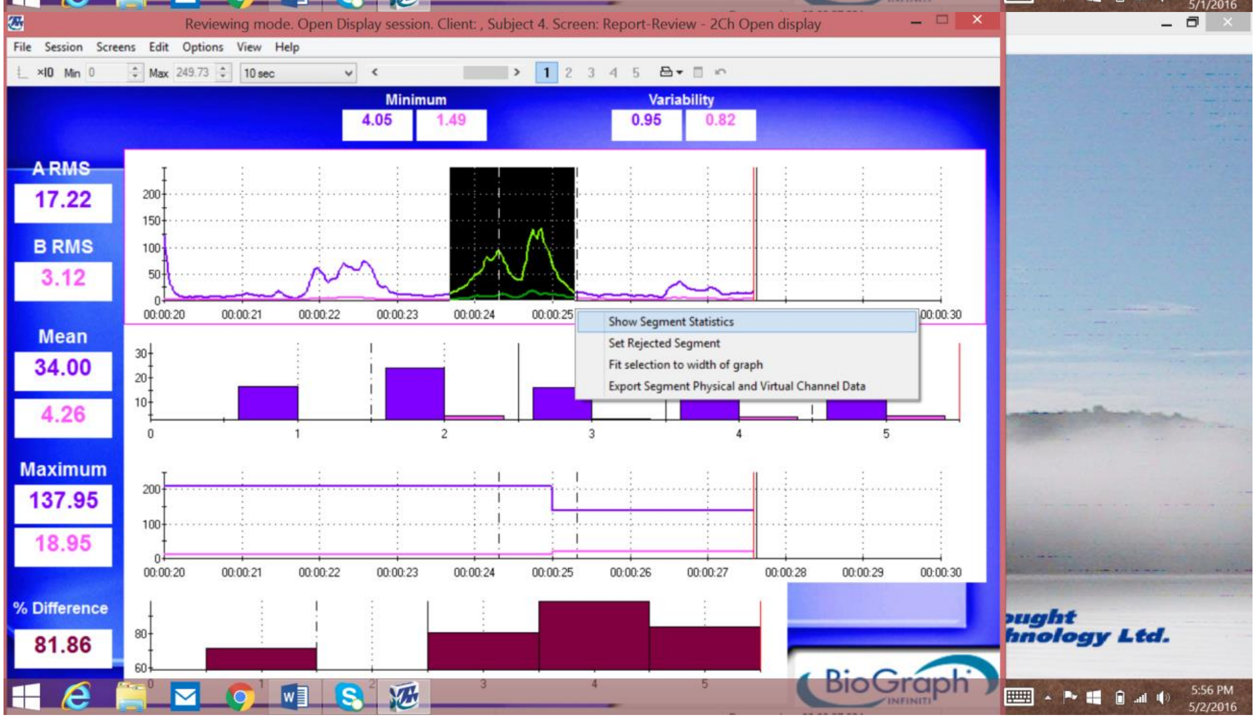
Trial 2


Reviewing mode. Open Display session. Client: , Subject 4. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
4.43
1.75
Variability
1.26
0.57
A RMS
122.52
B RMS
2.22
Mean
27.21
4.14
Maximum
208.36
10.97
% Difference
98.19
BioGraph INFINITI
7:55 PM
5/1/2016


Reviewing mode. Open Display session. Client: , Subject 4. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
4.43
1.75
Variability
1.26
0.57
A RMS
122.52
B RMS
2.22
Mean
27.21
4.14
Maximum
208.36
10.97
% Difference
98.19
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph INFINITI
5:54 PM
5/2/2016

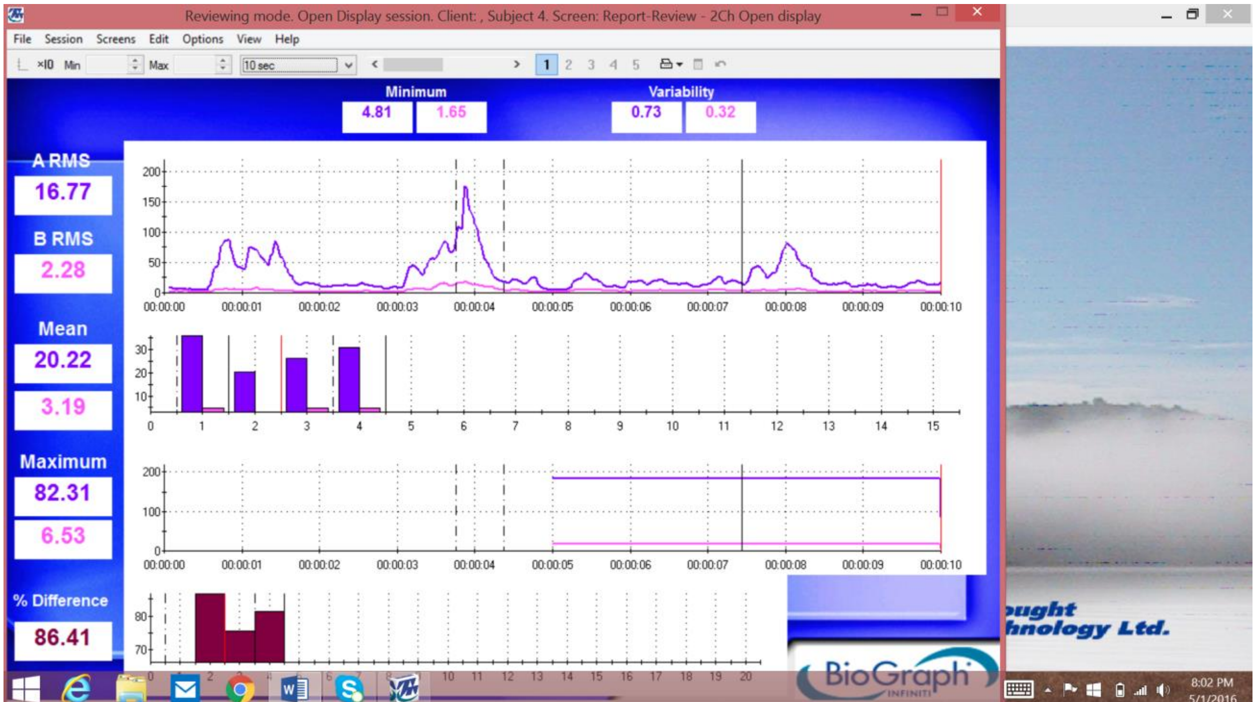
Trial 3

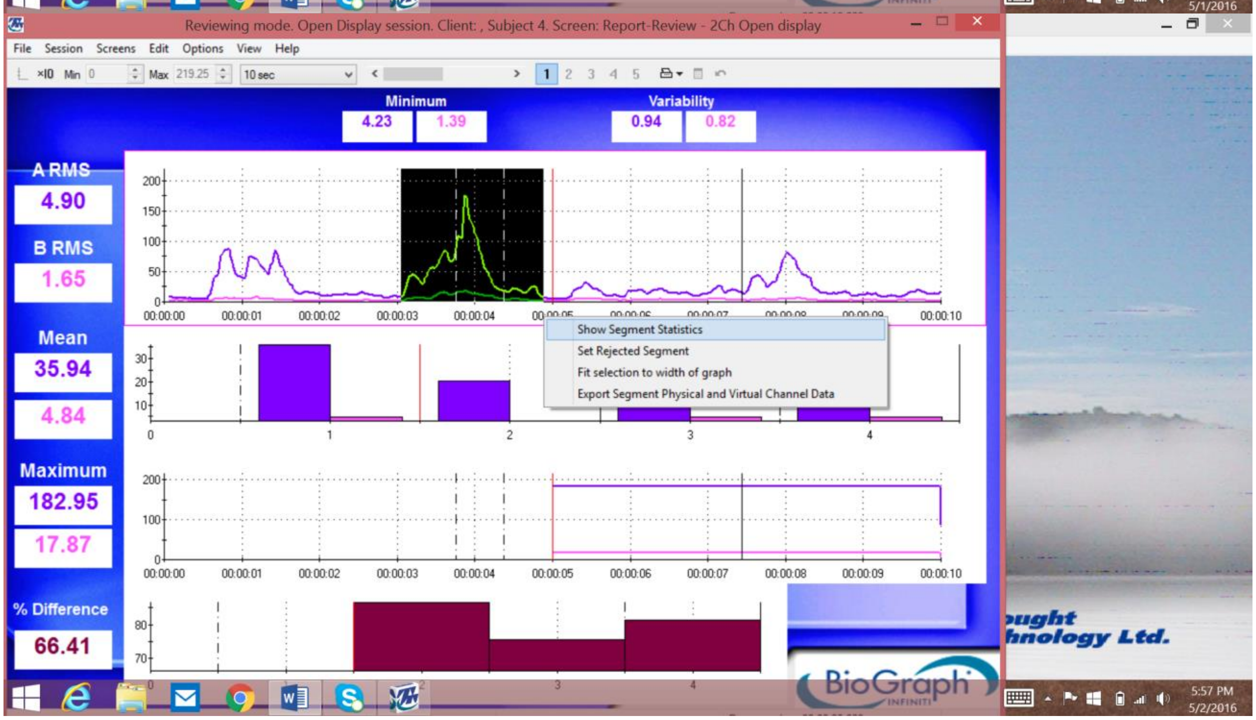

Reviewing mode. Open Display session. Client: , Subject 4. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
4.05
1.49
Variability
0.95
0.82
A RMS
17.22
B RMS
3.12
Mean
34.00
4.26
Maximum
137.95
18.95
% Difference
81.86
BioGraph INFINITI
7:58 PM
5/1/2016


Reviewing mode. Open Display session. Client: , Subject 4. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
4.05
1.49
Variability
0.95
0.82
A RMS
17.22
B RMS
3.12
Mean
34.00
4.26
Maximum
137.95
18.95
% Difference
81.86
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph INFINITI
5:56 PM
5/2/2016

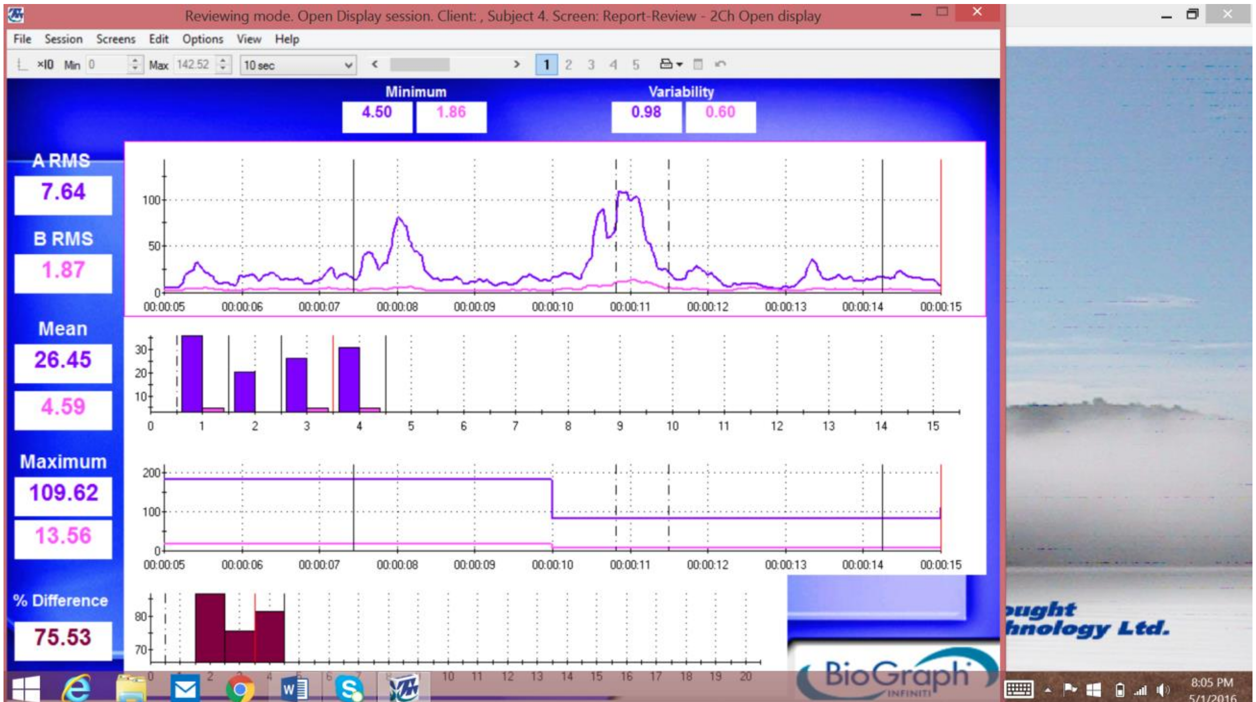
1 ½ pudding

Trial 1



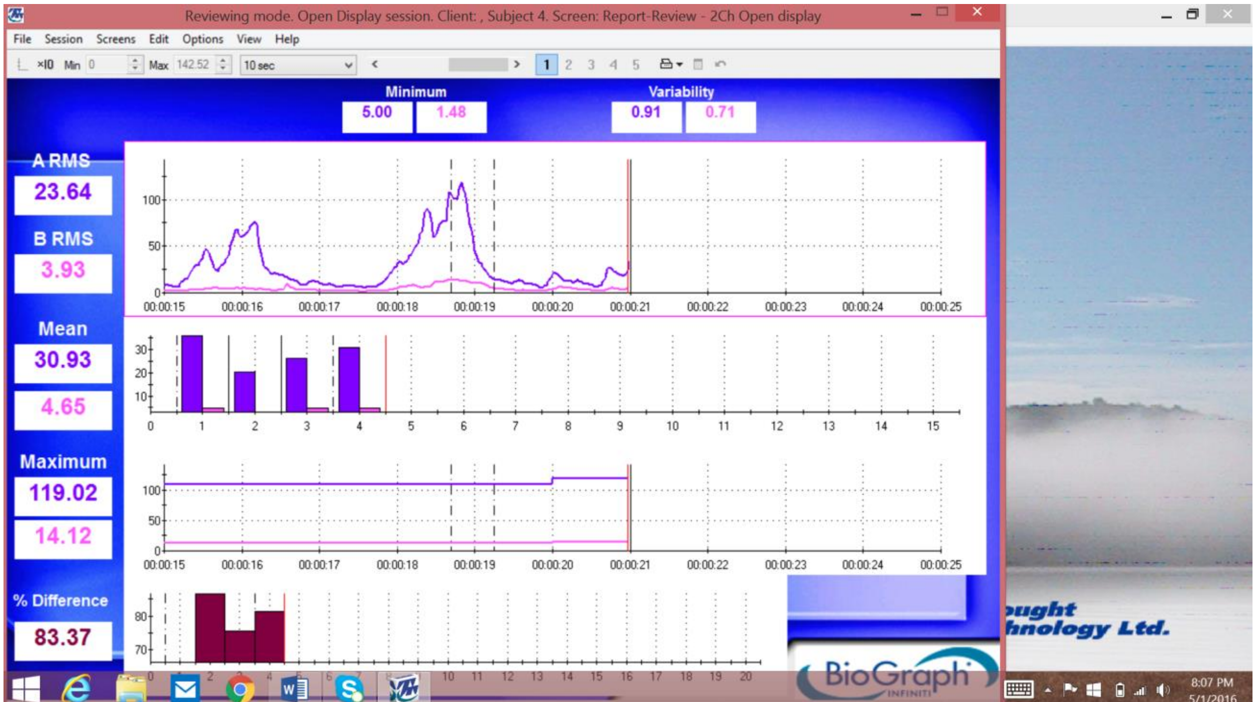


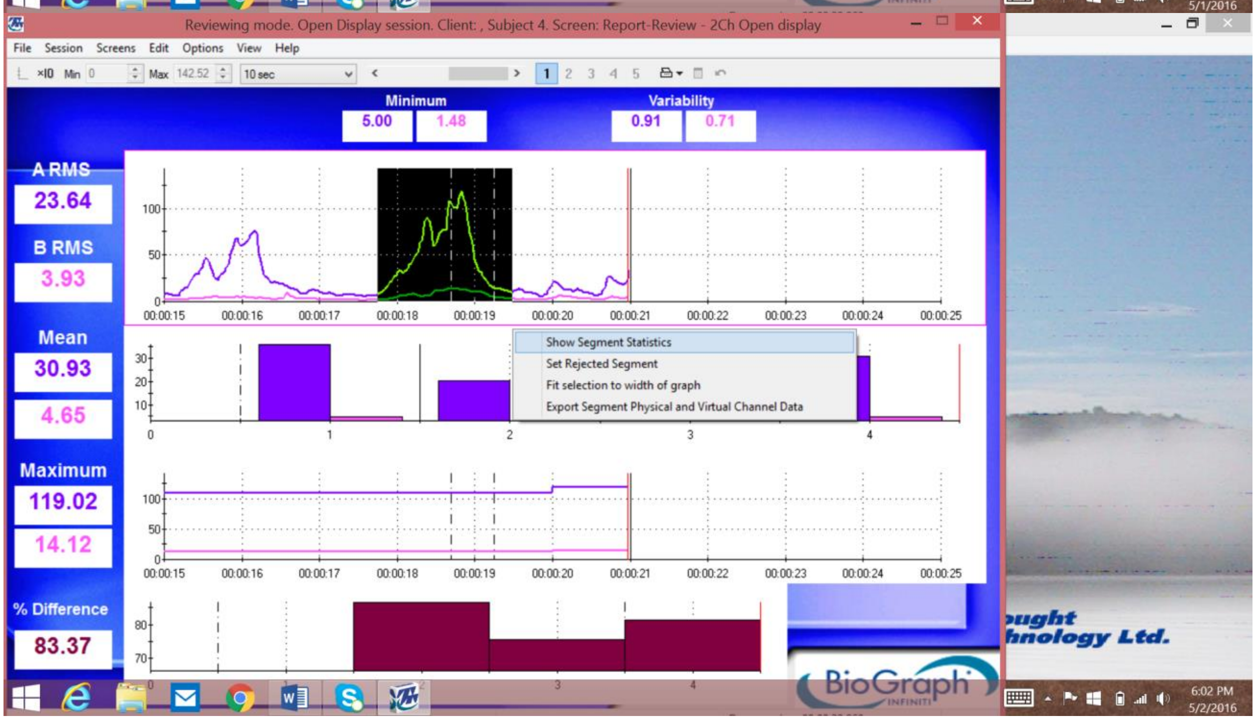
Trial 2


Reviewing mode. Open Display session. Client: , Subject 4. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
4.50
1.86
Variability
0.98
0.60
A RMS
7.64
B RMS
1.87
Mean
26.45
4.59
Maximum
109.62
13.56
% Difference
75.53
BioGraph
8:05 PM
5/1/2016


Reviewing mode. Open Display session. Client: , Subject 4. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
4.50
1.86
Variability
0.98
0.60
A RMS
7.64
B RMS
1.87
Mean
26.45
4.59
Maximum
109.62
13.56
% Difference
75.53
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph
5:59 PM
5/2/2016

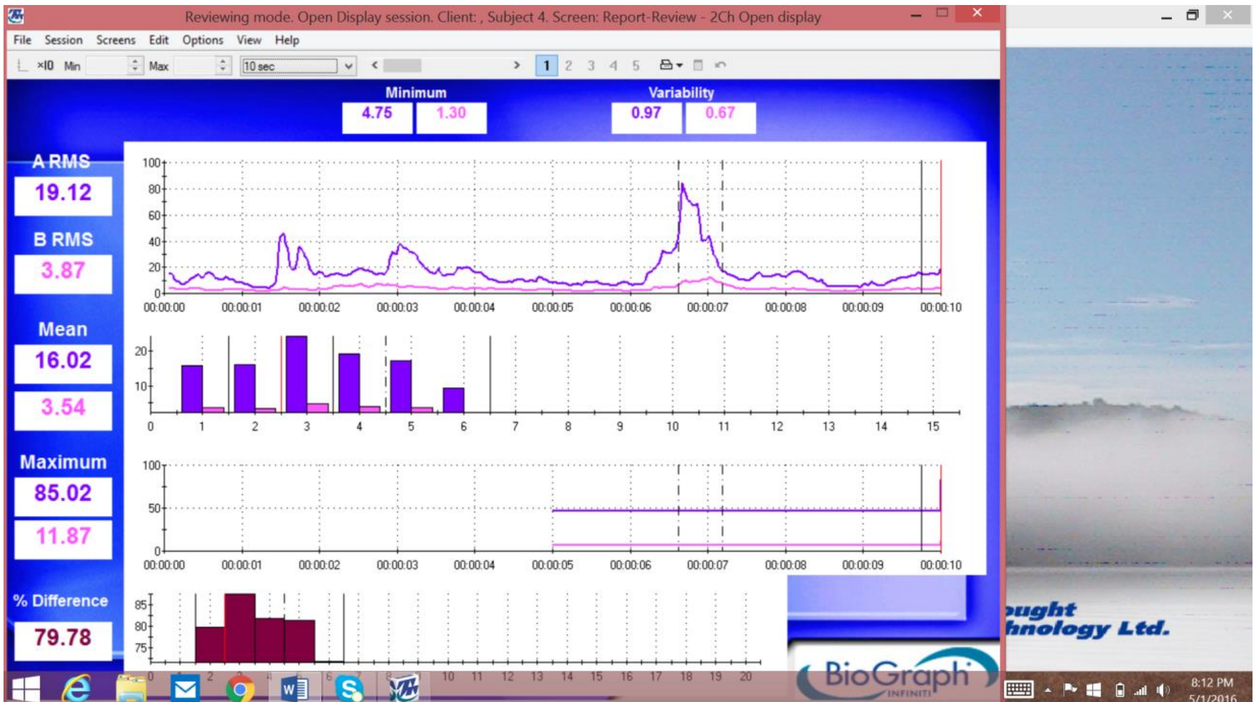
Trial 3

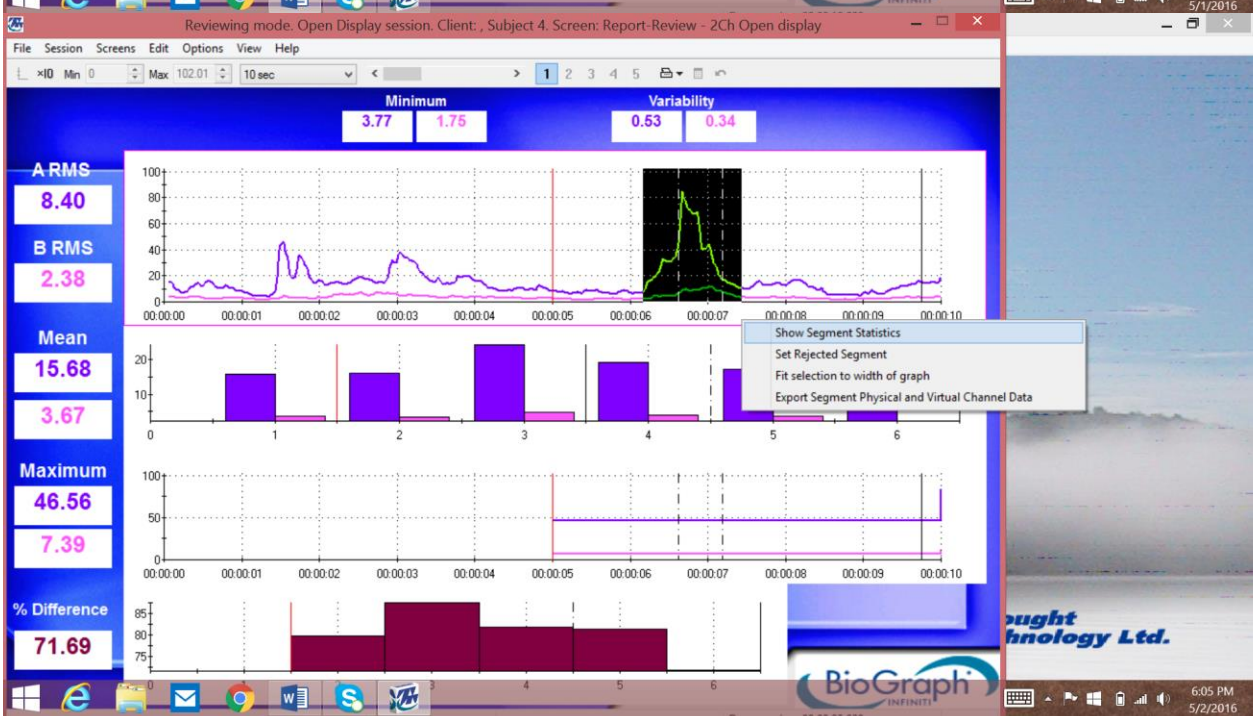

Reviewing mode. Open Display session. Client: , Subject 4. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
5.00
1.48
Variability
0.91
0.71
A RMS
23.64
B RMS
3.93
Mean
30.93
4.65
Maximum
119.02
14.12
% Difference
83.37
BioGraph
INFINITI
8:07 PM
5/1/2016


Reviewing mode. Open Display session. Client: , Subject 4. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
5.00
1.48
Variability
0.91
0.71
A RMS
23.64
B RMS
3.93
Mean
30.93
4.65
Maximum
119.02
14.12
% Difference
83.37
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph
INFINITI
6:02 PM
5/2/2016

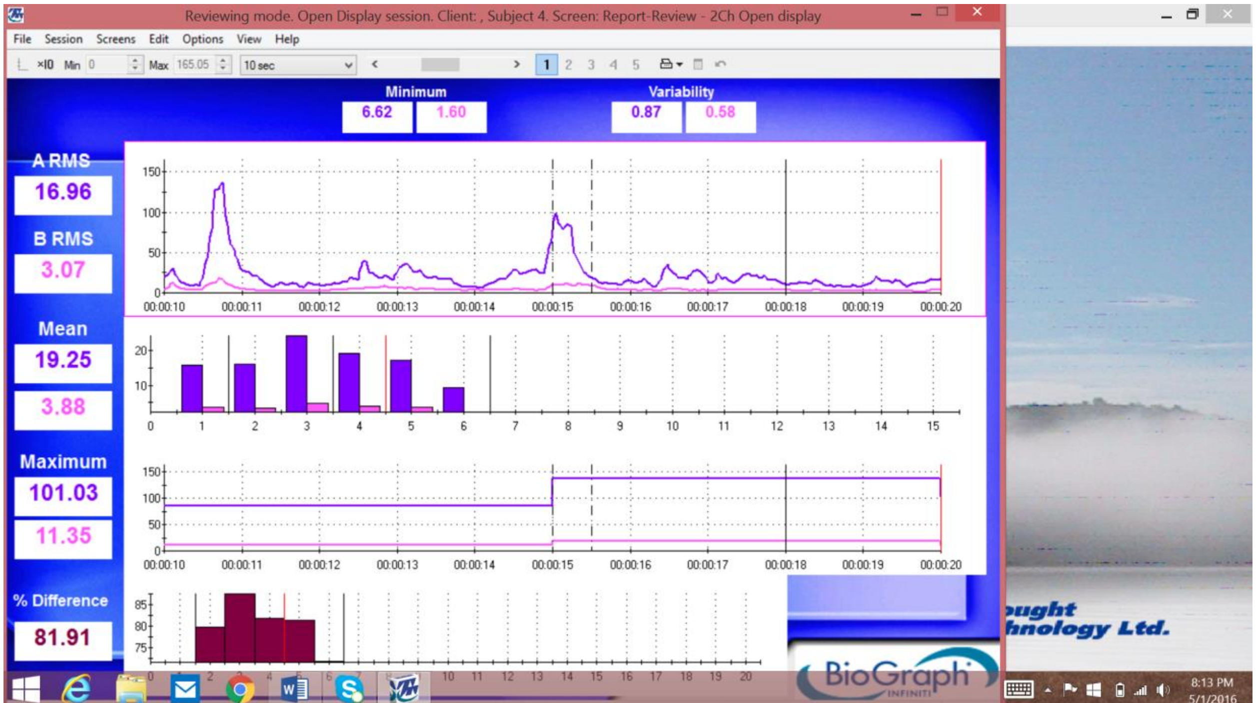
Water

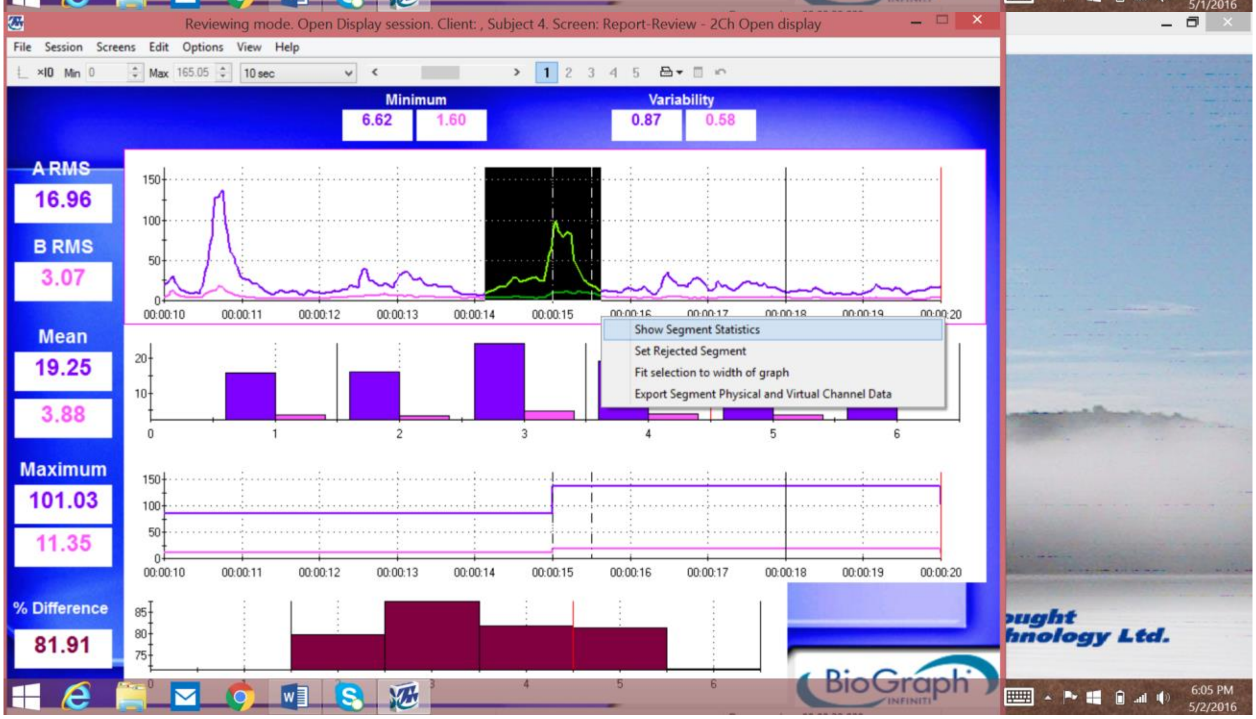
Trial 1



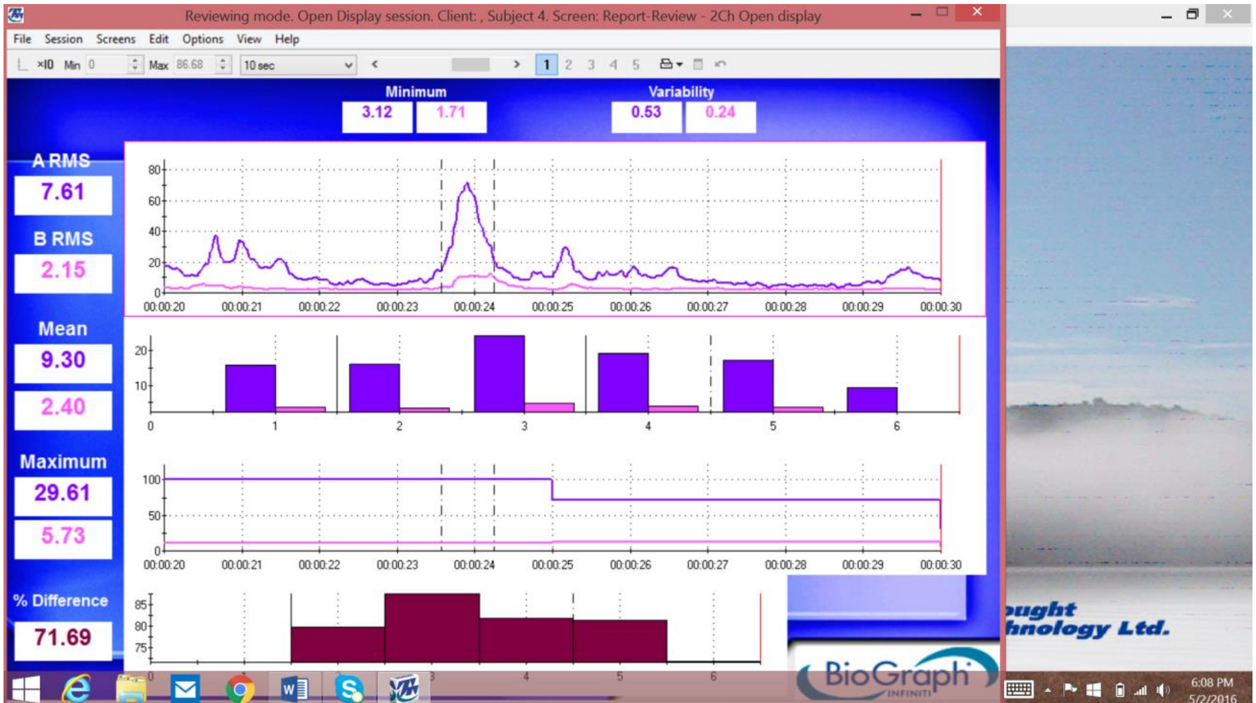


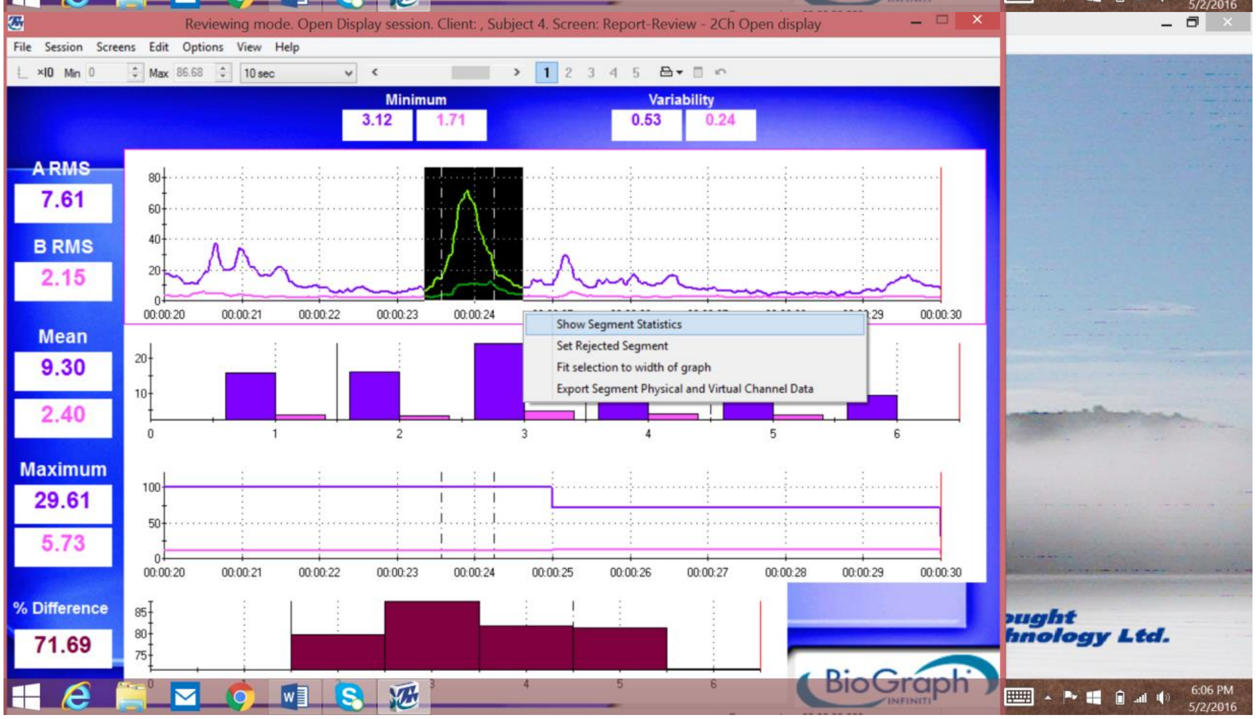
Trial 2


Reviewing mode. Open Display session. Client: , Subject 4. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
6.62
1.60
Variability
0.87
0.58
A RMS
16.96
B RMS
3.07
Mean
19.25
3.88
Maximum
101.03
11.35
% Difference
81.91
BioGraph INFINITI
8:13 PM
5/1/2016


Reviewing mode. Open Display session. Client: , Subject 4. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
6.62
1.60
Variability
0.87
0.58
A RMS
16.96
B RMS
3.07
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
Mean
19.25
3.88
Maximum
101.03
11.35
% Difference
81.91
BioGraph INFINITI
6:05 PM
5/2/2016

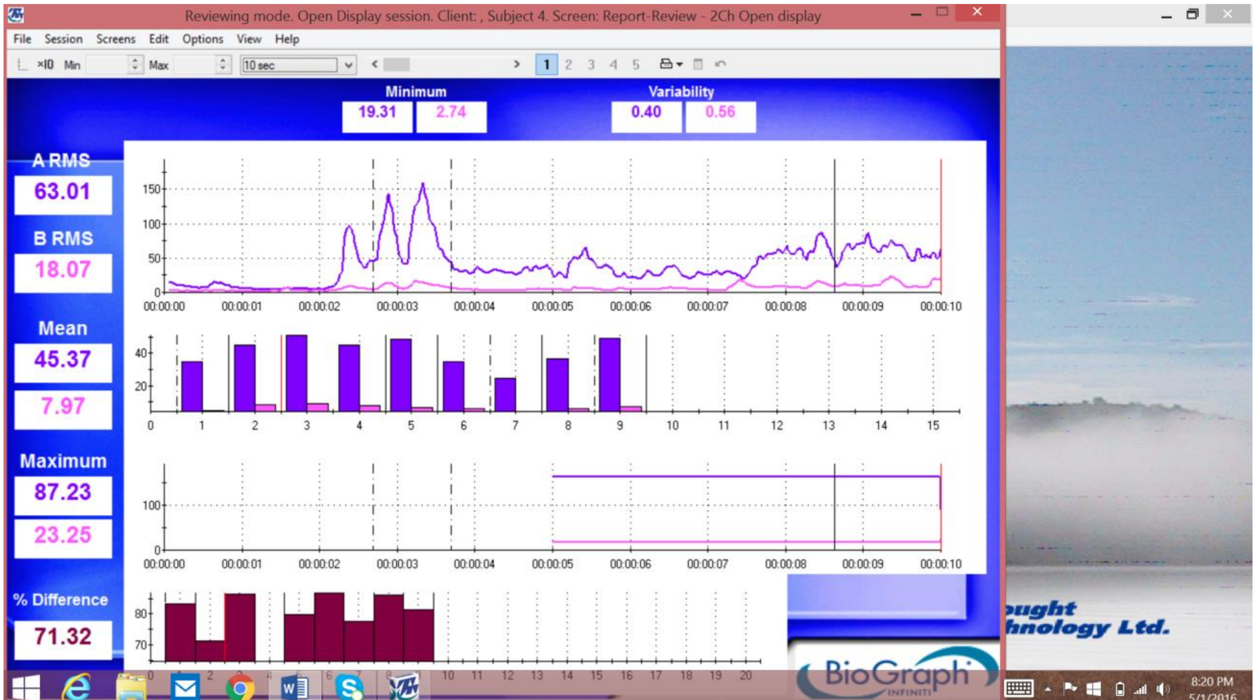
Trial 3

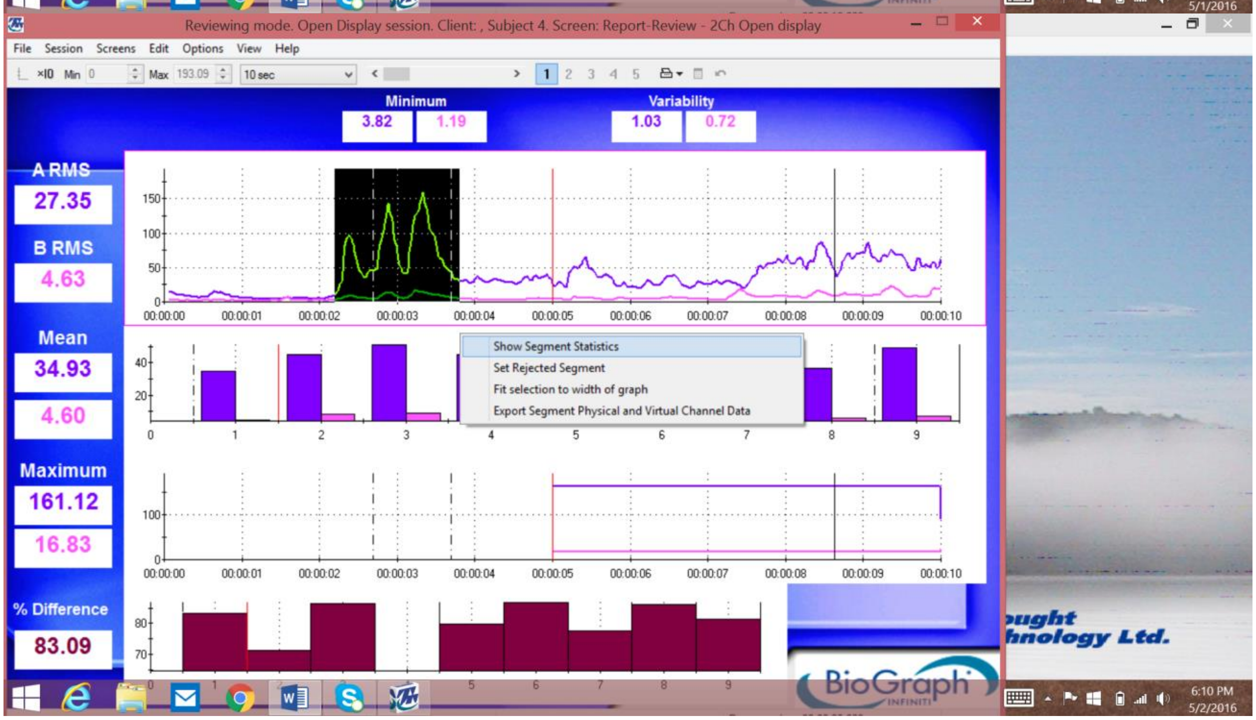

Reviewing mode. Open Display session. Client: , Subject 4. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
3.12 1.71
Variability
0.53 0.24
A RMS
7.61
B RMS
2.15
Mean
9.30
2.40
Maximum
29.61
5.73
% Difference
71.69
BioGraph INFINITI
6:08 PM
5/2/2016


Reviewing mode. Open Display session. Client: , Subject 4. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
3.12 1.71
Variability
0.53 0.24
A RMS
7.61
B RMS
2.15
Mean
9.30
2.40
Maximum
29.61
5.73
% Difference
71.69
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph INFINITI
6:06 PM
5/2/2016

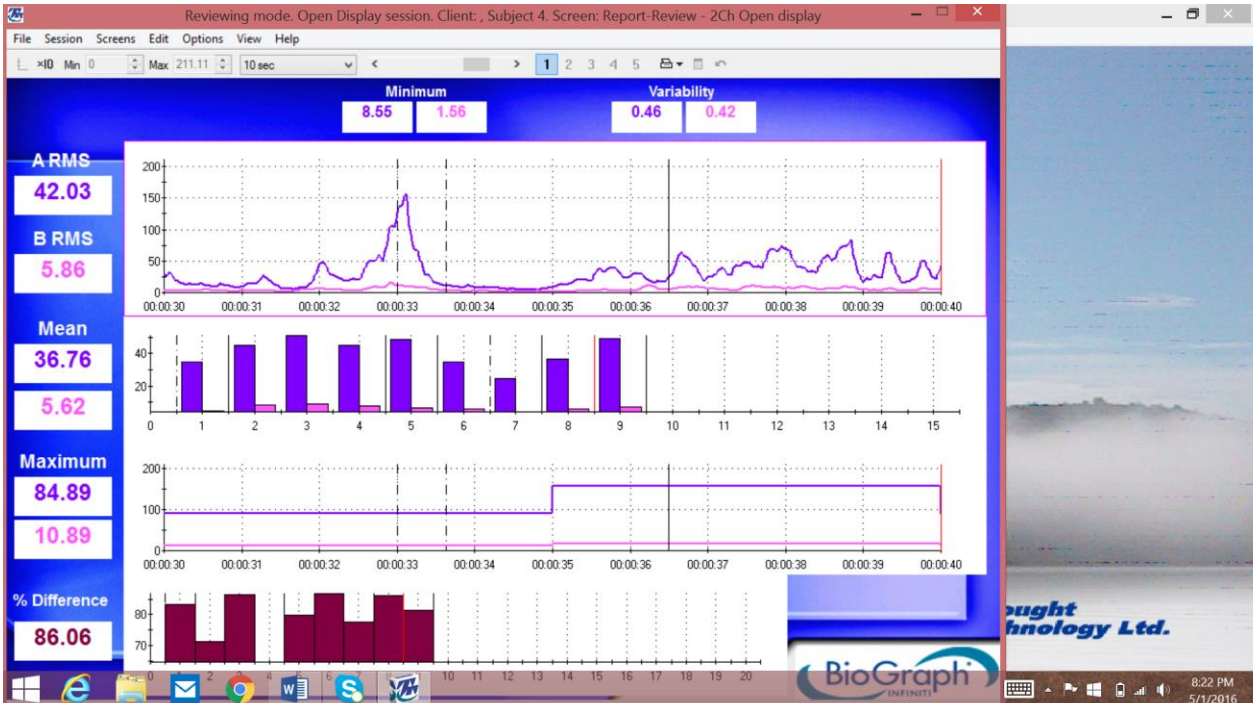
Triscuit

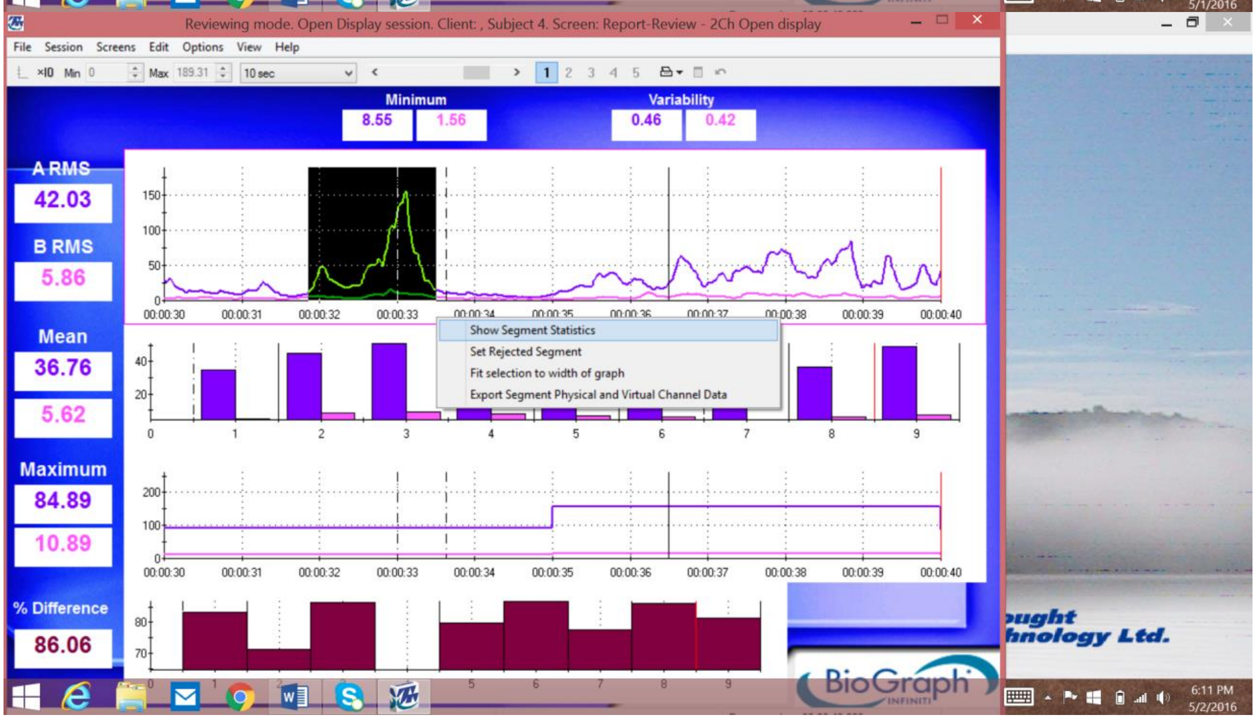
Trial 1



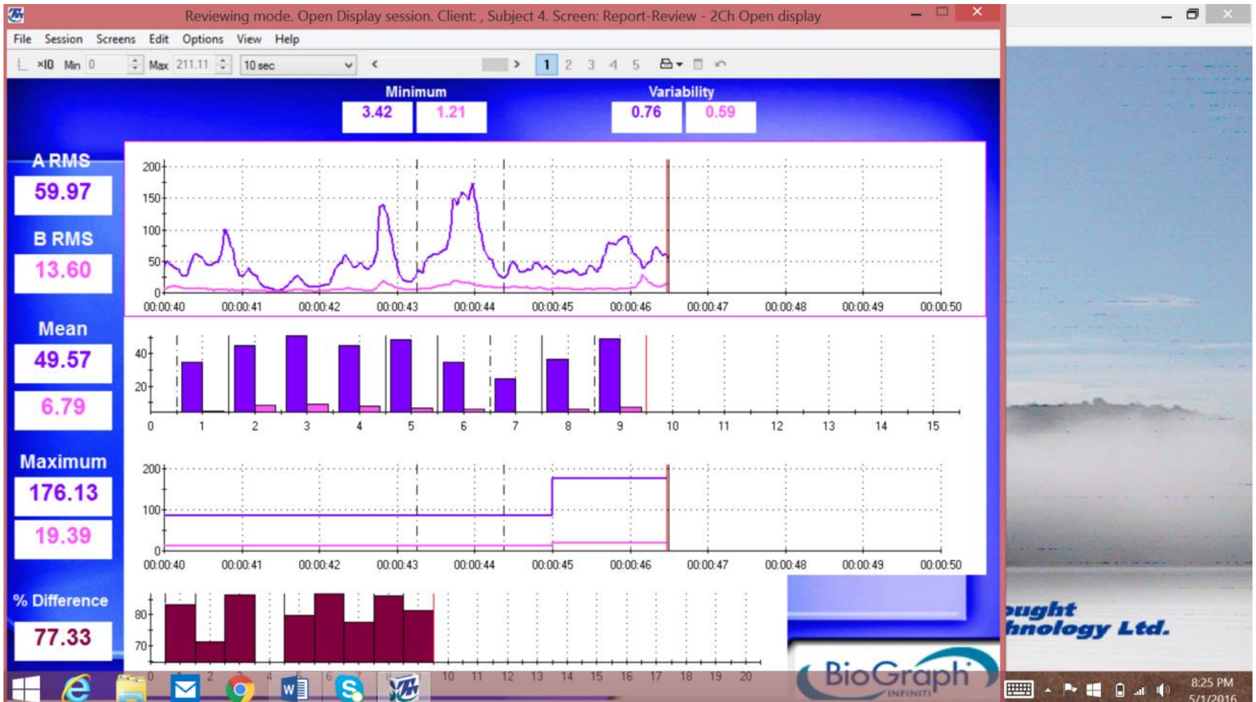


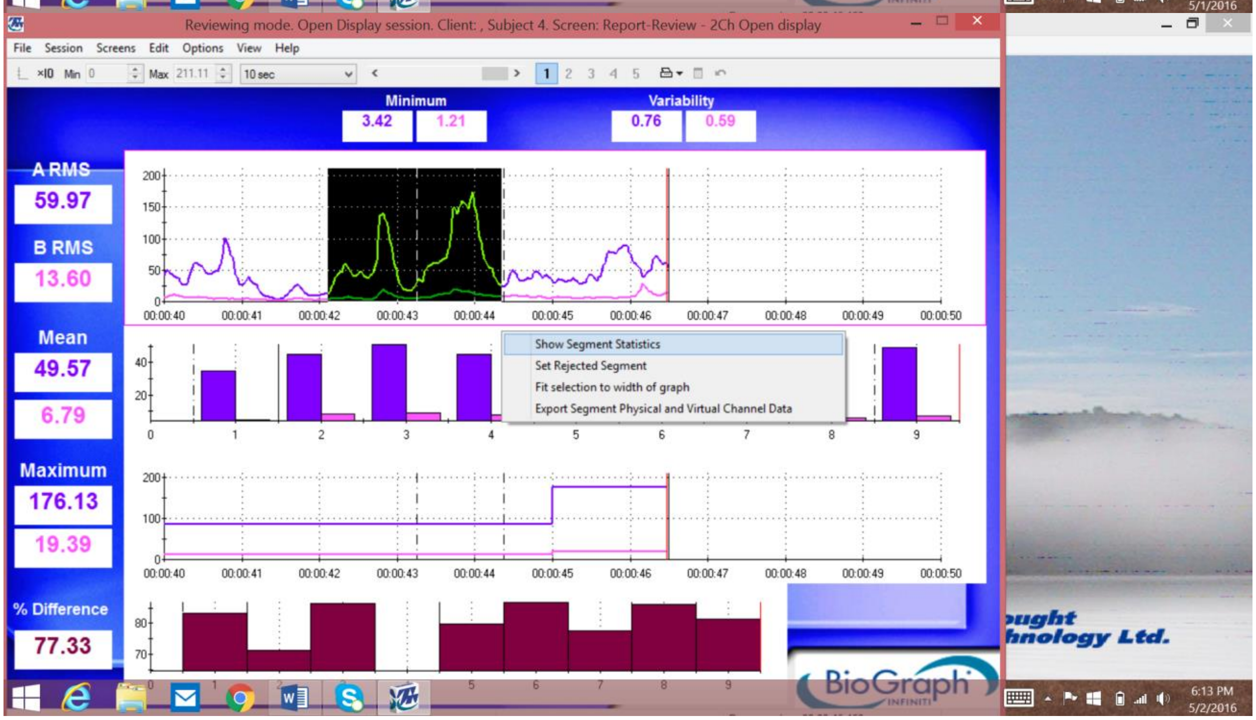
Trial 2


Reviewing mode. Open Display session. Client: , Subject 4. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
8.55
1.56
Variability
0.46
0.42
A RMS
42.03
B RMS
5.86
Mean
36.76
5.62
Maximum
84.89
10.89
% Difference
86.06
BioGraph INFINITI
8:22 PM
5/1/2016


Reviewing mode. Open Display session. Client: , Subject 4. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
8.55
1.56
Variability
0.46
0.42
A RMS
42.03
B RMS
5.86
Mean
36.76
5.62
Maximum
84.89
10.89
% Difference
86.06
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph INFINITI
6:11 PM
5/2/2016

Trial 3

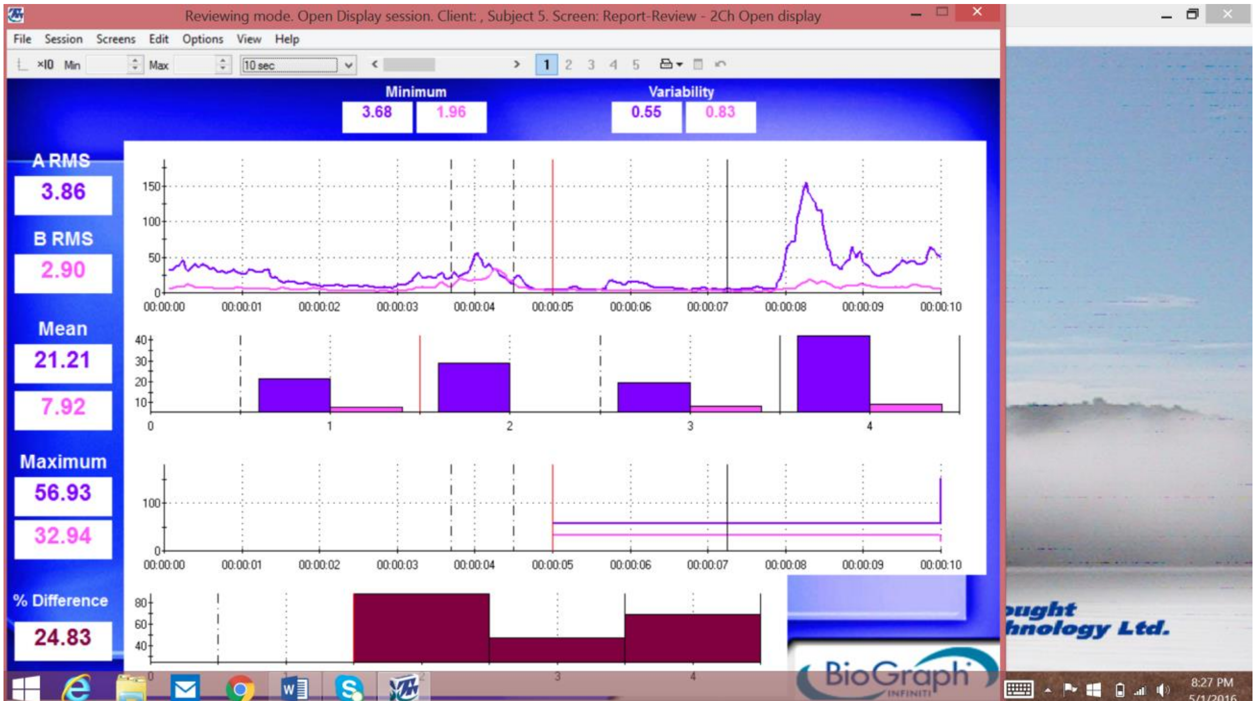

Reviewing mode. Open Display session. Client: , Subject 4. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
3.42
1.21
Variability
0.76
0.59
A RMS
59.97
B RMS
13.60
Mean
49.57
6.79
Maximum
176.13
19.39
% Difference
77.33
BioGraph INFINITI
8:25 PM
5/1/2016

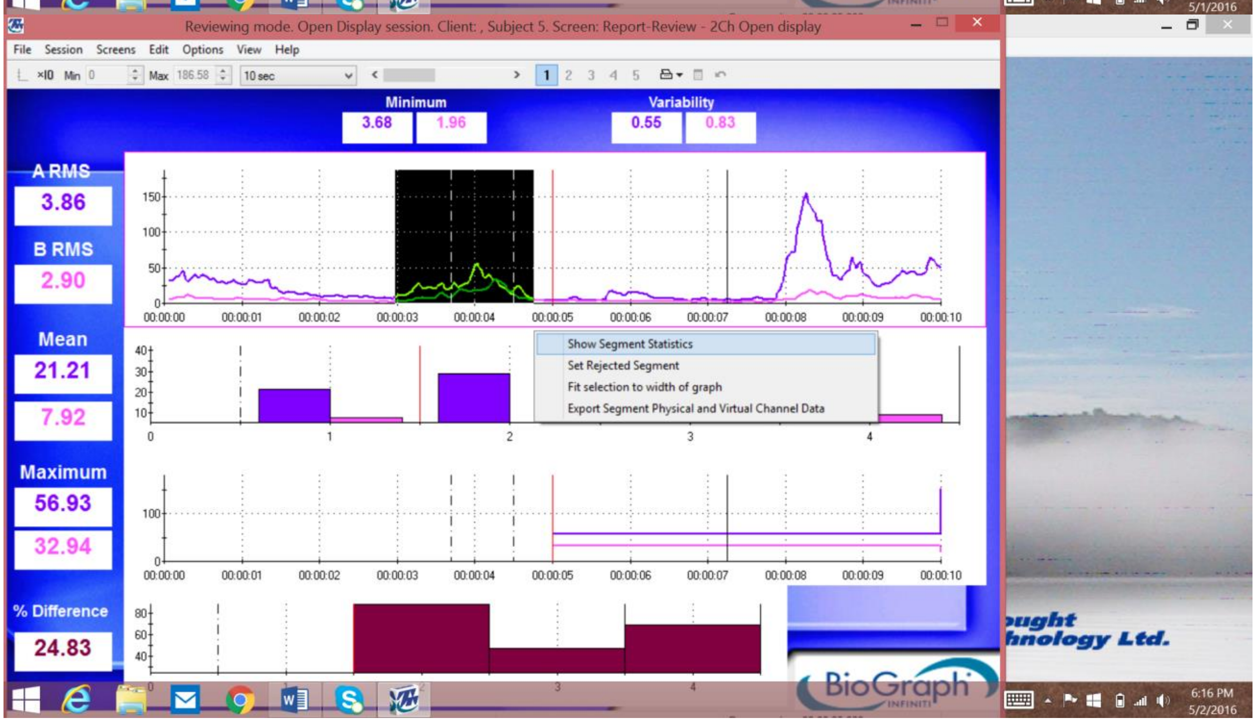

Reviewing mode. Open Display session. Client: , Subject 4. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
3.42
1.21
Variability
0.76
0.59
A RMS
59.97
B RMS
13.60
Mean
49.57
6.79
Maximum
176.13
19.39
% Difference
77.33
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph INFINITI
6:13 PM
5/2/2016

Subject 5

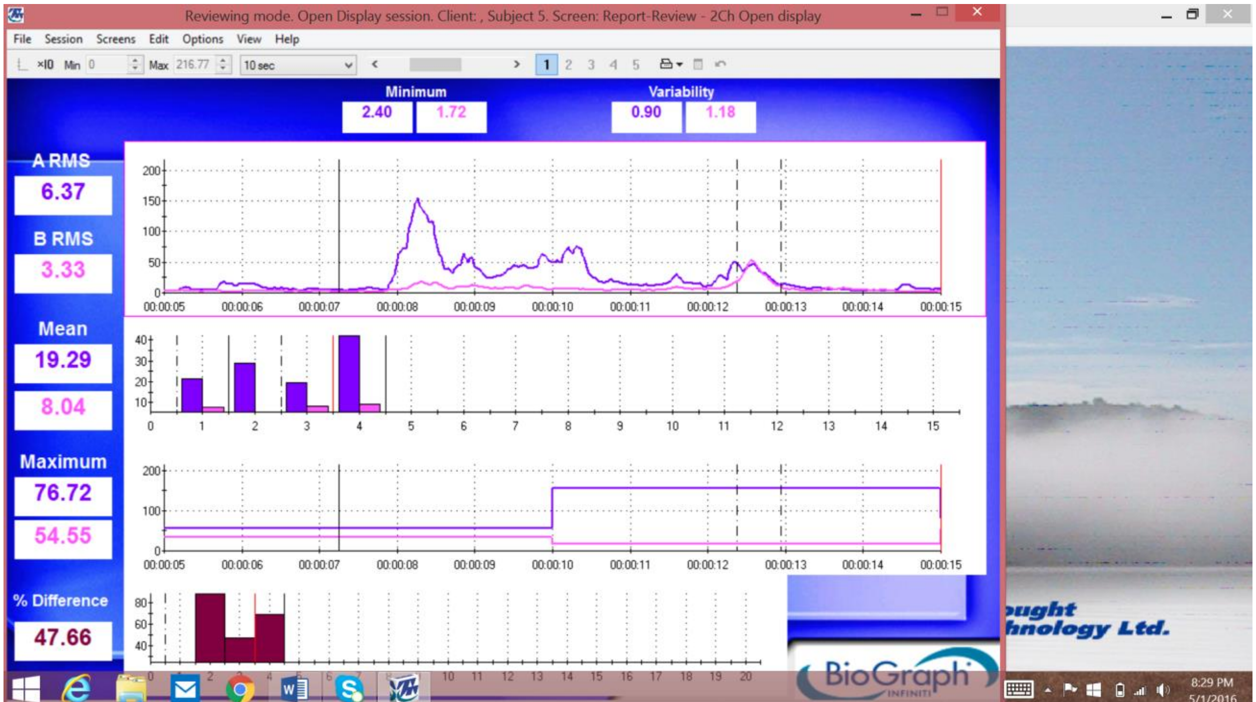
½ pudding

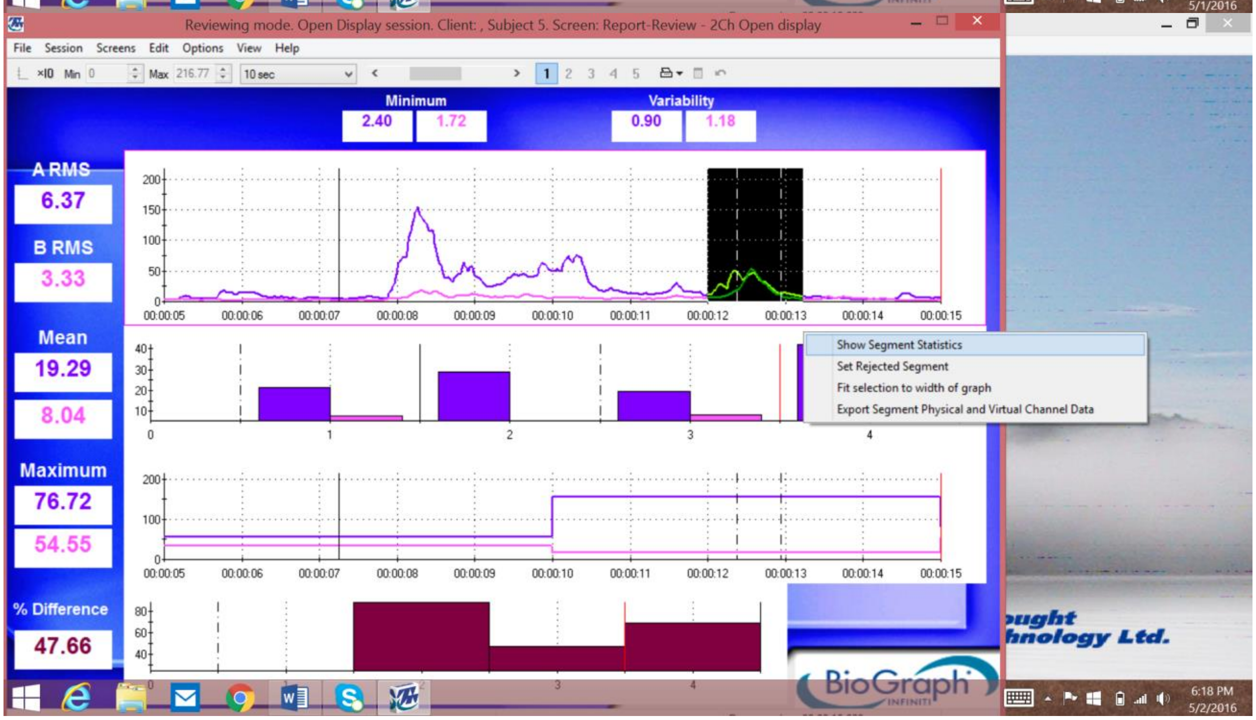
Trial 1



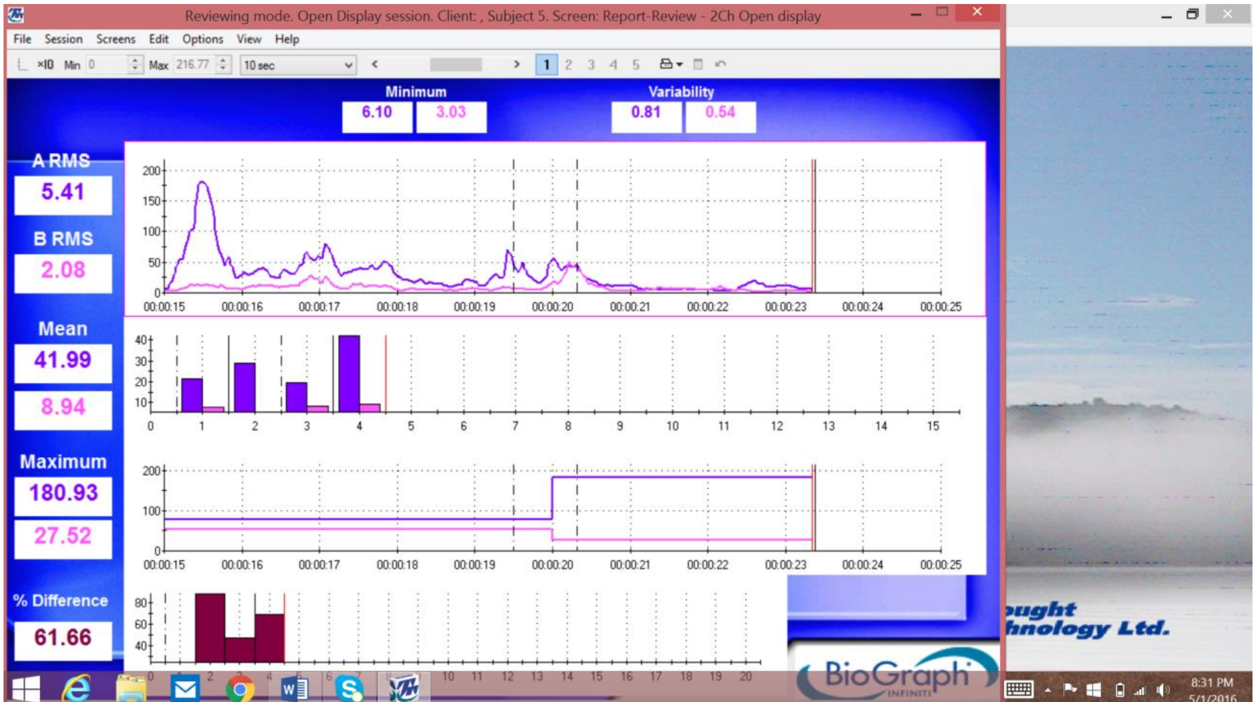


Trial 2


Reviewing mode. Open Display session. Client: , Subject 5. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
2.40
1.72
Variability
0.90
1.18
A RMS
6.37
B RMS
3.33
Mean
19.29
8.04
Maximum
76.72
54.55
% Difference
47.66
BioGraph INFINITI
8:29 PM
5/1/2016


Reviewing mode. Open Display session. Client: , Subject 5. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
2.40
1.72
Variability
0.90
1.18
A RMS
6.37
B RMS
3.33
Mean
19.29
8.04
Maximum
76.72
54.55
% Difference
47.66
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph INFINITI
6:18 PM
5/2/2016

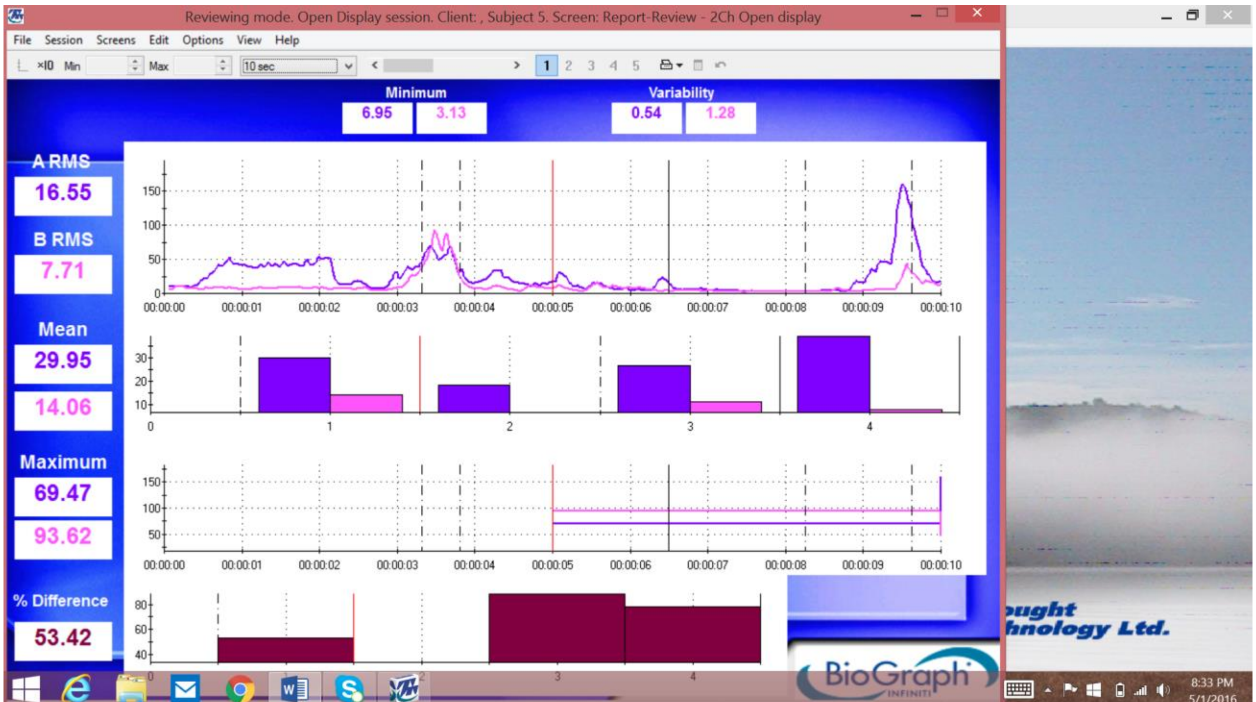
Trial 3

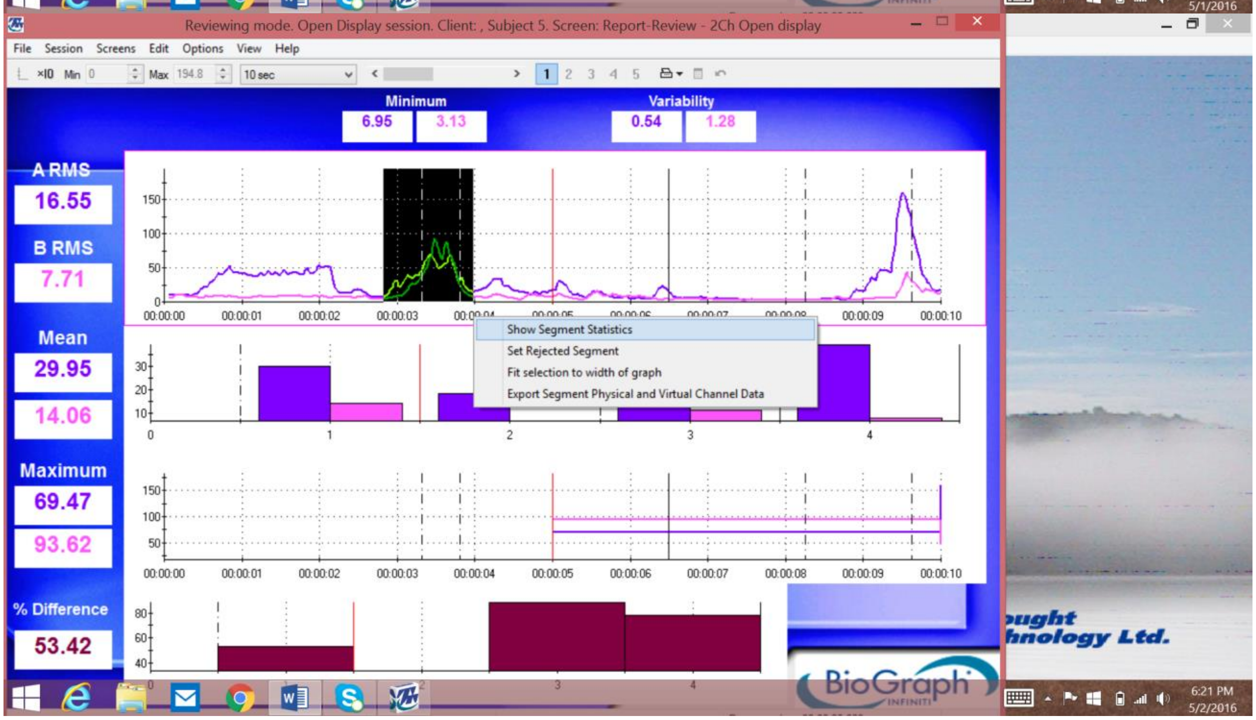

Reviewing mode. Open Display session. Client: , Subject 5. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
6.10 3.03
Variability
0.81 0.54
A RMS
5.41
B RMS
2.08
Mean
41.99
8.94
Maximum
180.93
27.52
% Difference
61.66
BioGraph INFINITI


Reviewing mode. Open Display session. Client: , Subject 5. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
6.10 3.03
Variability
0.81 0.54
A RMS
5.41
B RMS
2.08
Mean
41.99
8.94
Maximum
180.93
27.52
% Difference
61.66
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph INFINITI

1 ½ pudding

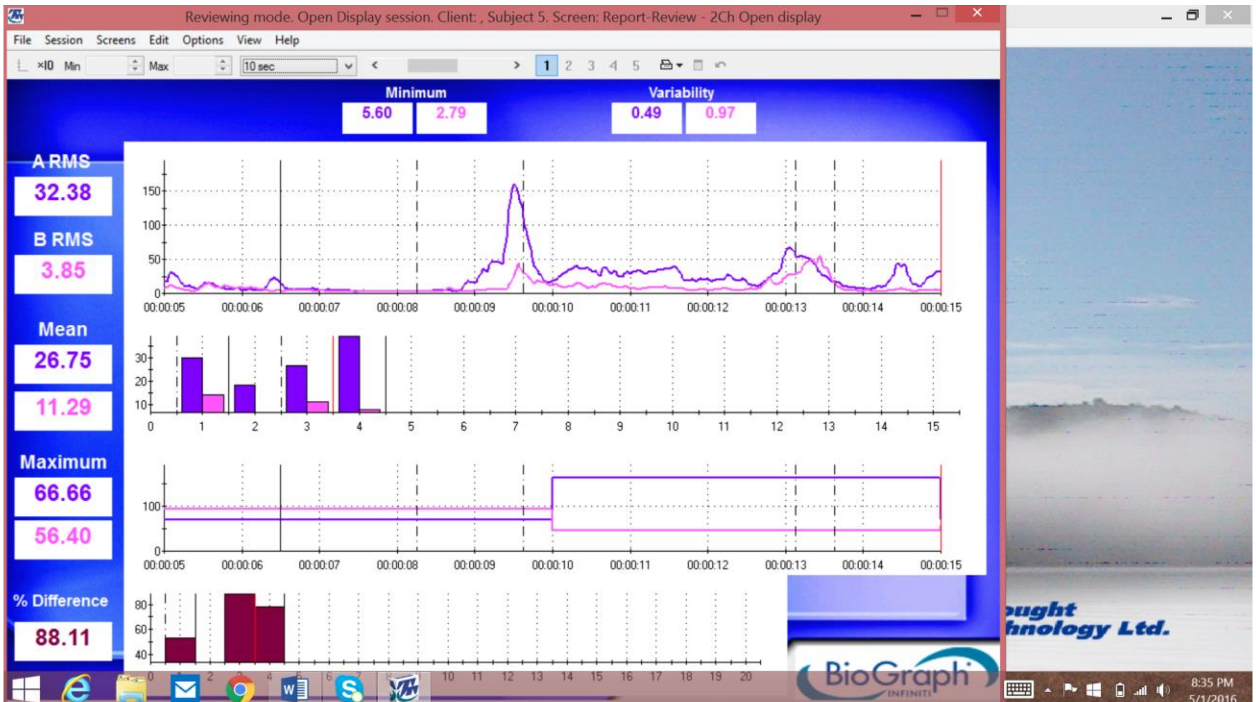
Trial 1

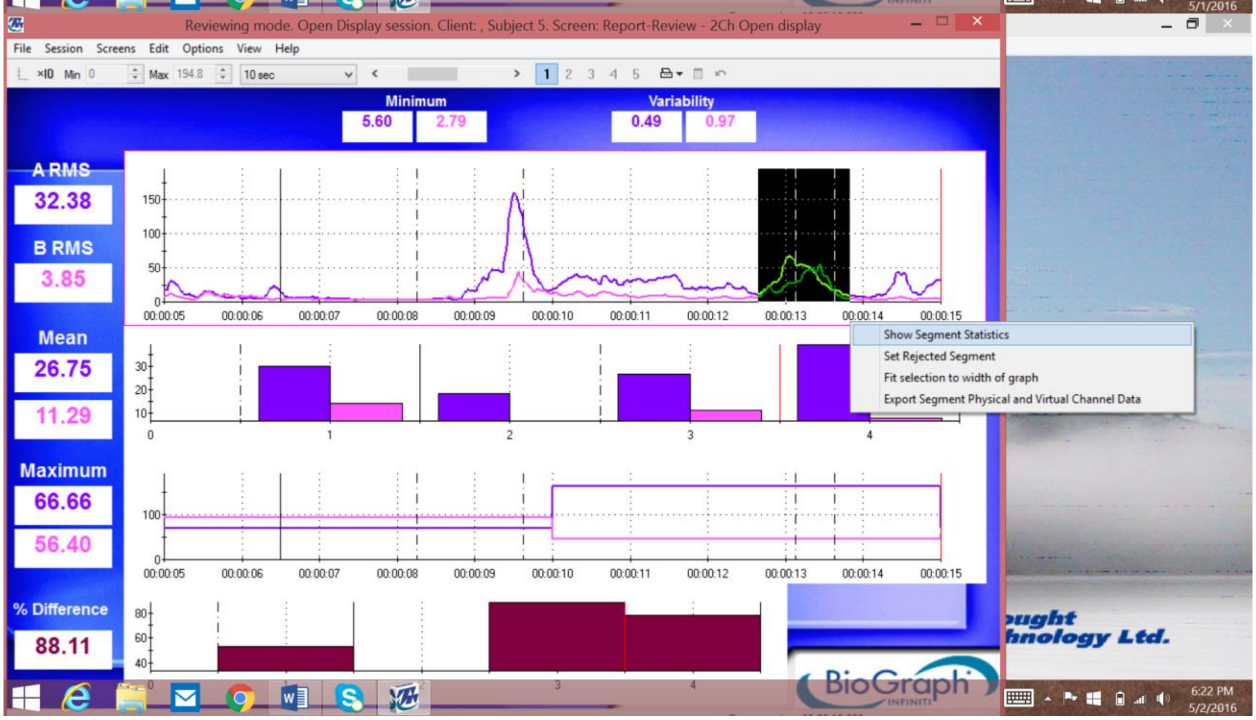




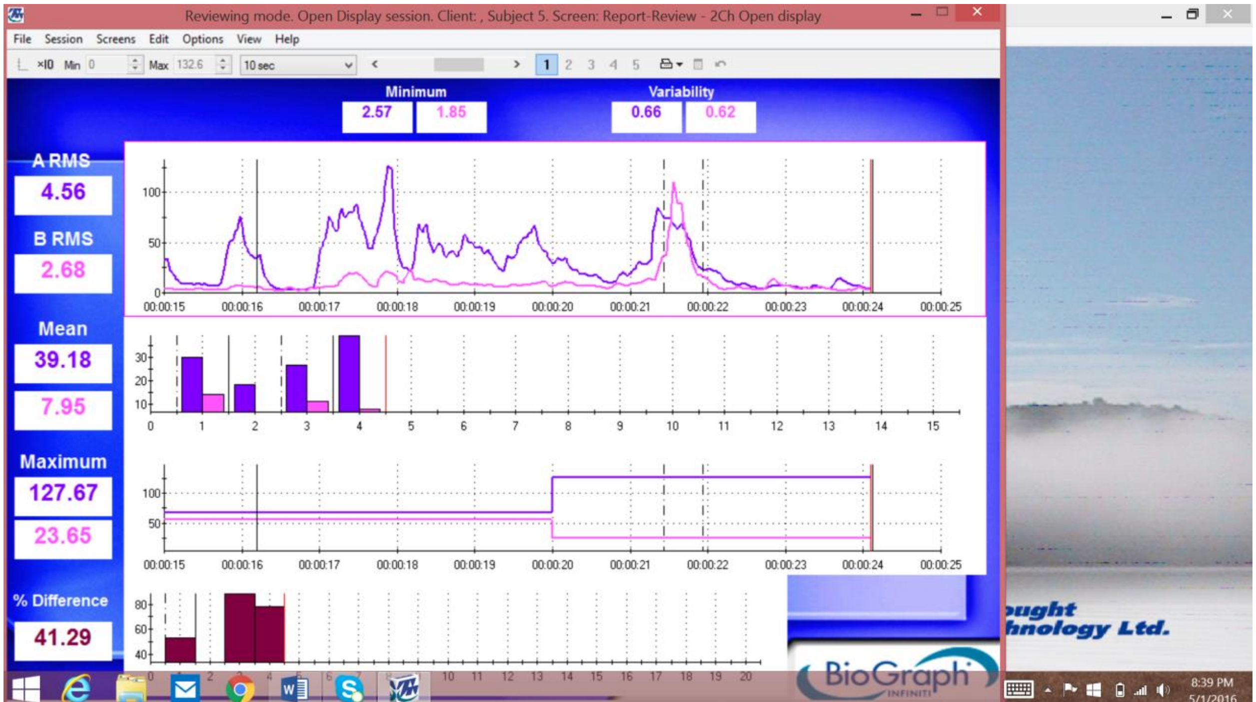
Trial 2

Note: actual swallow is indicated by the markers between 13-14 seconds. The first two markers between 8-10 seconds were accidental by the researcher.





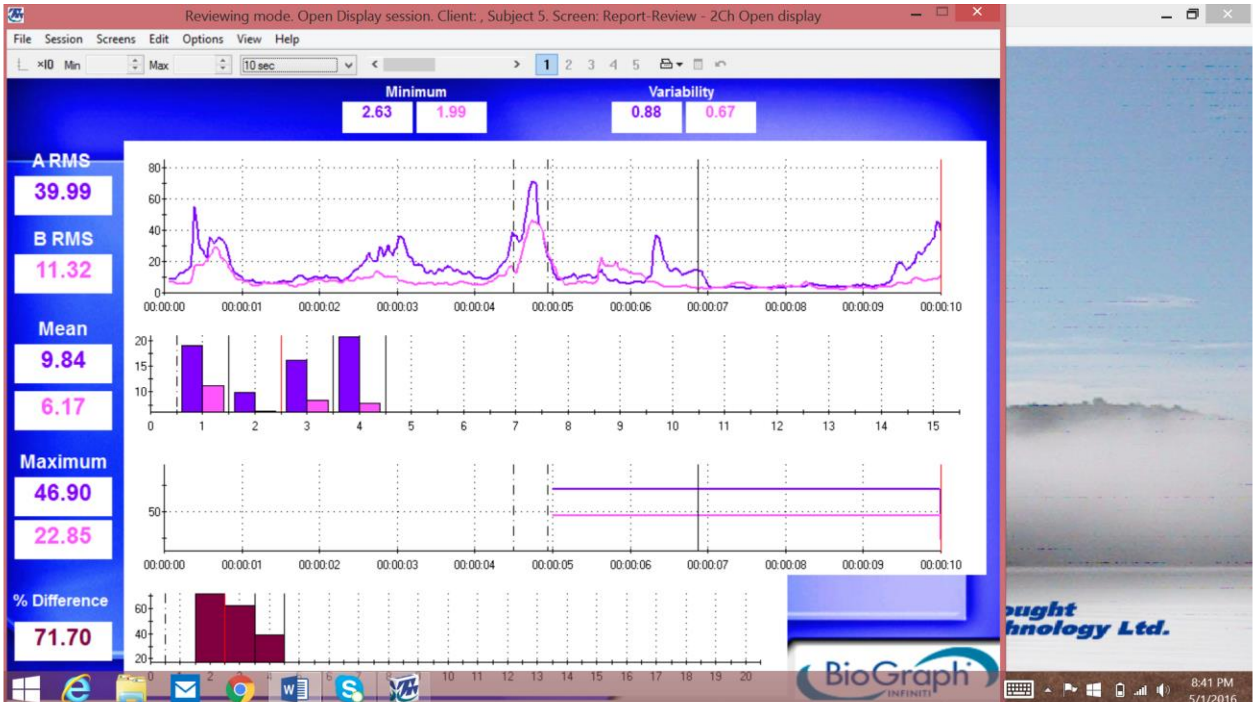
Trial 3

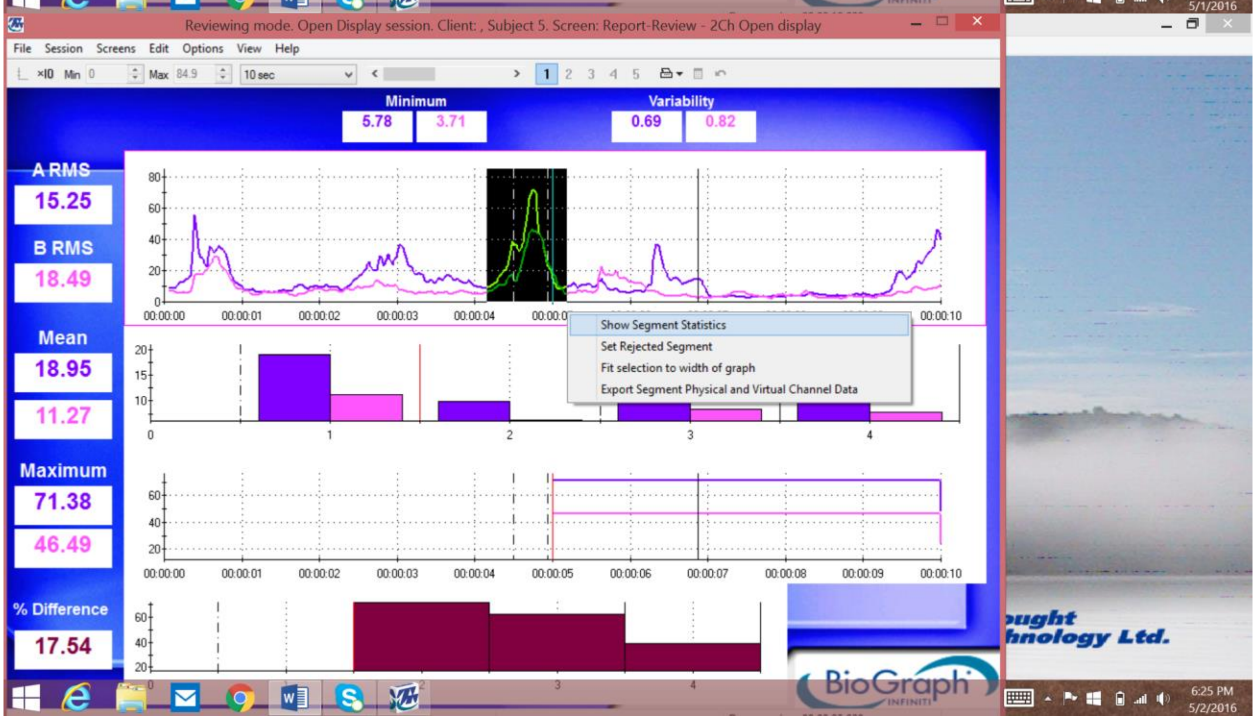

Reviewing mode. Open Display session. Client: , Subject 5. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
2.57
1.85
Variability
0.66
0.62
A RMS
4.56
B RMS
2.68
Mean
39.18
7.95
Maximum
127.67
23.65
% Difference
41.29
BioGraph
8:39 PM
5/1/2016


Reviewing mode. Open Display session. Client: , Subject 5. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
2.57
1.85
Variability
0.66
0.62
A RMS
4.56
B RMS
2.68
Mean
39.18
7.95
Maximum
127.67
23.65
% Difference
41.29
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph
6:23 PM
5/2/2016

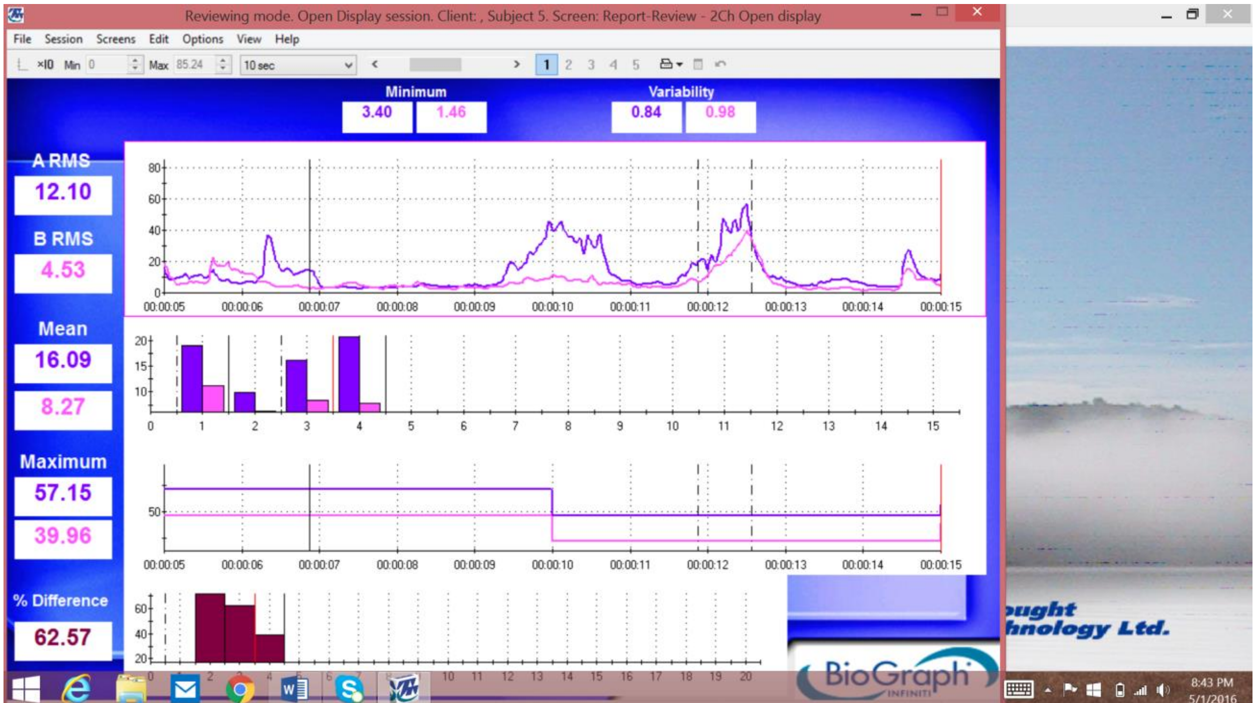
Water

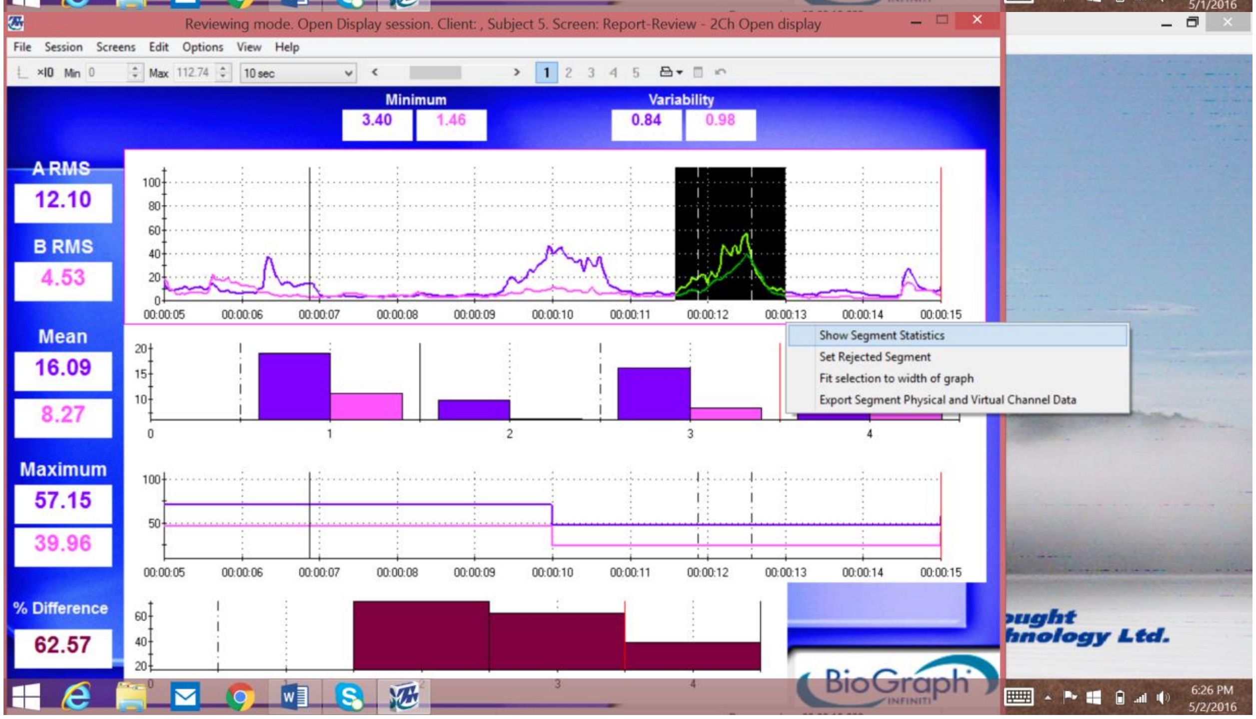
Trial 1



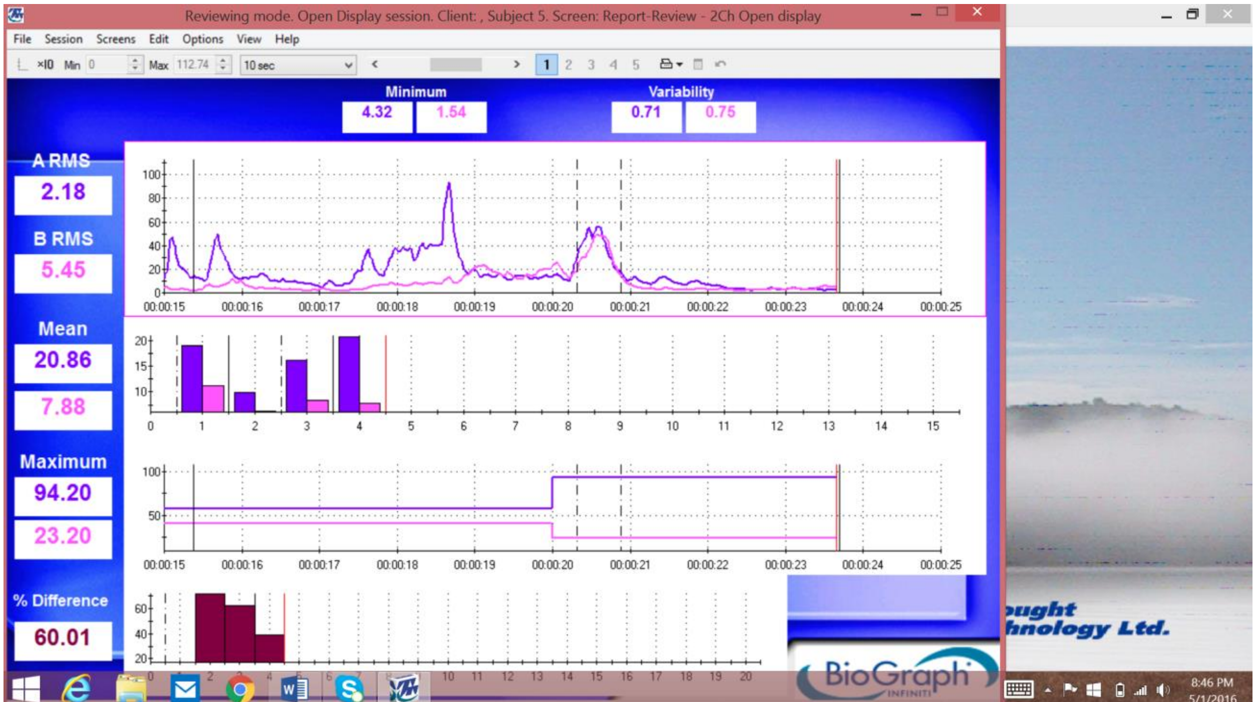


Trial 2


Reviewing mode. Open Display session. Client: , Subject 5. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Min 0 Max 85.24 10 sec
Minimum 3.40 1.46
Variability 0.84 0.98
A RMS 12.10
B RMS 4.53
Mean 16.09 8.27
Maximum 57.15 39.96
% Difference 62.57
BioGraph INFINITI
8:43 PM 5/1/2016


Reviewing mode. Open Display session. Client: , Subject 5. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Min 0 Max 112.74 10 sec
Minimum 3.40 1.46
Variability 0.84 0.98
A RMS 12.10
B RMS 4.53
Mean 16.09 8.27
Maximum 57.15 39.96
% Difference 62.57
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph INFINITI
6:26 PM 5/2/2016

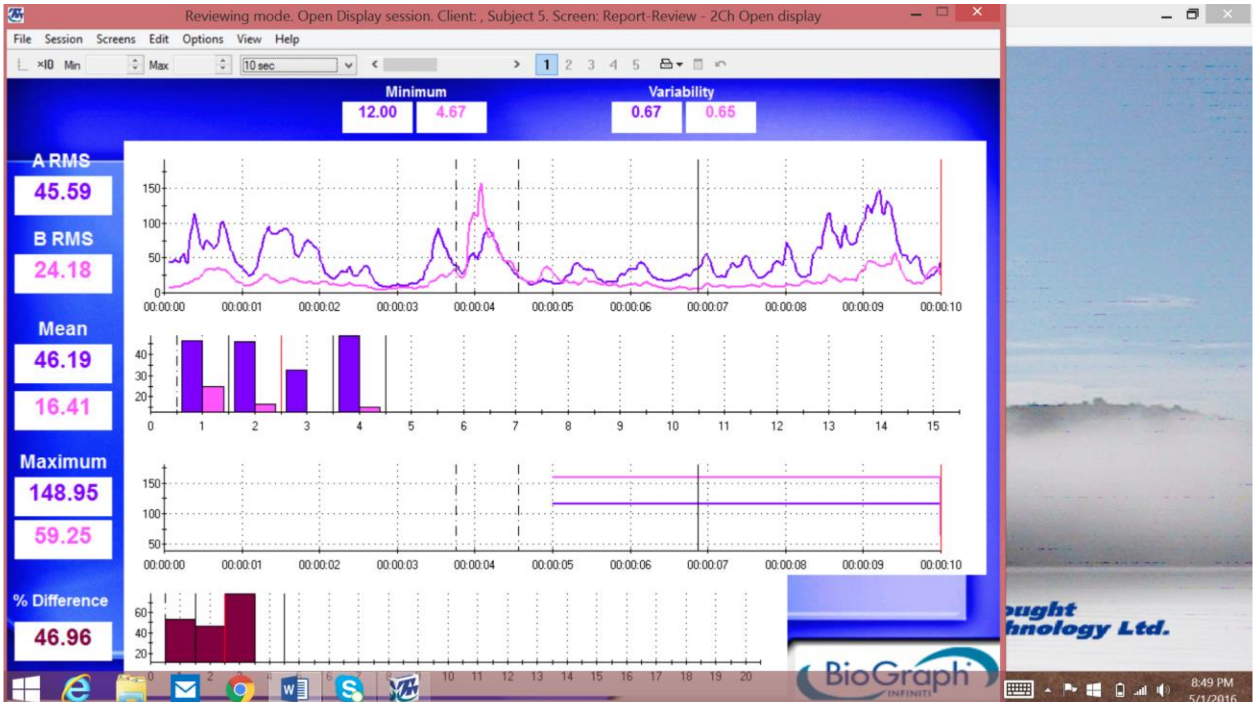
Trial 3


Reviewing mode. Open Display session. Client: , Subject 5. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
4.32
1.54
Variability
0.71
0.75
A RMS
2.18
B RMS
5.45
Mean
20.86
7.88
Maximum
94.20
23.20
% Difference
60.01
BioGraph
8:46 PM
5/1/2016

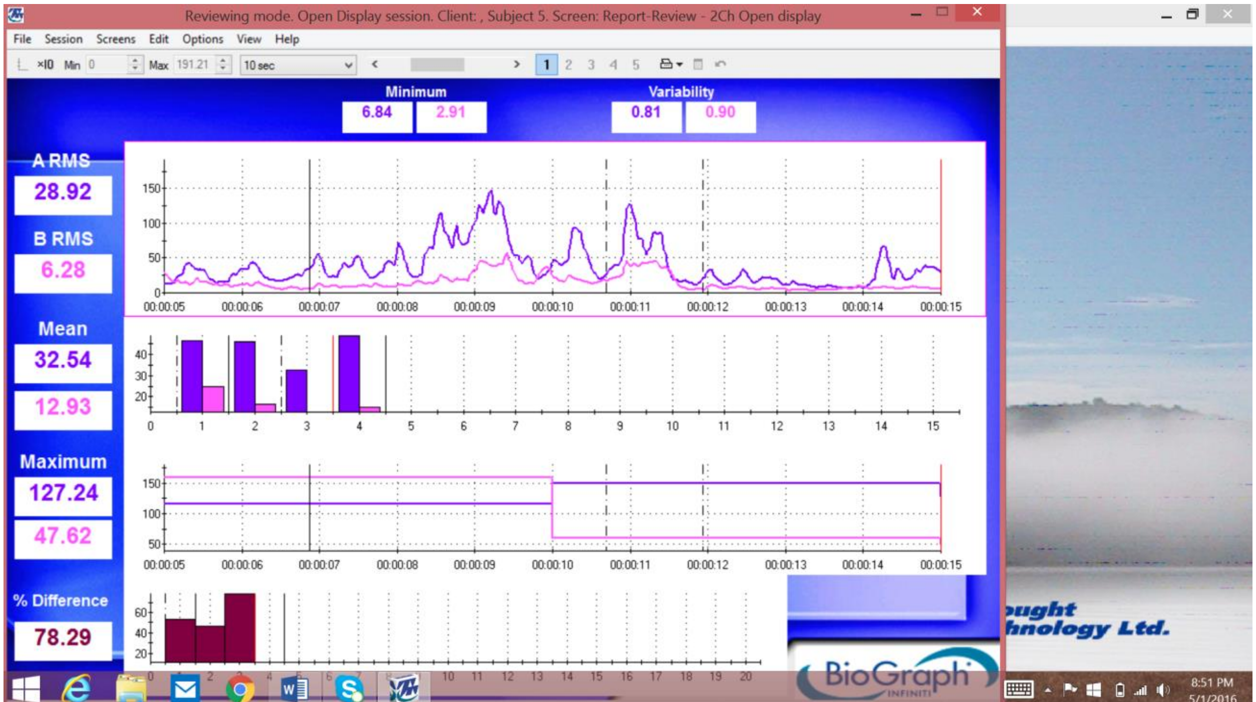

Reviewing mode. Open Display session. Client: , Subject 5. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
4.32
1.54
Variability
0.71
0.75
A RMS
2.18
B RMS
5.45
Mean
20.86
7.88
Maximum
94.20
23.20
% Difference
60.01
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph
6:35 PM
5/2/2016

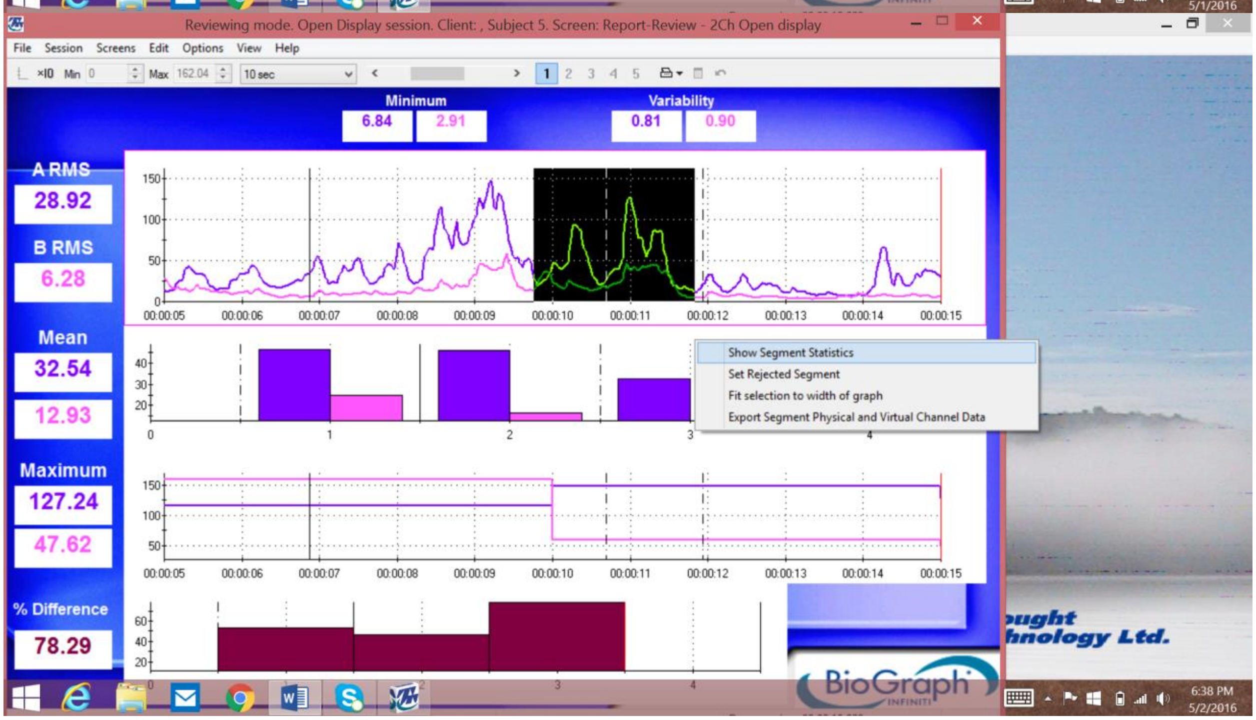
Triscuit

Trial 1

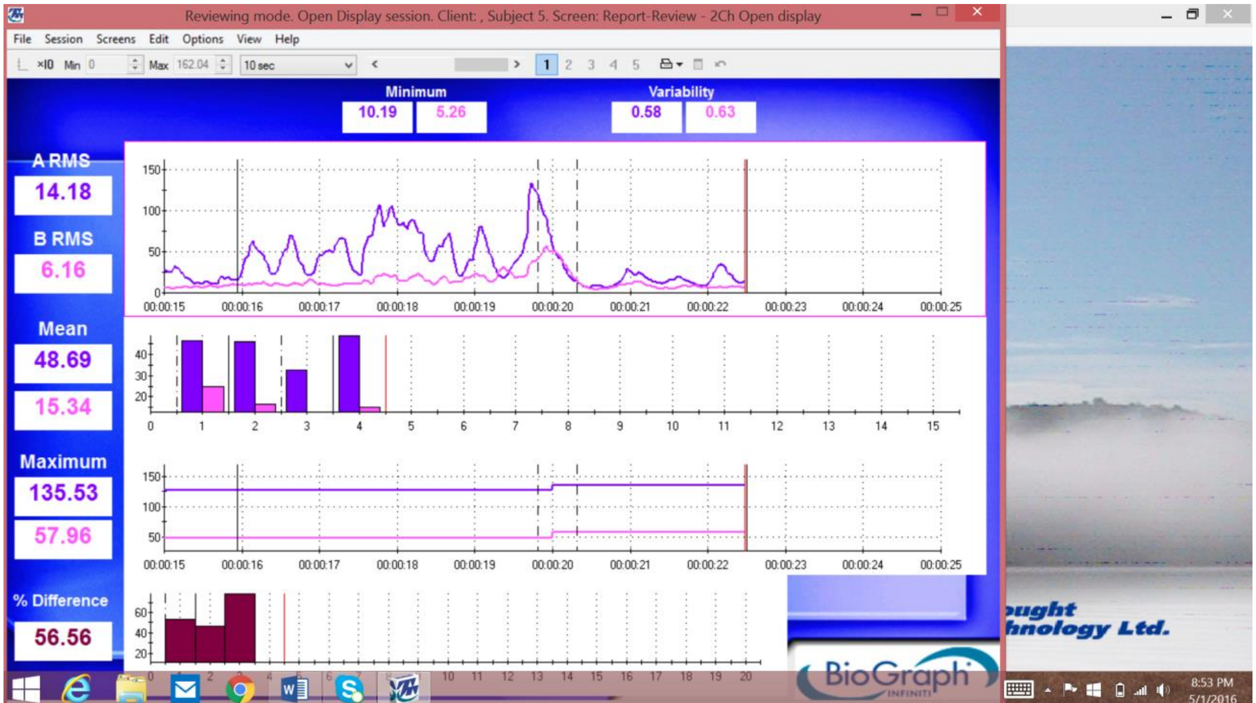


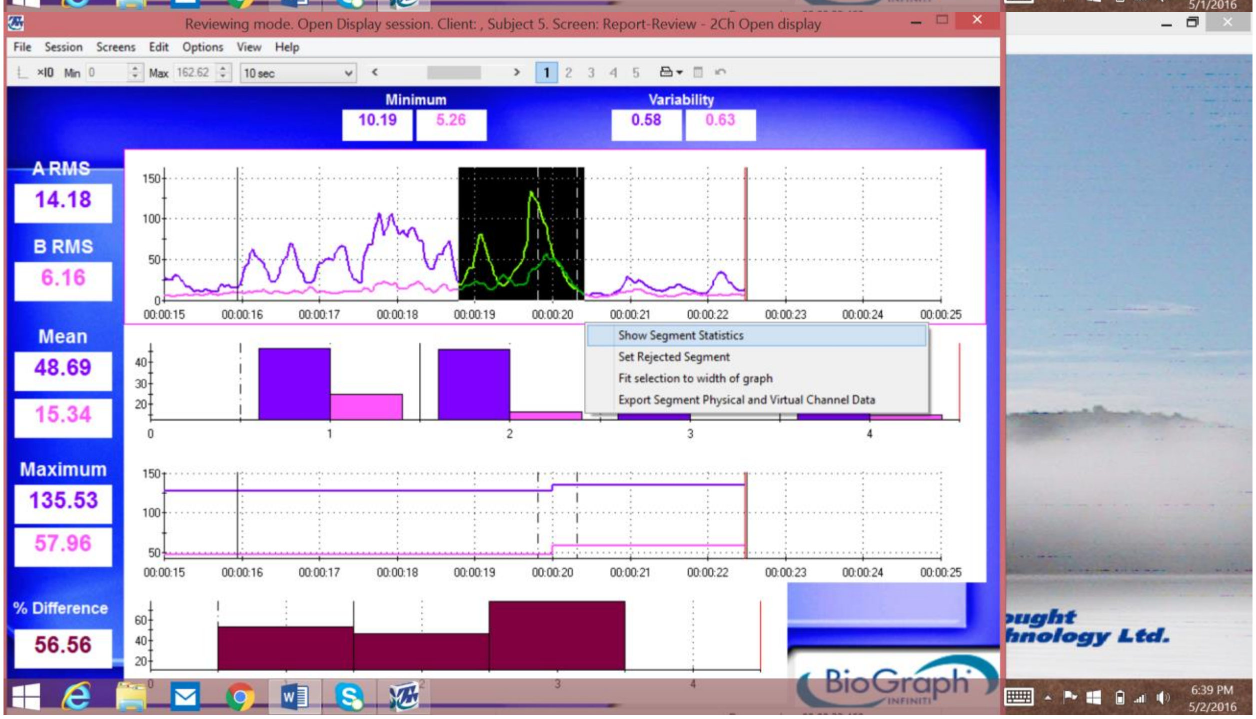
Trial 2


Reviewing mode. Open Display session. Client: , Subject 5. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
6.84
2.91
Variability
0.81
0.90
A RMS
28.92
B RMS
6.28
Mean
32.54
12.93
Maximum
127.24
47.62
% Difference
78.29
BioGraph INFINITI
8:51 PM
5/1/2016


Reviewing mode. Open Display session. Client: , Subject 5. Screen: Report-Review - 2Ch Open display
File Session Screens Edit Options View Help
Minimum
6.84
2.91
Variability
0.81
0.90
A RMS
28.92
B RMS
6.28
Mean
32.54
12.93
Maximum
127.24
47.62
% Difference
78.29
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph INFINITI
6:38 PM
5/2/2016

Trial 3


Reviewing mode. Open Display session. Client: , Subject 5. Screen: Report-Review - 2Ch Open display
Minimum
10.19
5.26
Variability
0.58
0.63
A RMS
14.18
B RMS
6.16
Mean
48.69
15.34
Maximum
135.53
57.96
% Difference
56.56
BioGraph
8:53 PM
5/1/2016


Reviewing mode. Open Display session. Client: , Subject 5. Screen: Report-Review - 2Ch Open display
Minimum
10.19
5.26
Variability
0.58
0.63
A RMS
14.18
B RMS
6.16
Mean
48.69
15.34
Maximum
135.53
57.96
% Difference
56.56
Show Segment Statistics
Set Rejected Segment
Fit selection to width of graph
Export Segment Physical and Virtual Channel Data
BioGraph
6:39 PM
5/2/2016