RESISTANCE STRAWS AND THE EFFORTFUL SWALLOW TECHNIQUE

A Thesis
By
NATALIA LOUISA SHELTON

Submitted to the Graduate School
Appalachian State University
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE

August 2011
Department of Communication Sciences and Disorders

RESISTANCE STRAWS AND THE EFFORTFUL SWALLOW TECHNIQUE

A Thesis
By
NATALIA LOUISA SHELTON
August 2011

APPROVED BY:

Heather Clark
Chairperson, Thesis Committee

William Irwin
Member, Thesis Committee

Michael VanLue
Member, Thesis Committee

Angela Losardo
Chairperson, Department of Communication Sciences and Disorders

Edelma D. Huntley
Dean, Research and Graduate Studies

FOREWORD

The research detailed in this thesis will be submitted to *American Journal of Speech-Language Pathology,* an internationally peer-reviewed journal. It is an official journal published by the American Speech and Hearing Association. This thesis has been prepared according to the standards set by the publication.

ABSTRACT

"RESISTANCE STRAWS AND THE EFFORTFUL SWALLOW TECHNIQUE"
(August, 2011)

Natalia Shelton, B.A., University of Florida

M.S., Appalachian State University

Chairperson: Heather Clark

ABSTRACT. Shelton N, Clark H.M. Resistance straws and the effortful swallow technique.

Objective: To assess the effects of TheraSIP™ high resistance straws, a recently developed procedure for enhancing effortful swallow rehabilitation, on the effortful swallow maneuver.
Design: Case-controlled design in which subjects completed three trial swallows under five swallow conditions and two effort conditions.
Setting: A university speech and swallowing physiology laboratory.
Participants: Forty-one healthy men and women between 18 and 59 years of age from the surrounding community.
Interventions: Participants sipped water (from four resistance straws of differing internal diameters)/(under five swallow conditions) and subsequently swallowed using both normally and using the effortful swallow maneuver.
Main Outcome Measures: The biomechanics of the swallows were analyzed from submental electromyographic and simultaneous oral pressure data.
Results: In all effort and swallow conditions, the dry swallow had the highest values for both muscle activity and lingual pressure. For lingual pressure, a significant main effect of straw condition was observed (p = .009). Follow-up comparisons revealed that the dry effortful swallow produced higher lingual swallowing pressures than swallows with the red straw (p = .001). Additionally, swallows with the blue straw produced higher pressures than those with the red straw (p = .001). For muscle activity, a significant main effect of straw condition was observed (p = .004). Follow-up comparisons revealed that the dry effortful produced higher lingual swallowing pressures than swallows with the red straw (p = .000). Additionally, swallows with the orange straw produced higher pressures than those with the red straw (p = .010).
Conclusion: The smaller diameter resistance straw did not elicit high muscle activity and lingual pressure in the subsequent normal and effortful swallows.
Key Words: Dysphagia, Resistance straws, Effortful swallow, sEMG, Lingual pressure

ACKNOWLEDGMENTS

This research was funded by a Graduate Research Associate Mentorship grant from the Appalachian State University.

TABLE OF CONTENTS

Introduction

Swallowing is a complex sensorimotor function that integrates movement from numerous muscle groups (Crary, Carnaby Mann, & Groher, 2006). Swallowing requires greater muscular contraction and range of motion than speech. It also creates higher pressures than speech (Neel, 2008; Robbins et al., 1998). Logemann (1998) identifies four main components that all swallows must have in order to successfully clear food from the oral cavity and pharynx while protecting the airway. First, there must be a means of oral propulsion of the bolus into the pharynx. This movement is achieved through the usage of various tongue, cheek and palatal muscles. Second, there must be airway closure in order to avoid aspiration of the bolus. This is accomplished by velar elevation that protects the nasopharynx, epiglottic inversion and adduction of the vocal folds to close the entrance to the trachea. Third, the upper esophageal sphincter muscle must actively relax and open to allow for passage of the bolus. Lastly, the bolus must be propelled through the pharynx and into the esophagus. This is achieved though constriction of the tongue base to the pharyngeal wall and subsequent esophageal peristalsis (Logemann, 1998).

Because adequate oral strength is required for each of these steps, it follows that weakness in the oral musculature might result in inadequate swallow function. Patients suffering from dysphagia are often prescribed resistance exercises to strengthen the swallowing mechanism in order to achieve better bolus control and avoid serious complications such as penetration and aspiration. Resistance exercises tax musculature beyond its normal use (i.e., overload), which leads to increased strength. As muscles increase in strength, it is necessary to increase exercise intensity to achieve the necessary level of overload. The Overload Principle states that, "exercise efforts that do not force the neuromuscular system beyond the level of usual activity will not elicit adaptation" (Polluck, 1998).

Swallowing musculature can be overloaded in multiple ways. For example, the Masako maneuver (Masako & Logemann, 1996) achieves overload by increasing the amount of posterior pharyngeal wall movement required to contact the tongue base (Crary & Groher, 2003), thus achieving overload. The Shaker head lift exercises (Shaker, et al., 1997) use the weight of the head to overload the musculature associated with laryngeal elevation.

The effortful swallow is a common dysphagia rehabilitation technique that encourages the patient to increase the force applied to a bolus (thus achieving overload) through high effort (Crary & Groher, 2003). Because the intensity of the effortful swallow may vary across trials and individuals, clinicians may seek methods for eliciting consistently strong effortful swallows. A recently developed procedure for enhancing effortful swallow rehabilitation is the TheraSIP™ Swallow Trainer resistance straw program (Speech and NeuroRehab, 2010).

TheraSIP utilizes a series of high resistance straws to elicit very small bolus volumes. The hypothesis driving the program is that the high effort required to draw liquid from the straws will carry over to the effortful swallows executed following each sip. The current study explored the physiology of effortful swallows preceded by sucks from high resistance straws.

Effortful Swallow

Swallow maneuvers that aim to achieve overload require concentration on the swallow and multi-step directions that target increased muscular effort. They aim to alter disordered swallowing physiology by improving range of motion that may be meditated by increased muscular effort and managing the timing of an individual's response (Corbin-Lewis, Liss, & Sciortino, 2005). Swallowing maneuvers function by modifying the timing of particular neuromuscular components (Lazarus, Logemann, & Gibbons, 1993). They usually alter some feature of the pharyngeal swallow by placing it under the patient's voluntary control (Logemann, 1998). As a result, some patients may experience a more synchronized pharyngeal swallow (Lazarus, Logemann, & Gibbons, 1993). However, success is often reliant on a patient's ability to successfully follow the steps of the technique (Logemann, 1998) .

The effortful swallow is widely known maneuver that can also serve as a compensatory technique for various dysphagia symptoms such as reduced pharyngeal constriction, pharyngeal and vallecular residue (Dejaeger, Pelemans, Ponette, & Joosten, 1997; Hiss & Huckabee, 2005) and reduced bolus control (Hind, et al., 2001). This technique uses increased neuromuscular drive as an indirect way of achieving overload (Logemann, 1998). The effortful swallow increases tongue base range of motion and improves contact between the tongue base and the posterior pharyngeal wall (Lazarus, Logemann, & Gibbons, 1993). Studies show that the effortful swallow increases pharyngeal pressure, which then pushes the bolus through the pharynx and upper esophageal sphincter. As a result, the amount of pharyngeal residue present after the swallow is decreased (Hiss & Huckabee, 2005). Effortful swallows can be differentiated from non-effortful swallows by force transducers (Coulas, Smith, Qadri, & Martin, 2009). Previous research shows that the effortful swallow can decrease the occurrence of penetration in individuals with pharyngeal disorders (Bulow, Olsson, & Ekberg, 2001). Aspiration risk is decreased during the effortful swallow because increased epiglottic inversion keeps the airway closed for a longer period of time. This in turn presents fewer opportunities for aspiration of material (Hind, et al., 2001).

In an evidence based systematic review of oropharyngeal dysphagia treatments on individuals receiving post cancer treatments, McCabe et al. (2009) stated that the effortful swallow produced the highest/greatest base of tongue to posterior pharyngeal wall pressure compared to all other maneuvers studied (Mendelsohn, supraglottic, super-supraglottic). This review concluded that this maneuver might help some patients attain near-normal swallowing pressures, which then improves their ability to efficiently clear the oropharyngeal cavity. However, it was also noted that the increased muscular effort required for the effortful swallow might increase fatigue which could then adversely affect the execution of this maneuver over time (McCabe, et al., 2009).

Huckabee et al. (2005) evaluated the effects of effortful and non-effortful swallows on surface electromyography (sEMG) measurement and pharyngeal manometric pressure. They found that the effortful swallow created higher activity in the muscles of the floor of the mouth in addition to increased pressure in the pharynx and decreased pressure in the upper esophageal sphincter (UES).

A small number of studies have examined using this maneuver as a treatment to improve underlying physiology as well. Theoretically, over-contracting the swallowing muscles should increase muscle strength over time. The effortful swallow would be expected to be most effective as an exercise when overload is maximized.

Straws

Clinicians recommending effortful swallows must identify innovative and effective ways of eliciting maximum neuromuscular drive during effortful swallows. A proposed method for achieving this aim involves high resistance straws (Smead, 2010). The TheraSIP Swallow Trainer™ employs several high resistance straws that require increased suction via the lips, tongue retraction, velopharyngeal closure and the glossopharyngeal valve in order to transport the liquid (Smead, 2010). This action is otherwise referred to as the "effortful suck" and is necessary to force water through the various straw diameters. The set includes four straws of increasingly smaller diameter. These provide escalating "effortful suck" intensity in order to maintain overload of the musculature over time even as the musculature gains strength. This strenuous effort in combination with the effortful swallow is the key component of the resistance therapy facilitated by the straw program.

Lingual Swallowing Pressure

A review by Wheeler-Hegland et al. (2009) found that the effortful swallow increases lingual pressures; duration of lingual, pharyngeal, and UES relaxation pressures; duration of hyoid and laryngeal displacement and submental muscle activation in participants with normal swallow function.

One of the physiological results of the effortful swallow is increased linguapalatal pressures. Huckabee and Steele (Huckabee & Steele, 2006) conducted a study that evaluated the influence of tongue-to-palate pressures on submental muscle activity during the effortful swallow. The results showed that instructing the subject to perform an effortful swallow while specifically focusing on pushing the tongue against the palate resulted in the subject generating higher muscle activity, swallow pressures and upper pharyngeal pressure than a 'normal' effortful swallow (Huckabee & Steele, 2006).

Surface Electromyography

Electromyography is a technique for evaluating and recording the electrical activity produced by skeletal muscles. Specifically, sEMG is frequently employed for measurement and evaluation of muscle activity during swallowing (Crary & Baldwin, 1997). Surface EMG has been employed in the study of both healthy and disordered swallowing (Crary & Baldwin, 1997; Crary, Carnaby Mann, & Groher, 2006; Crary, Carnaby Mann, & Groher, 2007; Huckabee, et al., 2005; Murray, Larson, & Logemann, 1998). Muscle activity may be measured as peak or average sEMG data. Peak sEMG is described as the point during the swallow when the greatest amount of muscle activity occurs. Average sEMG gives an estimate of the muscle activity for the length of the swallow (Crary & Groher, 2000).

Murray, Larson, & Logemann (1998) analyzed the difference in muscle activity of the lips during straw, cup and spoon drinking using electromyography. A greater amount of muscle activity was recorded in the lips during straw drinking as compared with spoon or cup usage (Murray, Larson, & Logemann, 1998).

Huckabee et al. (2005) evaluated the effects of effortful and non-effortful swallows on sEMG measurement and pharyngeal manometric pressure. They found that the effortful swallow created greater sEMG amplitudes and pharyngeal pressure than the normal swallow.

As the previously cited literature suggests, EMG and the manometric measure of swallowing pressures are measures that can be used to test the hypothesis that the effortful suck leads to a stronger effortful swallow. The following specific research questions were addressed: (1) Does the use of high resistance straws increase lingual swallowing pressures produced during the effortful swallow? (2) Does the use of high resistance straws produce greater submental muscle activity during the effortful swallow?

Method

This research was conducted with the approval of the Institutional Review Board of Appalachian State University and was funded by a Graduate Research Associate Mentoring Program grant.

Participants

This research focuses on data attained as part of a larger study examining the effects of exercise on swallowing variables (Clark & Shelton, 2010). The sample for this study included 41 participants recruited from Appalachian State University and the surrounding community. Data were collected from 36 females (age range 18 to 59) with a mean age of 22.3 years and 5 males (age range 22 to 50) with a mean age of 34 years. All participants had no reported history of speech or swallowing problems or of diseases that impact muscles used for speaking or eating. Participants who completed the entire larger experimental protocol were compensated $20 for their participation in the study.

Instrumentation

Swallowing pressures were obtained using the Iowa Oral Performance Instrument (IOPI). This device is a portable, hand-held mechanism that measures peak pressures exerted by the tongue on a small air-filled bulb. It consists of a pressure transducer connected to a battery-operated amplifier that displays peak pressure measured in kilopascals on an LCD. The IOPI bulb was positioned on the anterior hard palate to record pressures exerted by the anterior portion of the tongue during swallows. The waveform generated by the IOPI was digitally sampled by the Digital Swallowing Workstation at 4000 Hz and recorded simultaneously with the sEMG signal.

Electromyographic activity was recorded using surface electrodes attached submentally with the two recording leads placed horizontally in the anterior position and the grounding lead in the posterior position. Signals were digitized at a sampling rate of 250 Hz.

Participants performed effortful swallows during saliva swallows (dry swallows) and during swallows of water obtained using four TheraSIP straws that offer varying levels of resistance. Each straw differs in internal diameter and elicits significantly different sip volumes (Heitpas, Chandler, & Clark, 2009). The dimensions (length x internal diameter) and mean volume (SD) elicited by each color-coded straw is listed in Table 1.

[Insert Table 1]

Procedures

Prior to data collection, the researcher conducted the informed consent discussion with each participant. All details of the study were explained including expectations and compliance. The participant had the opportunity to ask the investigator questions regarding the study. Upon agreement, the participant signed two copies of the informed consent. Each participant received a signed copy of the informed consent while the other copy was kept on site by the investigator. Demographic information including participant's gender, age, handedness and pertinent medical history including that of dysphagia or dysarthria were collected.

Each participant performed three swallow trials using each straw. The first two trials were elicited with the instructions, “Take one sip as normally as possible and then swallow as normally as possible.” For the third trial, the participants were instructed to “take one sip, suck as hard as you can, and swallow as hard as you can." For the purpose of this study, participants were instructed to imagine drinking an extremely thick milkshake through a straw. In addition to straw swallows, each participant performed two noneffortful dry swallows and one effortful dry swallow. The order of swallows was randomized across participants.

Statistical analyses (repeated measures ANOVA) examined the effects of straw condition (dry, gray, blue, orange, red) on the dependent measures of peak lingual swallowing pressure and peak submental muscle activity. The conservative alpha level of .01 was selected with regard to significance.

Results

Swallowing Pressure

The mean peak lingual swallowing pressures for each swallowing condition are listed in Table 2. Observed pressures for non-effortful swallows with a straw ranged from 20.1 kPa (red) to 23.7 kPa (orange). However, the dry non-effortful swallow had the highest average pressure at 24.6 kPa. The recorded pressures for effortful swallow with a straw ranged from 26.0 kPa (red) to 29.9 kPa (blue). Again however, the pressure associated with the dry swallow was higher than any of the straws at 30.8 kPa. Therefore, the effortful swallow results in a gain of approximately 5-6kPa over a non-effortful swallow

[Insert Table 2]

A significant main effect of straw condition was observed [F (2.81, 112.6) = 4.19, *p*=.009]. Follow-up comparisons revealed that the dry effortful swallow produced significantly higher lingual swallowing pressures than swallows with the red straw [t(81) =

3.539 , *p* =.001]. Additionally, swallows with the blue straw produced higher pressures than those with the red straw [t(81) = 3.554, *p* =.001]. No other differences reached significance.

A significant main effect of swallow condition (effortful, non-effortful) was observed [F (1, 40) = 123.4, *p*=.000]. The amount of lingual pressure was greater during the effortful swallow than during the non-effortful swallow. In contrast, the interaction of straw and swallow condition was not significant [F (2.97, 118.8) = 2.22, *p* =.09], as depicted in Figure 1.

[Insert Figure 1]

Muscle Activity (EMG)

The mean peak muscle activity for each swallowing condition is listed in Table 3 and is similar to those for lingual pressure. Muscle activity for non-effortful swallows with a straw ranged from 69.1 µV (grey) to 76.5 µV (orange). However, the dry non-effortful swallow had the highest average muscle activity at 80.7 µV. As predicted, muscle activity for effortful swallows with a straw was higher compared to the noneffortful swallows, with a range of 98.0 µV (red) to 109.3 µV (gray). Again however, the dry swallow was higher than any of the straws at 113.4 µV. Therefore, these results show a gain of approximately 30µV over a normal swallow when an effortful swallow is performed.

[Insert Table 3]

A significant main effect of straw condition was observed [F (3.03, 118.3) = 4.7, *p*= .004]. Follow-up comparisons revealed that the dry effortful produced higher lingual swallowing pressures than swallows with the red straw [t(79) = 4.205, *p* = .000].

Additionally, swallows with the orange straw produced significantly higher pressures than those with the red straw [t(79) = 2.625, *p* =.010]. All other comparisons were not significant at the .01 alpha level.

A significant main effect of swallow condition was observed F (1, 39) = 112.6, *p* = .000]. The amount of muscle activity was greater during the effortful swallow than during the non-effortful swallow. In contrast, the interaction of straw and effort was not significant F (3.67, 143.3) = 2.52, *p* = .049] as depicted in Figure 2.

[Insert Figure 2]

Discussion

This project explored the physiology of effortful swallows preceded by sucks from high resistance straws. As suggested earlier in the paper, EMG and swallowing pressures can be used to test the hypothesis that the effortful suck leads to a stronger effortful swallow. The following specific research questions were addressed**:** (1) Does the use of high resistance straws increase lingual swallowing pressures produced during the effortful swallow? (2) Does the use of high resistance straws produce greater submental muscle activity during the effortful swallow?

Effortful versus Noneffortful

Since the effortful swallow encourages the patient to increase the force applied to a bolus through high effort (Crary & Groher, 2003), it was predicted that there would be significant difference in pressure between normal and effortful swallow. Swallowing pressures and muscle activity for effortful swallows with a straw were approximately 5-6kPa and 30μV higher, respectively, than their non-effortful counterparts.

These results confirmed our hypothesis and are consistent with previous findings (Coulas, et al., 2009; Huckabee, et al., 2005a; Huckabee, et al., 2005b; Huckabee & Steele, 2006). Although there is no previous research on resistance straws coupled with effortful and noneffortful swallows, studies on the effortful swallow in isolation do show that the technique generates higher muscle activity, swallow pressures and upper pharyngeal pressure than a 'normal' swallow (Huckabee & Steele, 2006).

Effects of Straw Diameter

It was predicted that the increased effort required to draw liquid from straws with smaller diameters would carry over to the swallow, resulting in higher lingual pressure and submental activity compared to swallows from straws with a larger diameter. However, the data failed to support this hypothesis. Instead, the findings were in the opposite direction as predicted, with larger straws eliciting numerically higher swallowing pressures and muscle activity relative to smaller straws. These findings are consistent with a small number of previous investigations demonstrating increased swallowing pressures (Robbins, et al., 2007) and muscle activity (Ertekin, et al., 1997) associated with larger bolus size. A 2009 study by Hietpas, et al. that focused on resistance straws illustrated that smaller straw diameter results in a decrease in bolus volume, as shown in Table 2 (Hietpas, et al., 2009). As a result, the outcomes of this study may reflect greater effects of volume than the intended focus on effort required to suck from the various resistance straws.

Individuals with dysphagia often have impaired bolus control and may have greater risk of premature spillage in the presence of a large bolus. With regard to clinical application, these results show that straws might be used as a way to limit liquid bolus sizes for patients who tend to aspirate liquids if taken in larger bolus sizes. It should be noted however, that the safety of straw drinking has been questioned in patients who may have decreased control over liquid volumes obtained from the straw, and/or display airway compromise by employing negative airway pressure, as opposed to negative oral pressure, to suck the liquid from the straw (Chandler, et al., 2009).

Effortful Swallow versus Straw + Effortful Swallow

It was predicted that coupling the use of high resistance straws with an effortful swallow would elicit higher swallowing pressures and muscle activity than simply performing an effortful swallow. However, there was no difference in pressures developed during isolated effortful swallows and those following sips from straws. Basically, the effortful swallow in isolation always produced higher values than coupling the effortful swallow with a resistance straw.

Although our findings do not support the hypothesis that supplementing effortful swallow therapy with high resistance straws leads to more intense effortful swallows, this study only addresses immediate effects of using the straw. Long-term effects may differ from those observed during this study. Strength training forces the neuromuscular system beyond the level of usual activity in order to elicit adaptations that occur to accommodate the increased demand (Chandler, et al., 2009). Previous research shows that the effortful swallow can be used to increase strength over time (Carroll, et al., 2007; Clark, 2005) Study of the use of resistance straws to augment the effortful swallow in strength training may reveal different findings than the immediate effects observed.

Dry Swallow versus Bolus Swallows

Dry swallows elicited the highest values for both swallow pressure and muscle activity in all swallowing and straw conditions. These findings support previous reports that dry effortful swallows elicit higher lingual pressures and muscle activity than bolus swallows (Witte, et al., 2008). There are several distinctions between saliva and bolus swallows that may explain these findings. The swallow reflex is initiated by touch receptors in the pharynx as a bolus is pushed to the back of the mouth by the tongue. Although saliva swallows are still reflexive, perhaps the lack of bolus sensation signals that greater effort is required. Additionally, water boluses flow more easily than saliva due to decreased viscosity. This may attribute to the increased effort required for dry/saliva swallows. Furthermore, several study participants reported that the straw water bolus swallows were perceptually easier than the dry swallows, despite very small bolus volumes.

Experimental Limitations and Next Steps

For this study, the isolated effortful and noneffortful swallows were always dry; the study did not include a non-straw bolus swallow. This is a study limitation because it does not allow for comparison of all possible swallowing and straw conditions. There is vast research on cup-, spoon- and syringe-delivered bolus swallows (Hollis & Castell, 1975; Kleinjan & Logemann, 2002; Kuhlemeier, Palmer, & Rosenberg, 2001) that support the differences between no-straw, liquid boluses and straw-delivered boluses. The non-straw bolus delivery may yield different results than those found in the current study for several reasons. For example, gravity plays a larger role in cup or spoon swallowing than in straw swallows. Also, negative pressure doesn't need to be generated in order to sip from a cup as it does for straw sipping. Both of these factors contribute to bolus transition between swallow stages and may have some effect on swallowing by people who display decreased bolus control or tongue range of motion.

Another point worth mentioning is that during this study, participants were first instructed to “sip and swallow as normally as possible,” which would constitute the aforementioned “effortful suck” as defined by Smead (2010). Next, they were instructed to “sip and swallow as hard as you can,” which would further increase neuromuscular drive, resulting in a type of *extra*-effortful suck. The noneffortful swallowing condition used in the current study is the closet match for the clinical protocol described by Smead. As a result, clinicians using the current outcomes for evidence-based practice may want to pay particular attention to those results.

In conclusion, the results from this study suggest that high resistance straws do not create a “ramping up” of neuromuscular drive that then overflows into a harder effortful swallow. Increased muscle activity and swallow pressures did occur with all resistance straws in the effortful swallow condition; however, contrary to the hypothesis, the larger diameter straws resulted in higher values than those with smaller diameters. Furthermore, the dry effortful swallow produced higher muscle activity and swallow pressures than any straw bolus swallows, effortful and noneffortful. These findings provide additional support for the well-documented benefits of the effortful swallow for patients with decreased swallowing pressures. Although immediate added benefits of high resistance straws were not observed, further research may identify particular training conditions under which resistance straws may be beneficial.

Figures and Tables

Table 1: Straw characteristics (Hietpas, et al., 2009)

Straw Color	**Diameter (in)**	**Volume (SD) (ml)**
Gray	.08 x 10.25 in	11.63ml (7.01)
Blue	.05 x 10.25 in	6.38 ml (4.00)
Orange	.03 x 10.25 in	3.14 ml (2.15)
Red	.025 x 10.25 in	2.11 ml (1.93)

Table 2: Mean peak lingual swallowing pressures in kilopascals

Straw Condition	**Mean (SD) Swallow Pressure (kPa)**	
	Non-effortful	**Effortful**
Dry	24.6 (9.7)	30.8 (12.8)
Gray	20.8 (9.5)	28.1 (14.1)
Blue	23.4 (9.5)	29.8 (13.2)
Orange	23.7 (10.0)	28.1 (11.5)
Red	20.1 (7.6)	26.0 (11.9)

Table 3: Mean peak muscle activity in microvolts

Swallowing Condition	**Mean (SD) Peak Muscle Activity (µV)**	
	Non-effortful	**Effortful**
Dry	80.7 (28.4)	113.4 (41.5)
Gray	69.1 (25.6)	109.3 (41.8)
Blue	72.5 (25.3)	106.7 (44.0)
Orange	76.5 (27.6)	102.4 (33.9)
Red	69.2 (20.7)	98.0 (32.7)

Figure 1: Mean peak lingual swallowing pressures in kilopascals

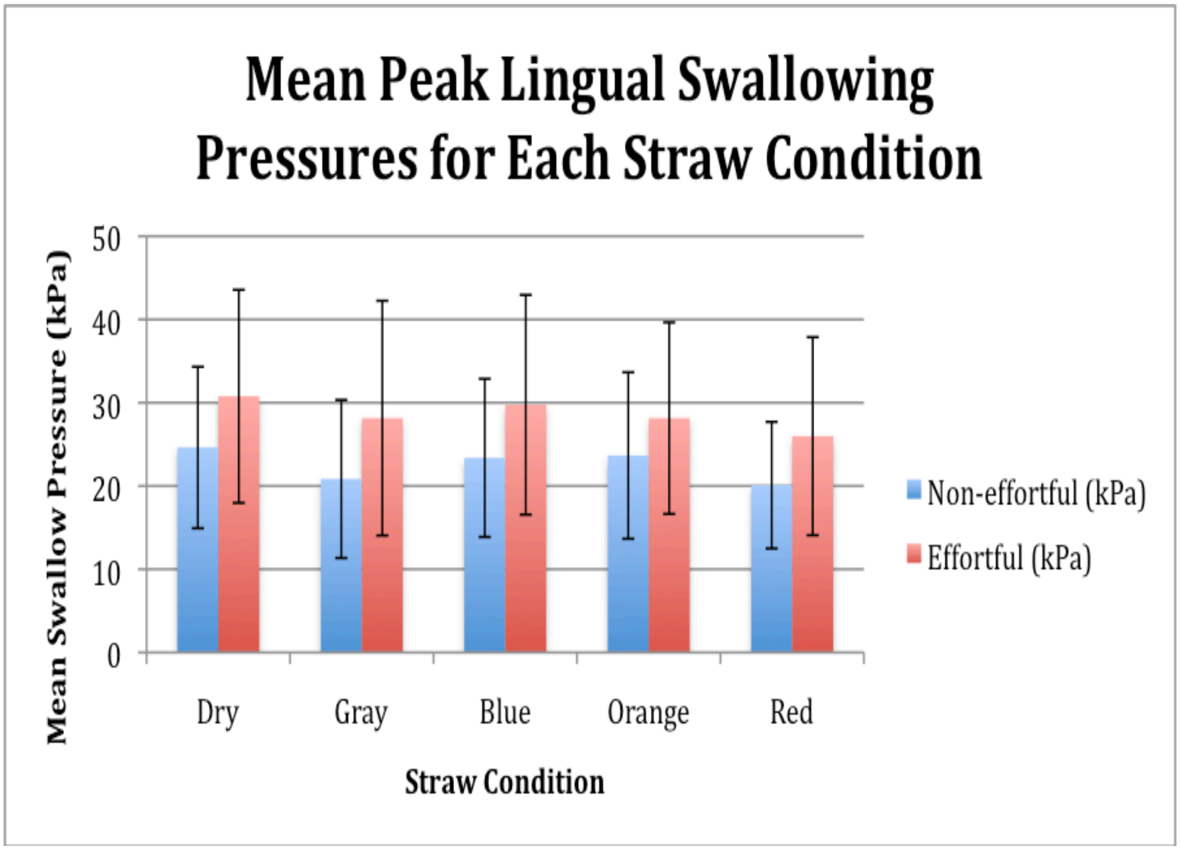


Figure 2: Mean peak muscle activity in microvolts

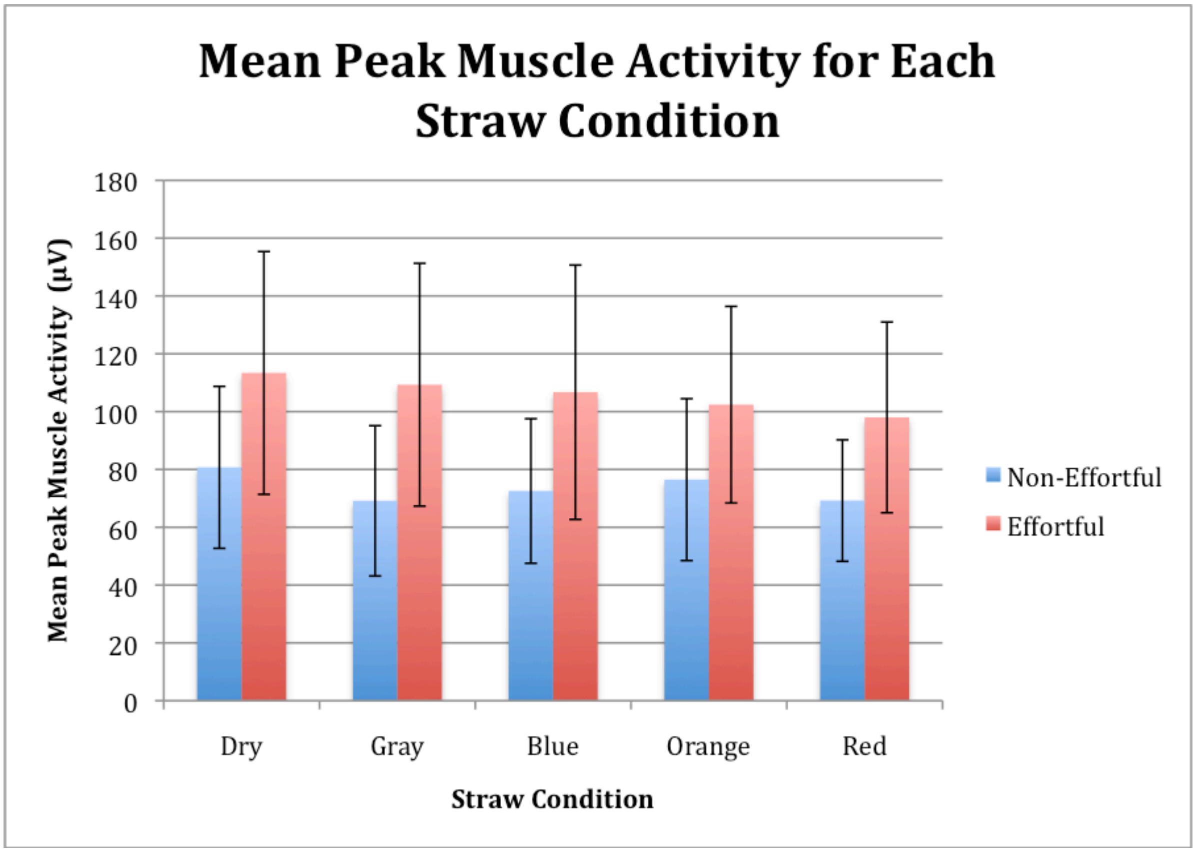
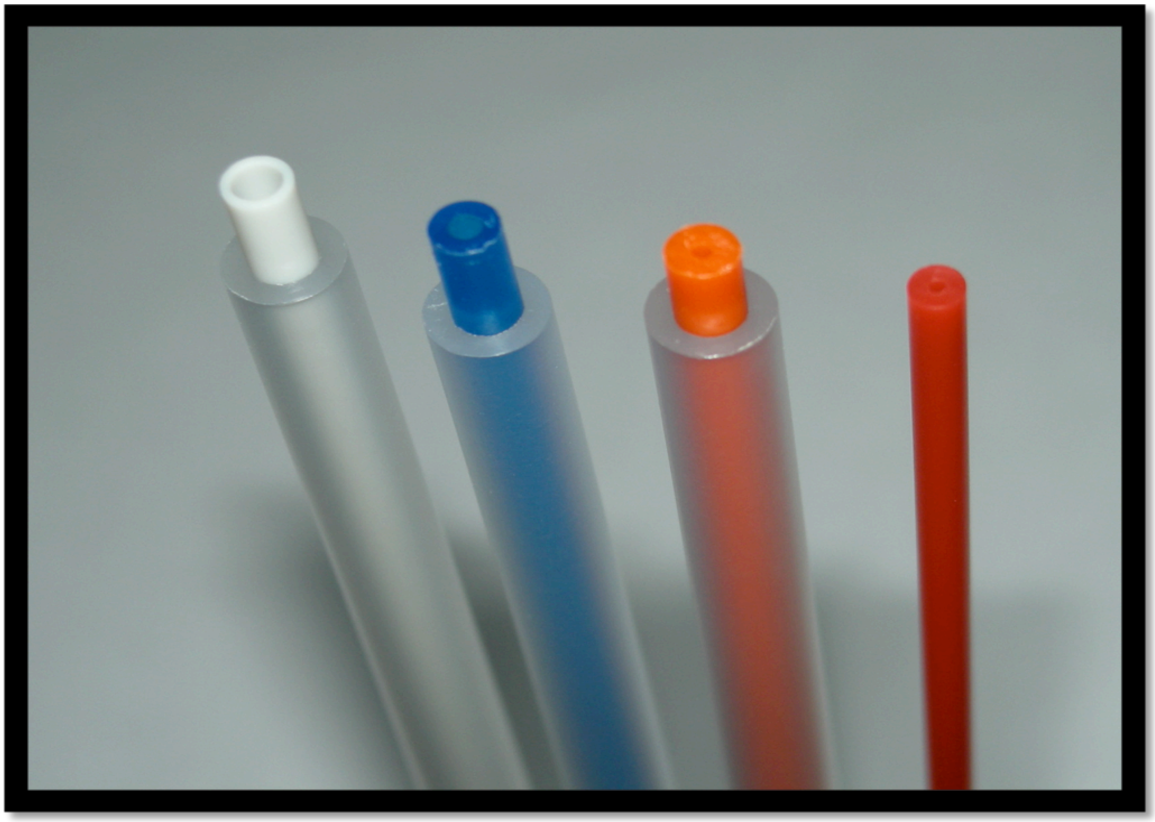


Figure 3: TheraSIP Resistance Straws



REFERENCES

Bulow, M., Olsson, R., & Ekberg, O. (2001). Videomanometric analysis of supraglottic swallow, effortful swallow, and chin tuck in patients with pharyngeal dysfunction. *Dysphagia, 16,* 190-195.

Carroll, W., Locher, J., Cannon, C., Bohannon, I., McCollach, N., & Magnuson, J. S. (2007). Pretreatment swallowing exercised improve swallowing function after chemoradiation. *Laryngoscope, 118*, 39-43.

Chandler, C., Hietpas, F., Clark, H. M., & Smead, K. (2009). *Respiratory patterns associated with straw drinking.* Paper presented at the Annual Meeting of the Dysphagia Research Society.

Clark, H. M. (2005). Therapeutic exercise in dysphagia managment: Philosophies, practices, and challenges. *Perspectives on Swallowing and Swallowing Disorders, 14*(2), 24-27.

Clark, H. M., & Shelton, N. S. (2010). Comparison of Two Treatments for Increasing Swallowing Pressures. Appalachian State University.

Corbin-Lewis, K., Liss, J. M., & Sciortino, K. (2005). *Clinical Anatomy and Physiology of the Swallowing Mechanism*: Thomson Delmar Learning.

Coulas, V. L., Smith, R. C., Qadri, S. S., & Martin, R. E. (2009). Differentiating effortful and noneffortful swallowing with a neck force transducer: Implications for the development of a clinical feedback system. *Dysphagia, 24*(1), 7-12.

Crary, M. A., & Baldwin, B. O. (1997). Surface electromyographic characteristics of swallowing in dysphagia secondary to brainstem stroke. *Dysphagia, 12*(4), 180-187.

Crary, M. A., Carnaby Mann, G. D., & Groher, M. E. (2006). Biomechanical correlates of surface electromyography signals obtained during swallowing by healthy adults. *J Speech Lang Hear Res, 49*(1), 186-193.

Crary, M. A., Carnaby Mann, G. D., & Groher, M. E. (2007). Identification of swallowing events from sEMG Signals Obtained from Healthy Adults. *Dysphagia, 22*(2), 94-99.

Crary, M. A., & Groher, M. E. (2000). Basic concepts of surface electromyographic biofeedback in the treatment of dysphagia: A tutorial. *American Journal of Speech-Language Pathology: A Journal of Clinical Practice, 9*, 116-125.

Crary, M. A., & Groher, M. E. (2003). *Introduction to Adult Swallowing Disorders*. St. Louis: Butterworth-Heinemann.

Dejaeger, E., Pelemans, W., Ponette, E., & Joosten, E. (1997). Mechanisms involved in postdeglutition retention in the elderly. *Dysphagia, 12*(2), 63-67.

Ertekin, C., Aydogdu, I., Yuceyar, N., Pehlivan, M., Ertas, M., Uludag, B., et al. (1997). Effects of bolus volume on oropharyngeal swallowing: An electrophysiologic study in man. *Am J Gastroenterol, 92*(11), 2049-2053.

Heitpas, F., Chandler, C., & Clark, H. M. (2009 March). *Effect of straw diameter on bolus volume and muscle activity*. Paper presented at the Annual Meeting of the Dysphagia Research Society.

Hietpas, F., Chandler, C., Clark, H. M., & Smead, K. (2009 March). *Effect of straw diameter on bolus volume and muscle activity*. Paper presented at the Annual Meeting of the Dysphagia Research Society.

Hind, J. A., Nicosia, M. A., Roecker, E. B., Carnes, M. L., & Robbins, J. (2001). Comparison of effortful and noneffortful swallows in healthy middle-aged and older adults. *Archives of Physical Medicine and Rehabilitation, 82*, 1661-1665.

Hiss, S. G., & Huckabee, M. L. (2005). Timing of pharyngeal and upper esophageal sphincter pressures as a function of normal and effortful swallowing in young healthy adults. *Dysphagia, 20*(2), 149-156.

Hollis, J. M., & Castell, D. O. (1975). Effect of dry swallows and wet swallows of different volumes on esophageal peristalsis. *Journal of Applied Physiology, 38*(6), 1161-1164.

Huckabee, M. L., Butler, S. G., Barclay, M., & Jit, A. (2005). Submental surface electromyographic measurement and pharyngeal pressures during normal and effortful swallowing. *Arch Phys Med Rehabil, 86*(11), 2144-2149.

Huckabee, M. L., & Steele, C. M. (2006). An analysis of lingual contribution to submental surface electromyographic measures and pharyngeal pressure during effortful swallow. *Arch Phys Med Rehabil,* 87(8), 1067-1072.

Kleinjan, K. J., & Logemann, J. (2002). Effects of repeated wet and dry swallows in healthy adult females. *Dysphagia, 17*, 50-56.

Kuhlemeier, K. V., Palmer, J. B., & Rosenberg, D. (2001). Effect of liquid bolus consistency and delivery method on aspiration and pharyngeal retention in dysphagia patients. *Dysphagia, 16*, 119-122.

Lazarus, C. L., Logemann, J. A., & Gibbons, P. (1993). Effects of maneuvers on swallowing function in a dysphagic oral cancer patient. *Head Neck, 15*(5), 419-424.

Logemann, J. A. (1998). *Evaluation and Treatment of Swallowing Disorders* (2 ed.). Austin, TX: Pro-Ed.

Masako, F., & Logemann, J. A. (1996). Effect of a tongue-holding maneuver on posterior pharyngeal wall movement during deglutition. *American Journal of Speech-Language Pathology, 5*, 23-30.

McCabe, D., Ashford, J., Wheeler-Hegland, K., Frymark, T., Mullen, R., Musson, N., et al. (2009). Evidence-based systematic review: Oropharyngeal dysphagia behavioral treatments. Part IV--impact of dysphagia treatment on individuals' postcancer treatments. *J Rehabil Res Dev, 46*(2), 205-214.

Murray, K. A., Larson, C. R., & Logemann, J. A. (1998). Electromyographic response of the labial muscles during normal liquid swallows using a spoon, a straw, and a cup. *Dysphagia, 13*(3), 160-166.

Neel, A. (2008). Can IOPI be used to measure tongue pressure for speech sounds? (Iowa Oral Performance Instrument). *Journal of Medical Speech - Language Pathology, 16*, 235-237.

Polluck, M. (1998). ACSM position stand: The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. . *Medicine and Science in Sports and Exercise, 30*(6), 975-999.

Robbins, J., Kays, S. A., Gangnon, R. E., Hind, J. A., Hewitt, A. L., Gentry, L. R., et al. (2007). The effects of lingual exercise in stroke patients with dysphagia. *Arch Phys Med Rehabil, 88*(2), 150-158.

Robbins, J., Levine R., et al. (1995). Age effects on lingual pressure generation as a risk factor for dysphagia. *Journal of Gerontology Series A: Biological Sciences and Medical Sciences, 50*(5), M257-262.

Shaker, R., Kern, M., Bardan, E., Taylor, A., Stewart, E. T., Hoffmann, R. G., et al. (1997). Augmentation of deglutitive upper esophageal sphincter opening in the elderly by exercise. *Am J Physiol, 272*(6 Pt 1), G1518-1522.

Smead, K. (2010). Strengthening the Swallow. Retrieved March 11, 2010, from http://speech-language-pathology-audiology.advanceweb.com/Editorial/Content/Editorial.aspx?CC=190090

Speech and NeuroRehab, I. (2010). Teach an effortful suck. Retrieved March 11, 2010, from http://www.therasip.com/index.cfm/fuseaction/instructions.index

Wheeler-Hegland, K., Ashford, J., Frymark, T., McCabe, D., Mullen, R., Musson, N., et al. (2009). Evidence-based systematic review: Oropharyngeal dysphagia behavioral treatments. Part II--impact of dysphagia treatment on normal swallow function. *J Rehabil Res Dev, 46*(2), 185-194.

Witte, U., Huckabee, M. L., Doeltgen, S. H., Gumbley, F., & Robb, M. (2008). The effect of effortful swallow on pharyngeal manometric measurements during saliva and water swallowing in healthy participants. *Arch Phys Med Rehabil, 89*(5), 822-828.

BIOGRAPHICAL INFORMATION

Natalia Louisa Shelton was born in Gainesville, Florida, on December 17, 1984. She attended elementary, and middle school in Daytona Beach, Florida, and graduated from Seabreeze High School in 2003. The following summer, she entered the University of Florida and in May 2007 she was awarded the Bachelor of Arts degree in Linguistics with a minor in Teaching of English as a Second Language. In the fall of 2009, she accepted a research assistantship in Speech-Language Pathology at Appalachian State University and began study toward a Master of Science degree. The M.S. was awarded in August 2011.

Ms. Shelton intended to begin work toward her Ph.D. in Speech-Language Pathology in August 2011. Her mailing address is 138 Wickham Square, Boone, NC 28607. Her parents are Dr. John Shelton and Mrs. Yvonne Shelton of Winston Salem, NC.