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Paige Licht
University of Northern Iowa

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COMPARISON OF TWO LEVELS OF INPATIENT DYSPHAGIA TREATMENT DOSAGES ON SWALLOWING OUTCOMES

A Thesis Submitted

in Partial Fulfillment

of the Requirements for the Designation

University Honors

Paige Licht

University of Northern Iowa

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This Study by: Paige Licht

Entitled: Comparison of two levels of inpatient dysphagia treatment dosages on swallowing outcomes

has been approved as meeting the thesis requirement for the Designation of University Honors

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Date Dr. Laura Pitts, Honors Thesis Advisor

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Date Dr. Jessica Moon, Director, University Honors Program

Abstract

Current research reveals great variability in many aspects of service delivery for swallowing rehabilitation, including dosage or intensity of treatment. Therefore, there is a need to investigate the effects of treatment intensity on swallowing rehabilitation outcomes. The purpose of this study is to determine whether two levels of treatment intensity produce different patterns of swallowing recovery for inpatients with neurogenic dysphagia. Blinded analysis of pre- and post-treatment videofluoroscopic measures of swallowing were completed for six inpatients at the Rehabilitation Institute of Chicago who were previously randomized to one of two dysphagia exercise programs. One arm consisted of traditional 30-minute treatment sessions, while the other arm consisted of 60-minute treatment sessions. This study contributes to the literature by exploring the following question: Do inpatients with neurogenic dysphagia receiving either 30-minute or 60-minute dysphagia treatment sessions exhibit differences in post-treatment gains on a videofluoroscopic swallow study? A descriptive, but non-significant, advantage was found for 60-minute dysphagia treatment sessions during inpatient neurorehabilitation when compared to 30-minute sessions, specifically in regard to timing and hyoid kinematics. Dysphagia rehabilitation administered more intensively may better improve swallowing physiology in neurogenic dysphagia. More research is needed to define more specific parameters of optimal treatment intensity to maximize swallowing recovery.

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Introduction

Swallowing is a crucial and complex event that requires the coordination of numerous nervous system pathways to safely and efficiently execute. When these systems are compromised, swallowing difficulty may arise. Such difficulty is known as dysphagia. Dysphagia impairs the safety and/or efficiency of a swallow and gives rise to multiple consequences. These consequences may include: malnutrition, prolonged hospital stay, reduced quality of life, and increased risk of death (Addington, Stephens, Gilliland, & Rodriguez, 1999; Alhashemi, 2010; Altman, Yu, & Schaefer, 2010; Ekberg, Hamdy, Woisard, Wuttge-Hannig, Ortega, 2002; Hansen, Larsen, & Engberg, 2008; Maeshima et al., 2011; Smithard et al., 1996).

In particular, dysphagia is a prevalent concern for survivors of a cerebrovascular accident (CVA) or traumatic brain injury (TBI). The most common cause of dysphagia in the adult population is CVA, and the majority of adult patients who have experienced a TBI will exhibit dysphagia (Bhattacharyya, 2014; Mackay, Morgan, & Bernstein, 1999). The negative consequences of dysphagia, especially malnourishment and aspiration pneumonia, can exacerbate the rehabilitative challenges these patients face. A majority of patients with severe TBI are malnourished as a result of dysphagia, which can lead to longer hospital stays and poorer rehabilitation outcomes (Finestone & Greene-Finestone, 2003; Finestone, Greene-Finestone, Wilson, & Teasell, 1996; Krakau et al., 2007). In patients with CVA, an alarming 34% will experience aspiration pneumonia that leads to death (Addington et al., 1999). Therefore, establishing effective treatments to address dysphagia in these neurogenic populations is critical.

Currently, exercise-based swallowing treatment demonstrates great promise to improve swallowing functioning and decrease the consequences of dysphagia (Malandraki et al. 2016). However, such treatment has been prescribed in an unstandardized manner across rehabilitation settings. The average intensity of swallowing treatment is 30-minutes a day; however, less than half of speech-language pathologists report consistently providing that same intensity of treatment (Carnaby & Harenberg, 2013). This is concerning in light of evidence that intensity of treatment does affect swallowing outcomes (Carnaby, Hankey, & Pizzi, 2006). Therefore, investigations regarding optimal treatment intensity for patients with dysphagia are needed. This study seeks to contribute to the literature by exploring the difference in swallowing outcomes between 30- or 60-minute treatment sessions of traditional dysphagia therapy for inpatients with neurogenic dysphagia.

Literature Review

Swallowing is a vital biological function to sustain life. It is an intricate process that requires both efficiency and safety to prevent health-related consequences, many of which may be life threatening and/or impair psychosocial well-being (Addington et al., 1999; Ekberg et al., 2002; Smithard et al., 1996). In healthy adults, swallowing of liquids has been traditionally explained and simplified into four phases: oral preparatory, oral transit/propulsive, pharyngeal, and esophageal (Dodds, Stewart, & Logemann, 1990; Miller, 1982); however, the ingestion of solid food also incorporates complex coordination between chewing and swallowing more recently categorized into five phases: intake, oral stage I transport, mastication, oral stage II transport, and swallowing (pharyngeal and esophageal phases; Inokuchi et al., 2014). For both liquids and solids, the phases of swallowing are precisely integrated and often overlapping (Palmer, Rudin, Lara, & Crompton, 1992).

Phases of a Healthy Swallow

The oral preparatory phase and the oral transit phase are important for safe swallowing. Specifically for liquids, oral preparation is the process of positioning the liquid on the tongue to prepare it for swallowing. During the oral preparatory phase, the liquid is brought to the mouth (e.g., via cup, spoon, or straw) and secured in the oral cavity. Subsequently, the liquid is contained in the mouth anteriorly, with an adequate labial seal; laterally, via cheek stabilization; and posteriorly, by the posterior oral tongue, which may help to prevent leakage of the liquid into the oropharynx before the swallow is initiated (Matsuo & Palmer, 2008).

The next phase in the swallowing of a liquid is the oral transit phase. This refers to the propulsion of the liquid through the oral cavity into the pharynx (Dodds et al., 1990).

For safe and efficient propulsion, a series of movements must occur. The tongue tip is elevated against the alveolar ridge, which effectively allows the liquid to be held against the hard palate, and the posterior portion of the oral tongue drops, creating an opening at the back of the oral cavity. The tongue then propels the bolus into the pharynx, moving in a peristaltic or wave-like fashion against the palate from front to back. Contact between the tongue and the palate results in positive pressure, which perpetuates movement of the liquid through the oral cavity into the pharynx. During swallows of liquid or solid material, the oral preparatory and transit phases are under greater volitional control than later phases of the swallow.

Specifically for the ingestion of solids, there are multiple volitional steps that work together to produce a safe swallow: intake, oral stage I transport, mastication, and oral stage II transport (Inokuchi et al., 2014). Intake refers to the step of placing the solid in the oral cavity (Palmer et al., 1992). Oral stage I transport consists of the movement of the food from the incisors to the postcanine teeth for chewing, which is also referred to as mastication (Inokuchi et al., 2014). Mastication mixes the material to be swallowed with saliva to produce a more cohesive unit of material, known as a bolus (Matsuo & Palmer, 2008). During mastication, the majority of the bolus remains in the oral cavity, anterior to the faucial pillars, until the pharyngeal swallow occurs; however, particularly in the case of solid foods, some of the bolus may be permitted to travel over the back of the oral tongue and rest in the valleculae (i.e., a space anterior to the epiglottis and posterior to the base of tongue) prior to the swallow (Palmer et al., 1992; Saitoh et al., 2007). Transportation of the bolus to the valleculae in the oropharynx is referred to as oral stage II transport (Matsuo & Palmer, 2008).

For both liquids and solids, the pharyngeal and esophageal phases are similar, patterned-based responses (Lang, 2009). Both of these phases are under involuntary control, mediated by the sensory inputs to the brainstem including cranial nerve (CN) circuitry (i.e., CN 5, 7, 9, 10) and the nucleus tractus solitarius. The pattern-based motor response is then executed through motor nuclei and nerves including the nucleus ambiguus, dorsal motor nuclei of vagus in the medulla, hypoglossal nuclei, and cranial and spinal nerves including CN 5, 7, 9, 10, 11, and 12 (Lang, 2009; Steele & Miller, 2010). The central control center for coordinating swallowing is located primarily in the medulla and is referred to as the central pattern generator. While these phases are largely under involuntary control, they are also adaptable. Therefore, altering the volume, texture, taste, and delivery of the bolus will cause the pattern of the swallow to be adapted (Hiiemae & Palmer, 1999; Saitoh et al., 2007).

Notably, these two phases (i.e., pharyngeal and esophageal) are different, yet interconnected. Specifically, the esophageal phase is inhibited by the reflexes that initiate the pharyngeal phase (Lang, 2009). The pharyngeal phase consists of transporting the bolus through the pharynx, safely around the opening to the lungs (i.e., the larynx) and into the esophagus. In order for the bolus to be safely transported, the airway must be protected. Therefore, the hyoid bone, which is connected to the larynx, moves superiorly and anteriorly thus tilting the larynx under the base of the tongue and inverting the epiglottis over the opening to the larynx, known as the laryngeal aditus. Additional protection is provided by the adduction of the true and false vocal folds, which creates a brief period of apnea during the swallow. In addition, the pharynx constricts from superior to inferior in a peristaltic motion to create positive pressure behind the bolus and negative pressure in front of the bolus to move it through the pharynx to the opening of the esophagus known as the upper esophageal sphincter (UES). The upper esophageal sphincter relaxes ahead of the bolus resulting in negative pressure in front of the bolus and allowing entry of the bolus into the esophagus (Hiiemae & Palmer, 1999; Matsuo & Palmer, 2008).

The esophageal phase specifically involves the propulsion of the bolus through the esophagus into the stomach (Dodds et al., 1990). Once the tail of the bolus passes through the UES, the sphincter contracts and esophageal peristalsis begins. In healthy adults, three waves of peristalsis may occur: primary, secondary, and tertiary. The lower esophageal sphincter also must relax to permit efficient entry of the bolus into the stomach (Hiiemae & Palmer, 1999; Matsuo & Palmer, 2008).

Swallowing Impairment

Unfortunately, if any of the above phases or a combination of phases is compromised, swallowing impairment or dysphagia may result. Dysphagia is an impairment in swallowing that hinders the efficiency and/or safety of a swallow beyond natural development or aging. When the efficiency of a swallow is reduced, the bolus may take increased time to move from the mouth to the stomach. For example, during the oral phase, reduced efficiency could be characterized by difficulty chewing or propelling the bolus from the oral cavity; in the pharyngeal phase, this may be caused by inadequate contraction of the pharynx; and impaired esophageal motility or impaired opening of the lower esophageal sphincter could potentially redirect or prolong the esophageal phase (Palmer, Drennan, & Baba, 2000). Reduced swallowing efficiency may also lead to retention of food, also referred to as post-swallow residue in the oral cavity, pharynx, or esophagus (Palmer et al., 2000). Deficits in swallowing efficiency do not preclude impaired swallowing safety, and in fact, often accompany reduced swallowing safety and contribute to the bolus entering the airway (Pearson, Molfenter, Smith, & Steele, 2013).

When swallowing safety is compromised, airway invasion occurs. Airway invasion is likely to occur secondary to dysphagia as the respiratory and digestive systems share anatomical structures (i.e., the pharynx and mouth), and both systems divert from the pharynx. The larynx diverts from the pharynx to transport air to the lungs, while the esophagus diverts from the pharynx to transport boluses to the stomach. Thus the pathways for both respiratory and digestive systems are shared, and when they diverge are located close to each other. This highlights the need for precise execution of the swallowing pattern to prevent airway invasion during swallowing (Matsuo & Palmer, 2008).

When the bolus enters the airway, it can be classified as either penetration or aspiration. Penetration is defined as material entering the larynx rather than the esophagus; however, the bolus does not pass inferiorly to the level of the vocal folds. Penetration may be ejected from the larynx or remain as post-swallow residue in the larynx above the vocal folds. Aspiration occurs when material enters the larynx and passes beyond the level of the vocal folds, regardless if the bolus is later ejected or remains as post-swallow residue (Matsuo & Palmer, 2008). Penetration and aspiration may occur secondary to impaired closure of the larynx, post-swallow residue, and/or bolus misdirection (Palmer et al., 2000).

Neurogenic Dysphagia

Although not fully known, it is thought that one in every 25 U.S. adults will experience dysphagia (Bhattacharyya, 2014). In particular, dysphagia is a prevalent concern for individuals with neurogenic disorders, such as survivors of a cerebrovascular accident (CVA) or traumatic brain injury (TBI). According to Bhattacharyya (2014), the most prevalent cause of dysphagia within the adult population is CVA. In fact, approximately 44% of stroke survivors and 60% of adults with TBI will exhibit dysphagia (Flowers, Silver, Fang, Rochon, & Martino, 2013; Mackay et al., 1999). Unfortunately, the health-related consequences associated with dysphagia are significant and negatively impact both general health and psychosocial well-being.

Consequences of Neurogenic Dysphagia

There are a number of negative health-related consequences associated with the presence of neurogenic dysphagia. When swallowing is impaired, it may lead to prolonged hospital stay, malnutrition, aspiration pneumonia, reduced quality of life, and increased risk of death (Addington et al., 1999; Alhashemi, 2010; Altman et al., 2010; Ekberg et al., 2002; Hansen et al., 2008; Maeshima et al., 2011; Smithard et al., 1996). According to Altman et al. (2010), the National Hospital Discharge Survey between 2005 and 2006 indicated the median number of hospitalization days for all patients with dysphagia is approximately two days longer than for patients without dysphagia. An earlier study done by Altman et al. (2007) found that specifically the length of stay for stroke survivors with dysphagia is extended to seven days or more for 73.9% of these patients, while only 14% of patients without dysphagia have a length of stay greater than seven days. Furthermore, greater length of stay due to dysphagia is a poor prognostic indicator for rehabilitation potential, exemplifying the importance of dysphagia intervention (Altman et al., 2010).

The presence of dysphagia can also lead to malnutrition, especially for persons post-CVA or post-TBI (Alhashemi, 2010; Smithard et al., 1996). An alarming 68% of patients with severe TBI are malnourished (Krakau et al., 2007). Malnourishment contributes to other difficulties such as prolonged length of stay, poor rehabilitation outcomes, and exacerbated swallowing dysfunction (Finestone & Greene-Finestone, 2003; Finestone et al., 1996).

Another common consequence of dysphagia is aspiration pneumonia, which occurs when bacteria enter and colonize the lungs by way of either aspirated saliva or bolus. Between 51-73% of patients who have had a stroke aspirate, which may lead to aspiration pneumonia. Pneumonia is the underlying cause of approximately 34% of all stroke-related mortalities, which demonstrates the grave concern for dysphagia in stroke survivors (Addington et al., 1999). The incidence of pneumonia is also high among populations with TBI, both within intensive care (44-60%) and rehabilitation units (12%; Hansen et al., 2008).

Quality of life is also impacted for individuals with neurological dysphagia. Particularly, the place of residence is a significant factor of quality of life for patients with dysphagia, as returning home is related to higher quality of life (Maeshima et al., 2011). According to Smithard, Smeeton, and Wolfe (2006), the likelihood of survival and the place of residence at three months post-stroke are related to the presence of dysphagia during the acute phase of stroke. Besides place of residence, quality of life can also be affected by the level of enjoyment a person experiences while eating and drinking. Individuals with dysphagia may experience a loss of enjoyment for eating and drinking, possibly because they experience embarrassment. Additionally, if their diet has been altered to ensure safe swallowing, they may be no longer able to enjoy the same foods they once were (Ekberg et al., 2002). Furthermore, patients with dysphagia experience reduced self-esteem and an increased sense of isolation (Ekberg et al., 2002). From the same study, only 45% of the participants with dysphagia found eating enjoyable. Because individuals with dysphagia may experience both medical consequences and reduced quality of life, it is critical that they receive effective rehabilitation.

Current Practices in Dysphagia Treatment

Treatment for patients with dysphagia is critical for optimal rehabilitation, however, there is still much to be learned about the best practices for swallowing therapy. In recent years, research on the efficacy of swallowing exercises to treat neurogenic dysphagia has demonstrated improvements in swallowing including advancing diet and increasing swallowing safety (Crary, Carnaby, LaGorio, & Carvajal, 2012; McCullough & Youngsun, 2013; Robbins et al., 2007). However, in current clinical practice, swallowing exercises are applied inconsistently (Carnaby & Harenberg, 2013).

Carnaby and Harenberg (2013) conducted a survey of 254 speech-language pathologists in the United States to ascertain and describe usual care practice for the rehabilitation of dysphagia. The study used a de-identified case of neurogenic dysphagia and asked each participating speech-language pathologist how they would provide therapy for the patient. A plethora of different treatment techniques and combinations were reported by the participants, revealing the inconsistency of current treatment practices, as well as a lack of reliance on research-based treatment techniques, such as prescribing swallowing exercises.

Carnaby and Harenberg's 2013 survey results revealed great variability in the typical dosage or intensity of treatment. Speech-language pathologists in the U.S. reported an average of 30-minutes of swallowing rehabilitation provided daily. However, this only represents 41% of the speech-language pathologists surveyed, with 59% of those surveyed reporting other variations in the duration of treatment sessions. This is concerning given recent research by Carnaby and colleagues (2006) which documents treatment intensity affects swallowing outcomes for patients with neurogenic dysphagia.

Carnaby et al. (2006) conducted a study in which patients with swallowing dysfunction following acute stroke were randomly assigned to three different treatment groups: usual care, low-intensity intervention, and high-intensity intervention. Usual care was managed by the physician and involved supervision of meals and the implementation of prescribed swallowing precautions. Each session lasted sixteen minutes. Low-intensity intervention was provided by a speech-language pathologist three times a week for a month or for the duration of a hospital stay, with each session lasting twenty-four minutes. Low-intensity therapy consisted of swallowing compensation strategies, safe swallowing advice, and dietary modifications. High-intensity intervention was also provided by a speech-language pathologist; however sessions occurred every day for a month or for the duration of a hospital stay and lasted for twenty-four minutes, direct swallowing exercises were applied, and dietary modifications made when appropriate.

Results for the three groups showed a more favorable outcome for those patients in the high-intensity group, as they showed a greater trend toward improved swallowing function and fewer chest infections (Carnaby et al., 2006). Therefore, these findings suggest the intensity of treatment influences swallowing outcomes, specifically in patients with dysphagia following acute stroke. Based on these findings, there is a great need to investigate optimal dosages of swallowing exercises in order to prescribe rehabilitation regimens that may best improve patient outcomes.

Present Investigation

The present study therefore contributes to the literature by comparing two inpatient swallowing rehabilitation regimens of differing intensities for persons with neurogenic dysphagia (i.e., CVA or TBI). The project analyzed changes in swallowing function across inpatients with dysphagia at the Rehabilitation Institute of Chicago who have been randomized and completed one of two dysphagia exercise programs. The two programs both consisted of 10 days of dysphagia intervention; however, they differed based on the principle of exercise intensity with one arm consisting of traditional 30-minute sessions of swallowing exercises and the second arm consisting of 60-minute sessions of swallowing exercises. Specifically, the research question explores: Do inpatients with neurogenic dysphagia receiving 60-minute dysphagia treatment sessions exhibit a difference in post-treatment gains on a videofluoroscopic swallow study compared to inpatients receiving 30-minute dysphagia treatment sessions? We hypothesized that inpatients receiving 60-minute sessions would demonstrate a significantly greater improvement in swallowing function as measured by videofluoroscopy than those randomized to 30-minute sessions.

Methodology

The research protocol was approved by the Institutional Review Boards at Northwestern University and the University of Northern Iowa. Data were analyzed by the author using computerized Swallowtail 2.0 software (BellDev Medical, 2017) for the completion of thesis requirements.

Participants

Six adults with oropharyngeal dysphagia secondary to acute onset of CVA or traumatic brain injury (i.e., aspiration, penetration, and/or pharyngeal residue as viewed on VFS with a Mann Assessment of Swallowing Ability (MASA) score < 178; Mann, 2002) provided consent for the study. Patient demographics are presented in Table 1. Two inpatients with dysphagia post-CVA and one inpatient with dysphagia post-TBI were randomized to each intervention group.

Table 1

Patient Demographics

Subject	Age	Gender	Etiology
Group 1			
ETTJA	24	M	TBI
RUBMA	80	M	CVA
RANHA	21	F	TBI
Group 2			
COSJO	56	M	TBI
BAKRI	59	M	CVA
ASTAS	23	M	TBI

Interventions

Participants were assigned via blocked randomization for etiology (i.e., CVA or TBI) to one of two treatment intensities that lasted for a duration of two weeks (10 sessions; 5 days a week). Study arms included either: 30-minutes of traditional swallowing exercises or 60-minutes of traditional swallowing exercises; both treatments were led by the same certified and experienced speech-language pathologist. Traditional exercise-based treatment included the following tasks: effortful swallow with or without a bolus depending on participant's risk of aspiration, anterior tongue press, Masako, base of tongue retraction via posterior lingual scrape across hard palate, Mendelsohn maneuver, and falsetto /i/ (Clark & Shelton, 2014; Fujiu & Logemann, 1996; Malandraki, Hind, Gangnon, Logemann, &

Robins, 2011; McCullough et al., 2012; Steele, Bailey, Molfenter, Yeates, & Grace-Martin, 2010; Veis, Logemann, & Colangelo, 2000).

Videofluoroscopic Swallow Studies (VFS)

A VFS is a swallow examination used to visualize and assess swallowing physiology by utilizing radiologic procedures. Patients are instructed to swallow varying textures and volumes of liquid or puree barium and food combined with barium while sequential videoradiographic images are captured. Barium is a contrast agent which allows the material to be viewed as it travels through the oral and pharyngeal cavities and the esophagus (Martin-Harris & Jones, 2008). Because VFS allows professionals to view the entirety of a swallow in real time, it is considered a gold-standard evaluation tool (Martin-Harris & Jones, 2008). In the present study, participants completed a VFS prior to receiving dysphagia intervention and following 10 sessions of treatment. VFS evaluations included swallows of: 1 mL, 3 mL, 5 mL, 10 mL, and single sips of thin liquid, 3 cc of pudding boluses of Varibar barium, and a quarter cookie combined with Varibar barium.

Videofluoroscopic Measures

Both temporal and displacement measures of swallowing ability were conducted (by the author) from VFS evaluations using a computerized analysis software known as Swallowtail version 2.0 (BellDev Medical, 2017). Select temporal and displacement measures are defined in Table 2. The author was blinded to both evaluation date (i.e., pre- versus post-treatment) and treatment allocation.

Table 2

Select Temporal and Displacement Measures Using Swallowtail Software

Temporal Measures	Definition
H1	start of hyoid movement
AEc	initiation of airway closure
HMax	time to maximal hyoid excursion
AC	airway closure duration
TPT	total pharyngeal transit time
Displacement Measures	
HMax	extent of maximal hyoid excursion
PESmDisplacement	extent of maximal pharyngo-esophageal sphincter displacement

Training

The author completed DVD-based trainings and practice measures produced by Dr. Leonard and BellDev Medical and utilized the Swallowtail instructions (Leonard & Kendall, 2013). The author also observed and applied Swallowtail measures with a mentor to two practice VFS evaluations of persons with dysphagia prior to completing Swallowtail measures on the entire sample of 12 VFS evaluations.

Analysis

Intrarater and interrater reliability. Three VFSs were reanalyzed using Swallowtail software by the author to determine intrarater reliability, and four VFSs were also analyzed by a second, trained rater to determine interrater reliability. Both raters were blinded to treatment allocation as well as to time of evaluation (i.e., pre-treatment or post-treatment).

Group differences. Independent *t*-tests were conducted to explore group differences in post-treatment gains for temporal and displacement measures between the two dysphagia exercise programs.

Results

Reliability

Intrarater reliability was excellent for temporal and displacement measures (Cronbach's $\alpha = .983$, Cronbach's $\alpha = .940$ respectively). Interrater reliability was moderate to strong with a single measures Intraclass Correlation Coefficient (ICC) for timing measures of 0.708 with a 95% confidence interval from 0.652 to 0.756 ($F(351, 351) = 5.845$, $p < .001$) and 0.851 for displacement measures with a 95% confidence interval from 0.757 to 0.910 ($F(54, 54) = 12.400$, $p < .001$). Reliability in the present investigation is consistent with prior reliability ratings of these temporal and displacement measures in both healthy adults (Kendall, McKenzie, Leonard, Gonçalves, & Walker, 2000; Leonard, Kendall, McKenzie, Gonçalves, & Walker, 2000) and persons with dysphagia (Kendall et al., 2016; Leonard & Belafsky, 2011).

Videofluoroscopic Outcomes

Temporal Measures. Baseline temporal measures (i.e., Start of Hyoid Movement (H1), Time Until Airway Closure (AEc), Time to Maximal Hyoid Excursion (Hmax), Duration of Airway Closure (AC) and Total Pharyngeal Transit Time (TPT)) did not differ between groups for thin liquid ($p > .298$), puree ($p > .174$), or solid boluses ($p > .442$) as explored by independent *t*-tests.

Group means and standard deviations for change between baseline and post-treatment performance on temporal videofluoroscopic measures are reported by bolus type in Table 3. At post-treatment, across all boluses (i.e., liquid, puree, and cookie), Group 2 demonstrated consistent and greater improvement in start of hyoid movement (H1), initiation of airway closure (AEc), and TPT. Across thin liquid boluses, temporal measures exhibited greater and consistent improvement for Group 2 compared to Group 1. Post-treatment changes for solids boluses demonstrated similar change in time to reach maximal hyoid excursion for puree swallows; however, airway closure during cookie swallows were lengthened for Group 1 compared to Group 2.

Table 3

Mean (SD) Change on Temporal VFS Measures (Baseline minus Post-Treatment) by Group.

	Group 1		Group 2	
Liquid	Mean	SD	Mean	SD
H1 (sec)	-.475	.521	.940	1.241
AEc (sec)	-.066	.939	.931	1.251
HMax (sec)	-.663	2.560	.010	.042
AC (sec)	.033	.176	-.073	.085
TPT (sec)	-.296	.944	.704	1.591
Puree				
H1 (sec)	-.765	.870	1.689	1.810
AEc (sec)	.270	1.535	1.629	1.646
HMax (sec)	-.044	.168	-.069	.097
AC (sec)	.022	.039	-.040	.109
TPT (sec)	.382	1.702	1.762	1.712
Cookie				
H1 (sec)	1.276	4.926	5.927	9.042
AEc (sec)	1.307	4.863	5.907	9.092
HMax (sec)	-.156	.139	.020	.066
AC (sec)	-.016	.058	.082	.189
TPT (sec)	1.305	4.860	5.958	8.994

Note. H1 = start of hyoid movement. AEc = initiation of airway closure. HMax = time to maximal hyoid excursion. AC = airway closure duration. TPT = total pharyngeal transit time.

Exploratory independent *t*-tests to examine group differences in change scores were conducted for all five temporal measures by bolus type and are reported in Table 4. No significant differences in change on temporal measures of swallowing were found between the two groups ($p > .05$). Trends emerged for an earlier start of hyoid excursion (liquid and puree boluses; $p = .143$, $p = .102$, respectively) and shorter time to reach maximal hyoid excursion (cookie bolus; $p = .119$) for Group 2 compared to Group 1.

Table 4

Independent t-Tests for Post- Treatment Change on Temporal Measures Between Groups and by Bolus

Liquid	*t*-value	df	*p*-value	*95% CI*
H1	-1.821	4	.143	-3.573, .743
AEc	-1.105	4	.331	-3.504, 1.509
HMax	-.455	4	.673	-4.776, 3.431
AC	.942	4	.399	-.207, .420
TPT	-.936	4	.402	-3.965, 1.966
Puree				
H1	-2.116	4	.102	-5.673, .766
AEc	-1.046	4	.355	-4.966, 2.248
HMax	.221	4	.836	-.286, .335
AC	.933	4	.404	-.123, .248
TPT	-.990	4	.378	-5.250, 2.490
Cookie				
H1	-.782	4	.478	-21.156, 11.853
AEc	-.773	4	.483	-21.129, 11.928
HMax	.202	4	.119	-.422, .071
AC	-.855	4	.441	-.415, .220
TPT	-.788	4	.475	-21.040, 11.735

Note. H1 = start of hyoid movement. AEc = time until airway closure. HMax = time to maximal hyoid excursion. AC = airway closure duration. TPT = total pharyngeal transit time.

Displacement Measures. Baseline displacement measures of PES displacement did not differ between groups for thin liquid ($p = .114$), puree ($p = .347$), or solid boluses ($p =$

.231) as explored by independent *t*-tests. Baseline displacement measures of maximal hyoid excursion was significantly greater for Group 1 compared to Group 2 for thin liquid ($p >$ .027), puree ($p = .041$), or solid boluses ($p = .009$) as explored by independent *t*-tests.

Group means and standard deviations in change between baseline and post-treatment performance on displacement videofluoroscopic measures are reported by bolus type in Table 5. Overall, improved displacement only occurred for liquid and cookie boluses, with both groups demonstrating less hyoid excursion and PES opening at post-treatment for puree boluses. During liquid swallows, Group 2 demonstrated improved maximal hyoid excursion at post-treatment with maintained PES opening; however, Group 1 declined in both maximal hyoid excursion and PES opening. For cookie boluses, Group 1 demonstrated improvement in the extent of maximal hyoid excursion and PES opening; however, Group 2 only demonstrated greater improvement in maximal PES displacement at post-treatment.

Table 5

Mean (SD) Change on Displacement VFS Measures (Baseline minus Post-Treatment) by Group.

	Group 1		Group 2	
Liquid	Mean	SD	Mean	SD
HMax	.938	.767	-.035	.210
PESmDisplacement	.290	.040	.002	.355
Puree				
HMax	.532	1.138	.401	.801
PESmDisplacement	.036	.156	.096	.052
Cookie				
HMax	-.156	.139	.020	.066
PESmDisplacement	-.109	.095	-.137	.036

Note. HMax = extent of maximal hyoid excursion. PESmDisplacement = extent of maximal pharyngo-esophageal sphincter displacement.

Significant differences between the two groups were not found in regard to the extent of change in displacement measures at post-treatment ($p > .05$). Independent *t*-tests between groups were conducted for both displacement measures by bolus type and are reported in Table 6. Trends emerged for Group 2 demonstrating greater improvements in extent of maximal hyoid displacement than Group 1 for all liquid boluses ($p = .102$); however, for cookie boluses Group 1 demonstrated greater improvements in extent of maximal hyoid displacement than Group 2 ($p = .119$).

Table 6

Independent t-Tests for Post- Treatment Change on Displacement Measures Between Groups and by Bolus

Liquid	*t*-value	df	*p*-value	*95% CI*
HMax	2.118	4	.102	-.302, 2.247
PESmDisplacement	1.395	4	.236	-.285, .861
Puree				
HMax	.163	4	.878	-2.100, 2.362
PESmDisplacement	-.634	4	.561	-.325, .204
Cookie				
HMax	-1.976	4	.119	-.422, .071
PESmDisplacement	.474	4	.660	-.134, .190

Note. HMax = extent of maximal hyoid excursion. PESmDisplacement = extent of maximal pharyngo-esophageal sphincter displacement.

Discussion

In summary, the purpose of this pilot study was to determine whether two levels of treatment intensity produced differing swallowing outcomes for inpatients with neurogenic dysphagia following two weeks of rehabilitation. Six adult patients with neurogenic dysphagia secondary to acute onset of CVA or TBI were randomly assigned to either 30-minutes or 60-minutes of traditional swallowing exercises. Changes in pre- and post-treatment swallowing performance on videofluoroscopy between the two groups did not significantly differ; however, overall trends suggest 60 minutes of traditional swallowing exercises may more effectively improve timing of the swallow and hyoid function specifically during liquid swallowing, compared to 30 minutes of traditional swallowing exercises.

Overall, the analyses utilizing the Swallowtail 2.0 software demonstrated strong intrarater and interrater reliability, as is consistently reported in the literature (Kendall et al., 2000, 2016; Leonard et al., 2000; Leonard & Belafsky, 2011). Specifically, intrarater reliability was excellent for both temporal and displacement measures with a Cronbach's alpha of .983 and .940, respectively. Interrater reliability was moderate to strong with ICC for timing and displacement measures falling within the 95% confidence interval at .708 and .851, respectively. Consistency in measurement within and between raters suggests such measures may be reliably used in clinical settings; however, clinical adoption of these measures is just beginning. Healthcare settings depend on repeatable measures and reliable interpretation of VFS in order to provide excellent patient care. Swallowtail measures may support such reliability; however, use of the software is dependent on extensive training which may slow adoption of such measures in a clinical setting. Furthermore, the process to complete multiple temporal and displacement measures is lengthy. For that reason, select pharyngeal measures of timing and displacement were chosen for the purpose of this study.

Effect of Treatment Intensity

Temporal Measures. When analyzing post-treatment gains in temporal measures of swallowing, significant differences were not found between the two groups; however, trends emerged demonstrating an overall greater improvement in timing of pharyngeal events for Group 2 when compared to Group 1. For example, patients who received 30-minutes of traditional swallowing therapy demonstrated, on average, a degradation in all timing measures for liquid swallows, while patients who received 60-minutes of therapy showed timing gains across all measures. This polar opposite effect found across thin liquid boluses may be due to the increased demand for speed during liquid swallows since liquid boluses flow faster than solid boluses (Taniguchi, Tsukada, Ootaki, Yamada, & Inoue, 2008). Considering there was a similar baseline performance between the two groups on these measures, there is potential that this overall effect of improved swallow timing is related to treatment intensity. Potentially, a more intense therapy program is necessary to produce positive change in swallowing timing, especially for swallows which may already occur with elevated speed, such as for liquid boluses.

For cookie boluses, there was also a trend for shorter durations to reach maximal hyoid excursion at post-treatment in Group 2 than in Group 1. These differences in the timing of hyoid movement between Group 2 and Group 1 may be due to the increased intensity of treatment that Group 2 experienced; however, specific gains in timing were not consistent across all boluses. This may suggest that hyoid movement is more responsive to intensive treatment within the early stages of recovery when compared to other measures of pharyngeal swallowing function. Perhaps, CN 5 and 7 and the suprahyoid muscles are demonstrating an earlier and greater benefit to intensive exercise, which may not be sufficiently elicited by a 30-minute program.

Displacement Measures. Similar to temporal measure findings, analysis of displacement measures revealed no significant differences between the two groups. Trends did emerge for greater improvements in maximal hyoid excursion across all liquid boluses for Group 2; however, Group 1 demonstrated greater improvements in maximal hyoid excursion for cookie boluses. No trends emerged for a group difference in PES opening.

Interestingly, improved maximal hyoid excursion co-occurred with improved speed of hyoid movement in Group 2, while improvement in maximal hyoid excursion was not accompanied by improved timing in Group 1. This suggests that increased intensity of treatment may be necessary in order to improve both the timing and extent of maximal excursion of the hyoid. Improvement in maximal hyoid excursion, however, only occurred for liquid boluses for Group 2. Group 2 demonstrated a degradation of maximal hyoid excursion for cookie boluses at post-treatment. Based on this result, it is possible that 60 minutes of traditional swallowing therapy may not be enough to influence a consistent improvement in hyoid displacement across all boluses.

Limitations and Future Research

Limitations of this study include a small sample size, which limits power of statistical analysis. Furthermore, it is difficult to determine if temporal and/or displacement measures at baseline or post-treatment are outside of healthy performance secondary to the limited normative data for Swallowtail measures. Swallowtail 2.0 does provide normative data by age and gender for thin liquid boluses of 1mL, 3mL, and 20mL, but not for boluses beyond those three. Due to the small sample size of only six participants, trends that emerged from the data should be considered with caution when generalized to the heterogeneous populations with dysphagia secondary to stroke or traumatic brain injury.

Future research may aim to have larger sample sizes and may also continue to block by etiology of neurogenic dysphagia (e.g., CVA versus TBI) and/or specific oropharyngeal deficits in timing and displacement. This may lead to more significant, disorder-specific, and conclusive findings. In addition to a larger sample size, it may be beneficial to investigate differing treatment intensities targeting dysphagia in other populations (i.e., head and neck cancer patients or neurodegenerative disease) as preliminary evidence suggest intensive exercise may be positive (Carnaby, Crary, Schmalfuss, & Amdur, 2012; Hutcheson et al., 2013).

The current study also consisted of a brief, two week treatment phase. Future research may be interested in investigating the long-term differences in outcomes based on the intensity of acute rehabilitation of neurogenic dysphagia. Specific areas of interest may focus on the relationship between acute rehabilitation of neurogenic dysphagia and length of stay/discharge rates, nutrition, pneumonia, and other rehabilitation outcomes (i.e., physical therapy, occupational therapy, and communication/speech therapy).

Conclusion and Clinical Implications

Increased intensity of traditional swallowing treatment may improve pharyngeal timing and the extent of maximal hyoid displacement in inpatients with neurogenic dysphagia. Even though current practice patterns vary widely in the prescribed intensity of swallowing exercises (Carnaby & Harenberg, 2013), this study extends the conversation of how best to prescribe exercises for patients within neurorehabilitation during early stages of recovery from a stroke or traumatic brain injury. More research is needed to delineate and clarify the potential short and long-term benefits of receiving more intensive therapy to rehabilitation swallowing function. The examination and establishment of optimal treatment intensities will inform service delivery to better address dysphagia and improve overall health and well-being for patients.

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