EFFECTS OF INTERDISCIPLINARY CHORAL SINGING THERAPY ON THE VOICE AND SWALLOWING FUNCTION OF INDIVIDUALS WITH PARKINSON'S DISEASE

By

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To my family

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure | page

Abstract of Thesis Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Master of Arts Degree

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Degenerative changes frequently occur to voice and swallowing function for many individuals with Parkinson's disease (PD) (Hoehn & Yahr, 1967; Sapienza & Hoffman Ruddy, 2009). Swallowing dysfunction in particular increases the risk of aspiration and pneumonia, a strong predictor of death (Fernandez & Lapane, 2002; Hoehn &Yahr, 1967). A small number of studies indicate that choral singing treatments are beneficial for improving vocal function in those with PD (Di Bennedetto et al., 2009; Haneishi, 2002). More research is needed to determine the effectiveness of choral singing treatments in treating voice problems in individuals with PD. No studies have discussed potential benefits of choral singing treatment on swallowing function.

The current study investigated an interdisciplinary approach to voice and swallowing treatment in those with PD that combined both music and voice therapy paradigms. Participants were three adult males between the ages of 67 and 85 years of age (H&Y $\leq$ 3.0; MMSE$\geq$24). This treatment involved an eight-week course of weekly one-hour combined modality sessions, implementing vocal, respiration, and articulation warm-up exercises, and choral singing of familiar songs. Intervention sessions were

supplemented with home practice, consisting of a CD of vocal function exercises and intervention session songs. Pre and post-test measures of maximal phonation tasks, maximum sound pressure level, maximum frequency range, maximum expiratory and inspiratory pressure, physiologic measures of swallow function, and quality of life related to voice and swallowing were compared to determine effects of the treatment.

Results indicate that after completing interdisciplinary choral singing therapy (ICST), all participants increased SPL, MEP, and MPT. Results for MFR and MIP indicated some reductions in those measures with treatment. Results for swallowing function revealed increases in the angle of elevation and magnitude of hyoid bone displacement during three sequential swallows each of 10 ml thin liquid and pudding thick barium.

The results of this study suggest that ICST can result in positive voice and swallowing outcomes for those with PD. This motivating and socially engaging therapy option may be used alone or in conjunction with more established therapy programs.

CHAPTER 1
INTRODUCTION

Parkinson's disease (PD) is a neurodegenerative disease that affects the extra pyramidal system of the brain, primarily the substantia nigra in the basal ganglia (Brissaud, 1925; Greenfield and Bosanquet, 1953). Parkinson's disease causes disordered movements of the body, most commonly hypokinesia, as first described by James Parkinson in 1817 as Shaking Palsy or "Paralysis Agitans". These disordered movements are a result of dopamine depletion within the striatum of the brain (Bertler & Rosengred, 1959). Parkinson's disease affects approximately 50 per 100,000 people above the age of 50 years, causing devastating changes to the body and severely impacting quality of life (Duffy, 2005). The etiology of PD is unknown, but there is evidence of both environmental and genetic contributing factors (Moore, West, Dawson, & Dawson, 2005). According to Duffy (2005), the primary characteristics of parkinsonism are tremor at rest, rigidity, bradykinesia, or reduction in muscle speed of activation, and loss of postural reflexes. A study by Hoehn and Yahr (1967) indicated that initial symptoms most frequently include tremor, gait disturbance, slowness, stiffness and muscle pain, loss in handwriting dexterity, drooling, facial masking or facial hypomimia as well as dysphagia and speech/voice difficulties, most often in the form of hypokinetic dysarthria.

Voice Disorders

Voice Disorders in Persons with PD

Approximately 89% of people worldwide with idiopathic PD have disordered communication (Fox et al., 2006), and approximately 90% of individuals with idiopathic PD develop hypokinetic dysarthria (Muller, et al., 1971; Duffy, 2005). James Parkinson

(1817) described symptoms of hypokinetic dysarthria when he described a patient exhibited reduced loudness and imprecise articulation to the point that caregivers could not understand. Hypokinetic dysarthria is a motor-speech disorder characterized by imprecise articulation, monotone prosody, increased or decreased rate of speech, and/or insufficient respiratory drive (Darley, Aronson, & Brown, 1969). The voice disorder within the defined hypokinetic dysarthria is characterized as hypophonia, or pathologically reduced loudness. It is also characterized by hoarseness/rough vocal quality, lowering or raising of average speaking pitch, and reduced pitch range (Duffy,2005; Sapienza & Hoffman Ruddy, 2009; Spielman et al., 2007; Narayana et al., 2010). Individuals with PD can also experience vocal tremor. These changes to the voice can have a significant impact on an individual's quality of life.

A study by Holmes, Oates, Phyland, and Hughes (2000) that examined 30 patients with early stage PD, 30 patients with late stage PD, and 30 healthy controls, found that men with PD showed increased jitter and harshness, and a high-speaking fundamental frequency that did not seem to degenerate with the progression of the disease. This study found that women with PD have reduced fundamental frequency variability that did not seem to degenerate with the progression of PD. In both men and women, loudness levels, breathy vocal quality, monopitch and monoloudness, and maximum pitch range worsened in the later stages of PD. Additionally, vocal tremor was found only in later stage PD (Holmes, Oates et al. 2000).   These findings were similar to another study by Gamboa and associates (1997), which measured the acoustic features of the voice in participants with PD compared to healthy control subjects. The researchers discovered increased jitter and lower harmonic/noise ratio during sustained vowel phonation of /a/ and lower frequency and intensity variability during connected speech of a sentence in those with PD. Also, a higher frequency of monopitch, voice arrests, and struggle were noted in those with PD compared to healthy controls.

Another study by Perez, Ramig, Smith, and Dromey (1996) determined that 55% of 22 individuals with idiopathic PD displayed predominantly vertical laryngeal tremor and phase asymmetry during sustained phonation while undergoing endoscopy and stroboscopy. This study also found that in the majority of the patients with idiopathic PD, vocal fold amplitude and mucosal wave were normal. Studies by Baker and associates (1998) and Luschei and colleagues (1999) indicated decreases in thyroarytenoid (TA) motor unit activity and firing rate, possibly adding to the decreased vocal loudness produced within the PD population, and suggesting that laryngeal dysfunction may be related to a sensory gating issue versus muscular rigidity(Ramig, Fox, Sapir, 2004).

Respiratory function also declines in individuals with PD (Ramig, Fox, & Sapir, 2004), contributing to the symptoms of reduced loudness and reduced sustained phonation duration. Phonation duration and intensity rely in part to the degree of respiratory pressures that are produced by an individual (Draper, Ladeford, & Whitteridge, 1959; Finnegan, Luschei, & Hoffman, 2000). Maximum voluntary ventilation (MVV), forced vital capacity (FVC), maximum expiratory pressure (MEP), and maximum inspiratory pressure (MIP) were all significantly reduced when compared to healthy control subjects in a study by Sathyaprabha and colleagues (2005). Improvement on pulmonary function testing measures was found when participants were in the “on” state with levodopa. Seccombe and associates (2011) also found that although exhibiting normal lung volumes and flow, the majority of patients with mild-moderate PD demonstrated MEPs and MIPs below the lower limit of norms (Black & Hyatt, 1969) and abnormal ventilatory control.

Current Voice Research

Research has been conducted investigating individual voice therapy and group voice therapy to improve hypophonia, respiratory functioning, speech intelligibility, and other vocal deficits of patients with PD. Individual therapy targeting speech and vocal function, completed before 1990, yielded limited generalization and magnitude of change (Searl et al., 2011). Some case control studies did reveal positive results, however. One study by Robertson and Thomson (1984) revealed that intense speech-therapy of 40 hours over 2 weeks yielded significant improvement in articulation and phonation. Another case control study by Johnson and Pring (1990) targeted maximum intensity and fundamental frequency in 10, 1-hour sessions over 4 weeks with the result of improved pitch, vocal intensity, and decreased dysarthria scores. These studies showed that with more intensive speech-therapy, improvements in speech and voice of patients with PD do occur.

Outcomes associated with group voice therapy are far less studied than outcomes associated with individual voice therapy. Recently, group voice therapy has been shown to increase voice-related quality of life (V-RQOL) scores and vocal symptoms scores in 12 adult teachers with hyperfunctional dysphonia, with the treatment gain lasting 6 months post-treatment (Law et al., 2012). A study by Searl and colleagues (2011) indicated that group voice therapy for individuals with PD is a feasible therapy option. This study collected positive participant and clinician feedback about an

8-week voice group utilizing modified LSVT tasks. Additionally, positive changes in loudness, pitch range, and Voice Handicap Index (VHI) were demonstrated for 15 adult subjects, with a mean age of 70.4 +/-11.1.

Established Voice Therapy

Treatment of disordered voice in those with PD has been historically difficult due to the variability of speech and vocal performance from day to day, at different times of the medication cycle, and due to interactions with age, sex, years since onset, and other variables (Denny & Behari, 1999). The most efficacious program to date is the Lee Silverman Voice Treatment (LSVT) program, first reported by Ramig, Countryman, Thompson, and Horii (1995). It is the only speech/voice treatment for those with PD that is supported by Level I efficacy data and not only has been shown to increase vocal loudness levels, but also has evidence of changes in vocal quality, speech intelligibility, and articulation (Ramig et al., 2001; Spielman et al.,2007). Specifically, Spielman and colleagues (2007) reported that LSVT improved vocal loudness by 8 dB SPL after patients received therapy 4 times per week for 4 weeks and in an extended version (LSVT-X), in which patients received therapy 2 times per week for 8 weeks. For the LSVT-X extended program, these increases were maintained after 6 months at 7.2 dB SPL. Further research investigations have shown that high-effort, intensive, amplitude training within the LSVT program led to improved laryngeal and respiratory measures, but also showed distributed effects to the speech intelligibility, swallowing, and facial expression (El-Sharkawi, et al., 2002; Spielman, Borod, & Ramig, 2003). A study by Fox and colleagues (2006), suggests that this may be due to “neural coupling” of orofacial muscles to the neurologic systems of respiratory and laryngeal control in normal human research.

Dysphagia

Dysphagia in Persons with PD

The act of swallowing is a mixed voluntary and autonomic controlled event, which occurs in three major stages: oral, pharyngeal, and esophageal (Logemann, 1983; Potulska, Friedman, Krolicki, & Spychala, 2003). It begins when food or liquid particles enter the oral cavity through feeding, are formed into a bolus by the oral cavity, and propelled into the pharynx and subsequently into the esophagus through the upper esophageal sphincter (UES). Swallowing involves muscles of the face, the palate, tongue and those involved in mastication, as well as the suprahyoid muscles, which elevate the hyolaryngeal complex, and pharyngeal muscles, which help with bolus propulsion into the esophagus (Logemann, 1983; Dodds, Stewart, & Logemann, 1990.)

Diminished vertical elevation of the hyolaryngeal complex has been shown to decrease the ability of the UES to open and ease transfer of bolus into the esophagus (Kendall & Leonard, 2001; Kendall, Leonard, McKenzie, 2004). Accordingly, it has been found that decreased hyoid bone displacement, in individuals with PD, is one cause of penetration and aspiration during swallowing (Troche et al., 2010). Kendall and Leonard (2001) found that older patients with swallowing difficulty versus younger patients with swallowing difficulty had a higher extent of hyoid displacement, but a lower duration of maximum elevation. The researchers of this study hypothesized that higher extent of hyoid displacement may be a compensation for slower initiation and duration of maximum excursion. Kendall, Leonard, and McKenzie (2004) discovered that healthy elderly subjects did not elevate the larynx or clear the pharynx to the same extent as younger control subjects, although point of maximum hyoid bone displacement did not differ between groups. The researchers indicated that hyoid to larynx approximation is important for pharyngeal propulsion of the bolus.

Dysphagia, or difficulty in swallowing, can occur at any of these three stages and can be categorized according to what stage difficulty occurs, according to “Taber's cyclopedic medical dictionary” by Davis (1993). Throughout this paper, dysphagia will refer specifically to oropharygeal dysphagia, difficulty that occurs when moving the bolus from the mouth to the esophagus (Davis, 1993; Groher & Crary, 2010). In recent years, dysphagia has been defined by Tanner (2006) as a deficit of sensory, cognitive, emotional, and/or motor acts involved in the transfer of a bolus from the mouth to stomach, which results in “failure to maintain hydration and nutrition, and an increased risk of choking and aspiration”(p. 152).

It is estimated that as many as 95% of individuals with PD have deficits in swallowing function (Fox et al., 2006; Potulska et al., 2003; El Sharkawi et al., 2002). Deteriorating swallowing function often causes aspiration of food and liquids into the lungs and subsequent pneumonia, which is a major cause of death in the PD population (Fernandez & Lapane, 2002; Hoehn &Yahr, 1967). In the oral phase, tremor in the oral cavity, piecemeal swallowing, repetitive tongue pumping and other aberrations in tongue movement, and impaired motility may occur (Potulska et al., 2003; Van Lieshout, Steele, and Lang, 2011). Difficulties associated with pharyngeal stage swallowing in those with PD include decreased hyolaryngeal excursion, deficient epiglottic positioning and range of motion, vallecular and pyriform residue, aspiration and penetration, and impaired motility (Leopold & Kagel, 1997; Groher & Crary, 2010; Troche et al., 2010). Dysfunction of the UES and delayed transport of the bolus in the esophageal phase can add to dysphagia severity in those with PD (Leopold & Kagel, 1997; Potulska et al., 2003; Groher & Crary, 2010).

A study by Potulska and colleagues (2003) assessed the swallowing reflex and different stages of swallowing using electromyography (EMG) and esophageal scintigraphy in 18 individuals with PD. This study revealed delayed triggering of the swallowing reflex, prolongation of laryngeal movement during the pharyngeal phase of swallowing, and prolonged esophageal phase of swallowing occurred. Furthermore, all participants demonstrated piecemeal deglutition, in which the participants took more than one swallow to clear one bolus into the esophagus. This was seen in participants that had no complaints of dysphagia symptoms. This suggests that dysphagia may occur at a subclinical level in early stages of PD. Additionally, Van Lieshout, Steele, and Lang (2011) found that 10 patients with mild-moderate PD showed smaller and more variable tongue movements in the horizontal plane, showing subclinical change in earlier stages of PD than previously thought.

Current Dysphagia Research

Before 2008, studies investigating behavioral therapy for orophayngeal dysphagia in patients with PD were diverse in therapeutic methods and outcome measures and most were non-randomized clinical trials consisting of fewer than 12 participants (Baijens & Speyer, 2008). A recent exception to this finding includes a study of expiratory muscle strength training (EMST) by Troche et al. (2010) of 60 patients with PD. Baijens and Speyer (2008), in a review of dysphagia therapy in PD patients, found that outcomes for behavioral treatment or swallowing training, however, have been more positive in comparison to studies investigating surgical and medicinal interventions. For example, a meta-analysis by Menezes and Melo (2009) of five studies recounting swallowing function in patients using levodopa, none of these studies indicated that levodopa intake had any effect, whereas LSVT (El Sharkawi et al., 2002) EMST (Pitts et al., 2009; Troche et al., 2010) and highly intensive speech therapy (Robertson & Thomson, 1984) have resulted in positive swallowing outcomes, with sample sizes of 8, 60, and 18, respectively (Russel, et al., 2010).

Long-lasting therapeutic benefits for rehabilitation of PD have occurred when the therapy is swallowing-specific, due to the “somatotopical organization” of the basal ganglia and importance of context on degrees of motor movement and impairment (Russel et al., 2010). Despite the expectation that benefit most likely would occur from dysphagia therapy involving swallowing-specific tasks, both EMST and LSVT have documented positive swallowing outcomes for non-swallowing specific activities. These outcomes suggest that there may exist some “cross system-interactions” in which shared central and peripheral circuits are activated (Russel et al., 2010). Findings from LSVT study by El Sharkawi and colleagues in 2002 discussed that positive swallowing outcomes may have originated from activation of neuromuscular control of the entire aerodigestic tract.

Lee Silverman Voice Therapy, an established voice treatment for individuals with PD, has shown reductions in swallowing motility disorders and reduced temporal measures in 8 subjects with PD (El Sharkawi et al., 2002). Although LSVT-LOUD does not specifically target swallow function, the exercises recruit many of the same muscles involved, such as the submental muscles, and create positive outcomes for swallowing, possibly due to similarities in peripheral and central neural control elements (Russel, Ciucci, Connor, & Schallert, 2010). Another study by Robertson and Thomson (1984) discovered that 40 hours over 2 weeks of intensive speech therapy targeting phonation, respiration, prosody, and articulation resulted in significant improvement to swallow response time to solid food and liquid boluses for 18 subjects with PD.

Established Dysphagia Treatments

Current direct treatments for dysphagia include a variety of specific swallowing maneuvers, such as the Masako, or tongue hold maneuver, the Mendelsohn maneuver, super-supraglottic swallow, and the effortful swallow (Lazarus, Logemann, Song, Rademaker, & Kahrilas, 2002; Ashford et al., 2009; Groher & Crary, 2010). Lazarus and associates (2002) reported that these swallowing maneuvers improved tongue base-pharyngeal wall pressures and increased contact duration in individuals with head and neck cancer. Kyng and colleagues (2010), in a neuroimaging study reported that both the effortful swallow and the Mendelsohn maneuver elicited higher responses in brain regions related to swallowing compared to a dry swallow, suggesting enhanced cortical activation during the tasks. Positional modifications during the swallow such as tucking the chin down are commonly used to improve swallowing function and airway protection, as well (Welch, Logemann, Rademaker, & Kahrilas, 1993; Ashford et al., 2009). A review by Ashford and associates (2009) found, however, that although the chin tuck maneuver is used commonly, it provides only limited physiologic protection against aspiration for those with neurologic disorders, such as PD. The swallowing techniques listed above are task-specific, as they strengthen swallowing muscles and increase coordination through modified swallowing tasks (Lazarus et al., 2002; Logemann, 1983). They can be used with or without a bolus depending upon the deficit of the patient.

The Masako, or tongue hold maneuver, is completed when the patient swallows while holding the tongue anterior to the teeth, thus causing the posterior pharyngeal wall to bulge and create pressure that helps move the bolus into the pharynx (Fujui & Logemann, 1996; Fujui-Kurachi, 2002). The Mendelsohn maneuver is completed by asking the individual to hold an ongoing swallow at the top of hyolaryngeal excursion during swallow for a few seconds before relaxing and allowing the swallow to continue (Kahrilas, Logemann, Krugler, & Flanagan, 1991). In a study by Kahrilas and colleagues (1991), the Mendelsohn maneuver increased the duration of the anterio-superior excursion of the hyoid and larynx and delayed sphincter closure by maintaining traction on the anterior wall of the sphincter. The Mendelsohn maneuver has been cited to improve total oral feeding in two thirds of 58 tube-fed individuals with neurologic deficits (Neumann et al., 1995). The super-supraglottic swallow requires a breath-hold with effort during a swallow to target glottal closure and is designed to protect against aspiration (Donzelli & Brady, 2004). The effortful swallow, also called the forceful or hard swallow technique, requires the patient to “bear down” while swallowing in order to increase the forces of the structures inside the swallowing mechanism on the bolus (Pouderoux & Kahrilas, 1995). Hind, Nicosia, Roecker, Carnes, and Robbins (2001) found that 64 healthy middle-aged and older men and women increased the duration of hyoid maximum anterior excursion, laryngeal closure, and UES opening after using the effortful swallowing maneuver. A study by Felix, Correa, and Soares (2008) found that the effortful swallow improved clinical swallowing measures, such as the presence of coughing and choking after swallowing, alteration of vocal quality after swallowing, and residue in the oral cavity, especially when reinforced with biofeedback.

Expiratory muscle strength training, on the other hand, is a recently established therapy that has been shown to improve swallowing and cough function (Pitts et al., 2009, Troche et al., 2010). Improved cough function is linked to EMST improvements in MEP. A high maximum expiratory pressure is needed during a cough in order to aerosolize and dispel material from the airway. With the EMST device, users must create an isometric muscle contraction that is task-specific training to voluntary and reflexive cough (Pitts et al., 2009). It is, however, an example of a non-task specific swallowing exercise that has strong evidence of efficacy. Troche and colleagues (2010), in a Class 1 randomized trial of sixty patients with PD, have cited improvements to swallowing in those with PD after participation in a 4-week restorative program utilizing EMST, as evidenced by improved penetration-aspiration scores (P-A scores), most probably due to improvements to hyolaryngeal functioning. Additionally, this study showed improvements to a swallowing quality of life measure (SWAL-QOL), increases to the extent of hyolaryngeal magnitude displacement (in millimeters), and stability in the duration of maximum hyolaryngeal magnitude displacement versus a sham group.

Music Therapy and PD

Music therapy (MT) is defined as the intentional and planned use of music to improve the individual's psychological, social, physical, and spiritual well-being (Magee, Brumfitt, Freeman & Davidson, 2006). The field of formal music therapy began in the late 1940s, catalyzed by the large population of soldiers coming back to the United States from fighting in WWII with traumatic brain injuries from head wounds and post-traumatic stress disorder or "shell shock" (Sacks, 2007, pg. 272). Healthcare professionals noticed that music could decrease depression and pain, and improve blood pressure and pulse rates (Sacks, 2007, pg. 272). Additionally, a functional magnetic resonance imaging study has found that listening to and anticipating music has been shown to increase dopamine release in the striatal system in the basal ganglia (Salimpoor, Benovoy,Larcher, Dagher, & Zatorre, 2010).

Music therapy has been proven to be effective in management of functional communication in those with PD, in addition to other neurological deficits caused by Stroke and TBI. A study by Masayuki and Kuzuhara (2008) found that eight participants with PD increased the number of steps walked and timing of steps after receiving one session of music therapy in which participants were trained to “mentally sing” while walking. Another randomized and controlled study by Pachetti and colleagues (2000) found that 16 patients with PD who participated in MT versus 16 patients with PD who participated in traditional physical therapy improved bradykinesia, a slowed ability to initiate and continue motor movements, on the Unified Parkinson’s Disease Rating Scale-Motor Symptoms (Goetz et al., 2008). The MT group also improved emotional functions and Happiness Measure (Fordyce, 1988). The MT sessions consisted of choral singing, voice exercise, as well as free and rhythmic body movements. Maggee, Brumfitt, Freeman, and Davidson (2006), in a case study, revealed that after completing sessions of MT coupled with speech-language therapy, a patient with Parkinsonian vascular disease improved prosody, phonation, and measures of well-being. This study utilized physical, breathing, and vocal exercises. Vocal exercises included singing on an ascending and descending scale and manipulating and timing single open vowel sounds on a single exhalation. The MT sessions also consisted of singing simple, familiar songs (Magee et al., 2006).

Singing and Voice Treatment in PD

As previously discussed, recent voice and swallowing research has highlighted the importance of intensive treatment with a requirement of high levels of physical effort in order to improve speech and swallowing symptoms in those with PD. According to Ramig et al. (1995), patients also must be constantly motivated to high level of performance. In this context, a group program involving singing activity may be beneficial to patients, as singing may be a motivating experience that requires high phonation effort and respiratory coordination (Haneishi, 2001). Additionally, Kleber, Veit, Birbaumer, Gruzelier, and Lotze (2010) indicated that vocal skills training increased functional activation of the primary somatosensory cortex representing the larynx and articulators bilaterally. This study also demonstrated that expert classically trained singers showed increases of activation in the thalamus, cerebellum, and basal ganglia, areas responsible for enhanced sensorimotor regulation and kinesthetic motor control, which are often impaired in individuals with PD. Singing results in higher vocal intensities (Tokinson, 1994) than speaking, and may increase respiratory muscle strength (Wiens, Reimer, & Guyn, 1999). Singing classes have been used to increase maximum respiratory pressures in those with chronic obstructive pulmonary disease (Bonilha, Onofre, Vieira, Prado, & Martinez, 2009).

Musical and other Fine Arts activities have been established in the U.S. for patients with PD, such as the Creative Arts for Parkinson's music and theater program at Northwestern University Parkinson Disease and Movement Disorders Center (Science Daily, 2011). A controlled and randomized study by Modugno and colleagues (2010) reported that participation in an active theater program improved ratings of the Unified Parkinson's Disease Rating Scale (Goetz et al., 2008) for 10 subjects with PD.

Recent studies investigating the role of individual and choral singing on voice function in PD have revealed positive results. Haneishi (2001) discovered increased vocal intensity, improved speech intelligibility, and increased duration of maximal sustained phonation in four female participants after they were involved in Music Therapy Voice Protocol (MTVP). This intervention used vocal warm-ups and singing exercises for the duration of 12-14 sessions. Another study, by Di Benedetto and colleagues (2009), found that choral singing, if employing prosodic, respiratory and laryngeal exercise may lead to improvements in reading and vowel phonation. This study demonstrated that voice choral singing therapy (VCST) improved respiratory pressures (MEP and MIP) and volumes, increased maximum phonation time (MPT), and reduced vocal fatigue in 13 male and 7 female subjects with PD. These types of improvements did not transfer well to benefit overall vocal quality, however. Short-term versus long-term effects were not examined. It was noted, however, that the participants showed good treatment compliance, which was consistent with their hypothesis that choral singing might show comparable or higher participation compliance than traditional therapies (Di Benedetto et al., 2009). According to Wan, Ruber, Hohmann, and Gottfried (2009), although these two studies had relatively small sample sizes, the results of both studies show that singing may help to better speech deficits and that a therapy employing choral singing is worthy of further investigation.

These two studies represent only preliminary evidence and there is little indication that a program integrating MT and voice therapy would result in positive physiologic voice and swallowing disorders in individuals with PD. The therapy provided in the current study targeted respiratory, swallowing, and voice function, allowing for more support of a larger controlled study investigating interdisciplinary choral singing therapy (ICST). Interdisciplinary choral singing therapy was designed to utilize choral singing techniques, combining both voice therapy and MT paradigms. The aims and hypotheses for this study are as follows:

- Aim 1: To examine effects of ICST on physiologic and perceived changes in the voice.
- Hypothesis 1: Interdisciplinary choral singing therapy will increase measures of respiratory pressure and vocal functioning, and will improve voice-related quality of life.
- Aim 2: To examine effects of ICST on physiologic and perceived changes in the swallowing mechanism.
- Hypothesis 2: Interdisciplinary choral singing therapy will increase hyoid bone angle and magnitude displacement, improve penetration-aspiration scores, and improve swallowing-related quality of life.

CHAPTER 2
METHODS

Participants

Participants were three men, between the ages of 67 and 85 years of age, who were diagnosed with idiopathic Parkinson's disease (PD) by neurologists at the Center for Movement Disorders and Neurorestoration at the University of Florida. They were recruited from local support groups and from the Center for Movement Disorders and Neurorestoration at the University of Florida. Two participants had received at least one session of swallowing or speech/voice therapy since receiving their diagnosis of PD. Two participants had sung in church choirs in the past 10 years. See Table 2.1 for inclusion and exclusion criteria.

Table 2-1. Inclusion and exclusion criteria

#	Inclusion Criteria
1.	A clinical diagnosis of idiopathic PD using the UK Brain Bank criteria, made by a neurologist specializing in movement disorders.
2.	Modified Hoehn and Yahr stage of 2.5 or better in the "on medication" state.
3.	Age between 60-85 years
4.	A stable regimen of antiparkinsonian and psychotropic medications for 30 days prior to participation.
5.	Non-smoking or no smoking within the previous 5 years.
6.	Sufficient facial muscle strength in order to achieve and maintain lip closure around a circular mouthpiece.
#	Exclusion Criteria
1.	Significant cognitive impairment (MMSE<24)
2.	Major psychiatric disorder(major depression, generalized anxiety, schizophrenia)
3.	History of head and neck cancer
4.	History of asthma
5.	History of COPD
6.	History of untreated hypertension

Dropouts and Adherence

Participants were expected to commit for roughly 10 weeks, including the interventions and assessments. Adherence of over 80% was expected, while adherence of 100% was achieved. Intervention was provided over a period of 9 weeks.

All participants attended 8 out of 9 group sessions. This study was approved by the University of Florida Institutional Review Board (104-2011).

Data Collection Pre- and Post- Intervention

Evaluations were conducted pre- and post- intervention. The duration of the voice and swallowing evaluations was approximately 2.5 hours, due to collection of other measures that are a part of a larger research study, not discussed in this paper. All evaluations were conducted at the University of Florida Speech and Hearing Clinic and Radiology Department of UF Shands by one of the researchers or researcher's trained staff assistants. To reduce the potential effects of waning medication on performance, all participants were "non-fluctuating" patients and at the time of evaluation were in the patient's defined fully medicated state (within 1-2 hours of taking anti-parkinsonian medicine). The pre- and post- evaluations were completed at the same time of day, in order to minimize potential medication and fatigue effects. Informed consent was obtained in accordance with UF institutional review board standards.

During the voice evaluation, the maximum phonation time (MPT) for sustained vowels, maximum frequency range (MFR), maximum sound pressure level (SPL), MEPs and MIPs were collected. These maximum performance tests are commonly used to evaluate speech and voice in speech-language pathology and normative data is available and adequate (Kent, Kent, & Rosenbek, 1987). The MPT of vowels /a/ and /i/ were obtained over three trials at a comfortable pitch and loudness level for the participant. The longest duration trial out of three was recorded. The MFR was detected through a microphone held at a constant 15 centimeter distance from the participant. Three trials each of ascending and descending glides were performed. Maximum frequency range was analyzed using Kay Elemetrics Computerized Speech

Lab version (4500) software. The maximum ascending frequency from 3 trials and minimum descending frequency of three trials was recorded. Finally, the SPL of the vowel /a/ was collected by a digital sound pressure level meter, model 33-2055 A, at the standard distance of 30 centimeters, as the participant maintained loudness at a mid-range frequency. The average of three trials was recorded due to a wide range observed within the pre-testing scores. Finally, MEPs and MIPs were obtained through the use of a Micro Direct Respiratory Pressure Meter (http://www.microdirect.com/microRPM.asp), also called a manometer. Approximately six trials for both MEP and MIP were collected. The average of the best three trials each for MEP and MIP were reported.

Videoflouroscopic Procedure Pre-and Post- Intervention

Swallowing function was assessed pre-and post-intervention, utilizing modified barium swallow study (MBS) and administration of a psychometrically sound dysphagia-specific quality of life measure called SWAL-QOL (McHorney et al., 2000; McHorney, Martin-Harris, Robbins, & Rosenbek, 2006). The SWAL-QOL is a subjective measure on a Likert scale ranging from 1-5. A score of a 5 indicates that the statement in question is no problem or no concern whereas a score of 1 indicates great problem or great concern. The SWAL-QOL was completed by the patient prior to undergoing the MBS study during pre-and post-testing. A speech-language pathologist attended and directed the participant during each MBS study. Each MBS study was performed at the Radiology department of UF Shands in Gainesville, FL. A penny (length=18 mm on x-ray image) was used as a reference point, needed for measuring hyoid bone displacement through the MATLAB “mainrand” routine. The penny was placed on the videoflouroscope to mark the anterior temporal bone of each patient. During the fluoroscopic swallow study, participants were seated in a chair with shoulders down and hands placed in the lap. Left lateral images were taken as participants were asked to consecutively swallow three trials of 10 cc thin liquid barium, followed by three trials of 10 cc. pudding thick barium contrast.

Singing Therapy Intervention Procedures

Each group session took place at the Language over the Lifespan Laboratory at the University of Florida. Each session began and ended with social interaction activity songs. The song title for commencement of the session was entitled “If I Knew You Were Comin’ I Would’ve Baked a Cake” by Al Hoffman, Bob Merrill, and Clem Watts, published in1950. The commencement song required shaking of hands, eye contact, and smiling. After the greeting, the participants engaged in a series of vocal exercises, non-singing exercises targeting forward resonance, pitch range, respiratory coordination during phonation, and articulation. Vocal exercises were followed by choral singing of familiar songs. The song title for ending the session was “Show Me the Way to Go Home”, a folk song made famous in its 1925 adaptation by James Campbell and Reginald Connelly. Songs utilized were familiar to the participants. Each song consisted of a simple rhythm and melody.

Vocal Exercises

Lip buzzing was the first vocal exercise that the participants were asked to perform. Lip buzzing involves pushing air through approximated upper and lower lip resulting in a buzzing sound from the lip vibrations. The exercise was designed to target both respiratory coordination and forward vocal focus. The exercise was tiered weekly to allow for a progression to more difficult tasks. First, participants were asked to lip buzz with a straw, then without the straw but with no phonation. If they performed the task well, they progressed to a lip buzz using phonation at medium, high, and low pitches. Finally, participants maintained the lip buzzing while sliding from low to high and then high to low pitches during a glissando.

Next, participants were asked to perform glissandos using an open mouth, in order to target and expand vocal range. The task began by sliding, or slowly and gently changing pitch, an interval of a third and systematically progressed to sliding at an interval of an octave. Participants were instructed to produce an “easy voice”, to maintain a straight posture, and to monitor abdominal breathing. In later sessions, visualizations and hand movements were introduced to help the participants achieve forward resonance.

Messa di Voce exercises were performed in order to increase control of vocal intensity or loudness level. The participants held a single pitch for five seconds while gradually increasing their intensity level after the first two seconds. The expected loudness level for each participant was based upon dB SPL measures collected previous to intervention sessions. The loudness level increased from a soft phonation to each participant’s maximum loudness during the five second task. Maximum loudness levels were recorded each week by utilizing a Radioshack digital sound pressure level meters held at a constant 30 centimeter distance from the mouths of the participants. In order to reduce additive effect caused by recording in a group setting, all participants were seated equidistant from one another and all participants had an assigned chair which remained constant throughout the sessions. Measures collected during the sessions were used to provide visual and numerical feedback to the participants during vocal exercises and singing and should not be taken as absolute measures.

Articulation exercises were utilized in order to encourage active movement of the lips, tongue, and jaw. Participants sang a five-step scale using the nasal consonant /m/ in single-syllables “mee, meh, my, moh, moo” in order to encourage forward resonance. The initial consonant progressed weekly from nasal /m/ to non-nasal /t/, /d/, /k/, and /s/ during repetitions of the scale. The tempo was kept at a constant 100 beats per minute in order to allow the participants to concentrate on producing exaggerated crisp consonants and to regulate rhythm of speech.

Choral Singing

Choral singing utilized two popular songs from the 1940s, “Mairzy Doats” and “You are my Sunshine”. “Mairzy Doats” was composed by Milton Drake, Al Hoffman, and Jerry Livingston in 1943 and “You are my Sunshine” was composed by Jimmie Davis and Charles Mitchell, published in 1940. Familiarity was important in order to allow the participants to focus on therapy targets during the songs, reducing cognitive load. While singing “You are my Sunshine”, participants were asked to increase the number of syllables sung using one breath. They were asked to increase phonation time from approximately 5 syllables sung per breath to 10 syllables sung per breath. This task was designed to target the respiratory system in order to increase respiratory coordination and MPT. For the song “Mairzy Doats”, participants were encouraged to maintain clear consonant articulation and melodic pitch. In addition, participants were required to sustain a set sound pressure level as measured by a dB SPL sound level meter when singing each song. Distance from dB SPL meter was held constant at 30 cm for multiple trials during singing. The expected sound pressure level was typically at or above baseline or immediate preceding loudness levels. As all loudness levels were collected simultaneously during group singing. This was done both to provide feedback to the participants about their loudness level, and to eliminate anxiety about singing alone in front of a group. An additive effect to intensity data collected during singing sessions should be considered.

Data Analysis

Means and standard deviations for the voice measures were calculated. Statistical analysis was not completed due to the small n value (n=3). The greatest MPT out of three trials pre-and post-treatment was recorded for data analysis. Maximum frequency range was originally measured in Hertz. We measured the maximum difference between the lowest and highest fundamental frequency during glissando tasks, and then converted to the linear scale of semitones (ST). Maximum sound pressure level was recorded in dB SPL, collected from the sound pressure level meter mentioned above. Maximum expiratory pressures and maximum inspiratory pressures were taken pre- and post- intervention using a manometer, mentioned above.

The Penetration-Aspiration (P-A) Scale is a visually rated scale describing the presence and extent of penetration or aspiration during videoflouroscopic barium swallow study (Rosenbek, Robbins, Roecker, Coyle, & Wood, 1996). Three graduate student clinicians (two independent and the author), experienced in rating using this scale rated participant 1-3 for swallows of 10 cc of thin liquid barium according to the criteria (Table 2-2).

Table 2-2. Penetration-Aspiration Scale

1	Contrast does not enter the airway
2	Contrast enters the airway, remains above the vocal folds
3	Contrast remains above the vocal folds with visible residue
4	Contrast contacts vocal folds, no residue
5	Contrast contacts vocal folds, visible residue
6	Contrast passes glottis, no sub-glottic residue
7	Contrast passes glottis, visible sub-glottic residue despite patient response
8	Contrast passes glottis, visible sub-glottic residue, absent of patient response

Hyoid bone displacement was calculated using a MATLAB routine entitled "mainrand". "Mainrand" is a program developed by the Laryngeal Function Laboratory at University of Florida that measures hyoid-bone displacement frame-by-frame, point-referenced, over time (Wheeler, Martin-Harris, Brodsky, Thekkevalappil, & Sapienza, 2006). The program measures the distance traveled by the hyoid bone and corresponding angle of hyoid elevation with reference to the third cervical vertebra (C3). The pharyngeal phase of the swallow was measured for thin-liquid and pudding-thick bolus consistencies (Figure 2-2).

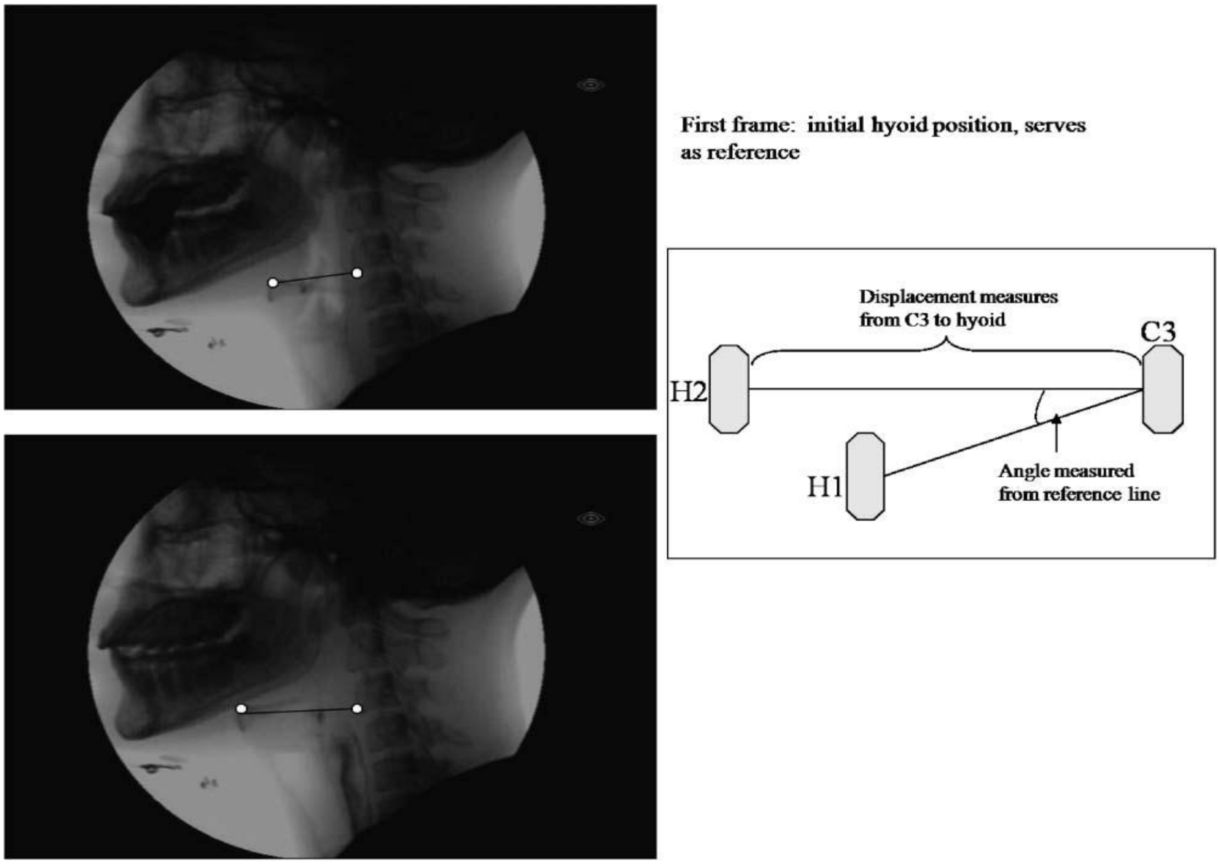


Figure 2-2. Example of measurements the Mainrand MATLAB routine makes during task analysis. H1=hyoid starting point in the first frame, H2=hyoid location in subsequent frame of the task, C3=third cervical vertebra (Wheeler-Hegland, Rosenbek, & Sapienza, 2008)

To use Mainrand routine in MATLAB (version 7.1), JPEG images were extracted from video-recordings. These images were created by independent computer technical support personnel of the Speech and Hearing Sciences at the University of Florida. Mainrand uses the first frame in the sequence of images as a reference line between the hyoid bone and the C3 (Wheeler-Hegland, Rosenbek, & Sapienza, 2008).

The most anterior inferior corners of C3 were marked and the most anterior superior corners of the hyoid bone were marked in all frames by the raters, in randomized order. When marking of reference points was completed, Mainrand calculated the angle (in degrees) and magnitude displacement as a ratio to the first frame (in millimeters) of hyoid elevation into Microsoft Excel (Windows 7).

Points of maximum angle and magnitude displacement were extracted from the data found within the Excel spreadsheet, created by MATLAB routine “mainplotn”. Measures discussed include the following:

- A1: Angle of hyoid elevation at the point of maximum magnitude displacement
- A2:.Maximum angle of hyoid elevation
- A3: Range of angle of hyoid elevation

- D1: Maximum hyoid magnitude displacement (anterior excursion)
- D2: Hyoid magnitude displacement at the maximum angle of elevation
- D3: Range of hyoid displacement

CHAPTER 3
RESULTS

Voice Measures

MPT

After treatment, two out of three participants improved MPT (in seconds) for the vowel /a/ (Figure 3-1). Participant 1 decreased by 4.2%, participant 2 increased by 161.5%, and participant 3 increased by 33.3%. Overall, MPT for /a/ increased by 47.3% (pre = 18.33 ± 5.51, range = 13.0 – 24.0; post = 27.0 ± 6.08, range = 23.0–34.0). Two out of three participants improved MPT for the vowel /i/ post-treatment (Figure 3-2). Participant 1 decreased by 4.5%, participant 2 increased by 44.4%, and participant 3 increased by 30.0%. Overall, MPT for /i/ increased by 14.1% (pre=21. 33 ± 3.06, range=18-24; post=24.33. ± 2.89, range=21-26).

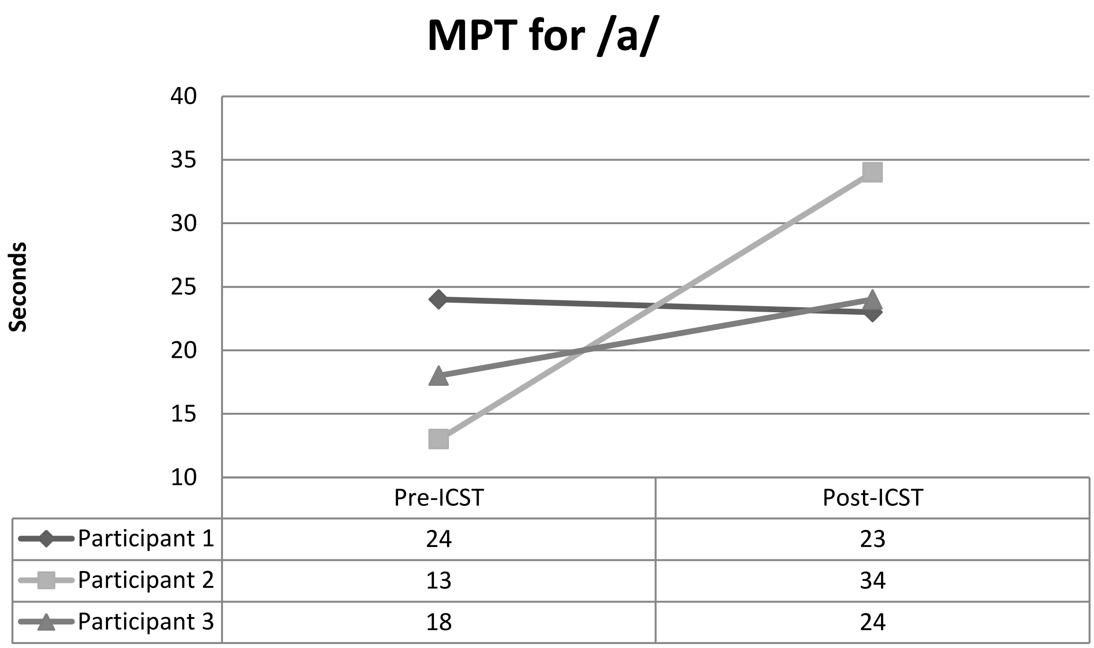


Figure 3-1. Maximum phonation time of /a/ (in seconds) pre- to post-treatment

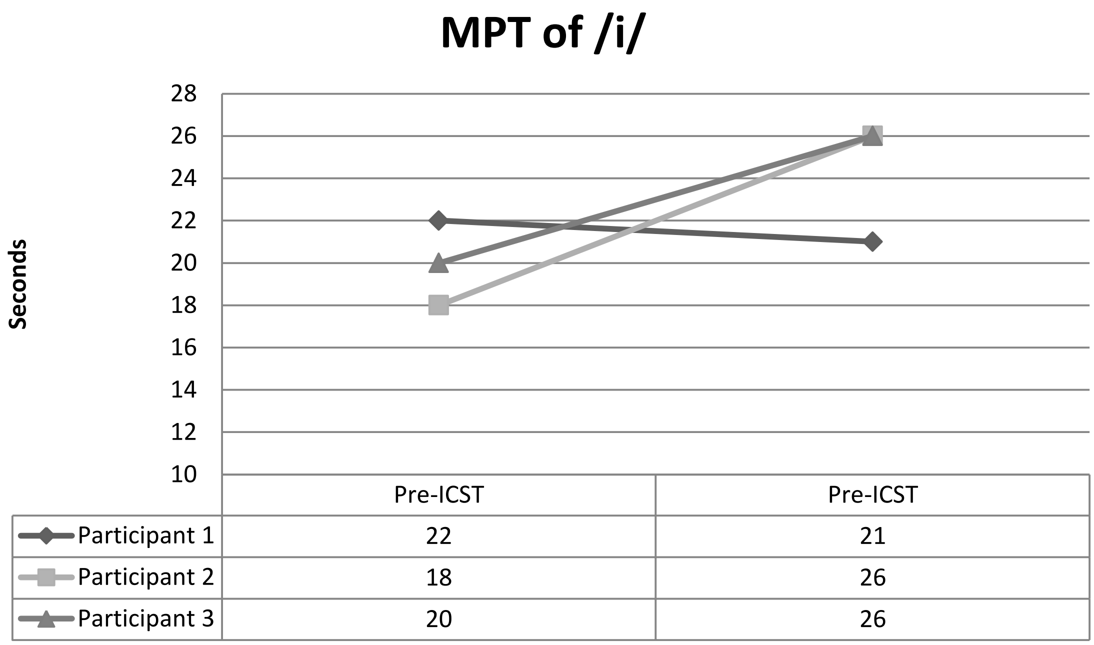


Figure 3-2. Maximum phonation time of /i/ (in seconds) from pre- to-post-treatment

MFR

Only one participant increased MFR (in semitones) after treatment (Figure 3-3). Participant 1 increased by 33.5%, participant 2 decreased by 21.1%, and participant 3 decreased by 10.1%. Overall, there was a 3.04% decrease in the MFR (pre=33.78, ± 4.89, post=32.76 ± 3.61) (Figure 3-6).

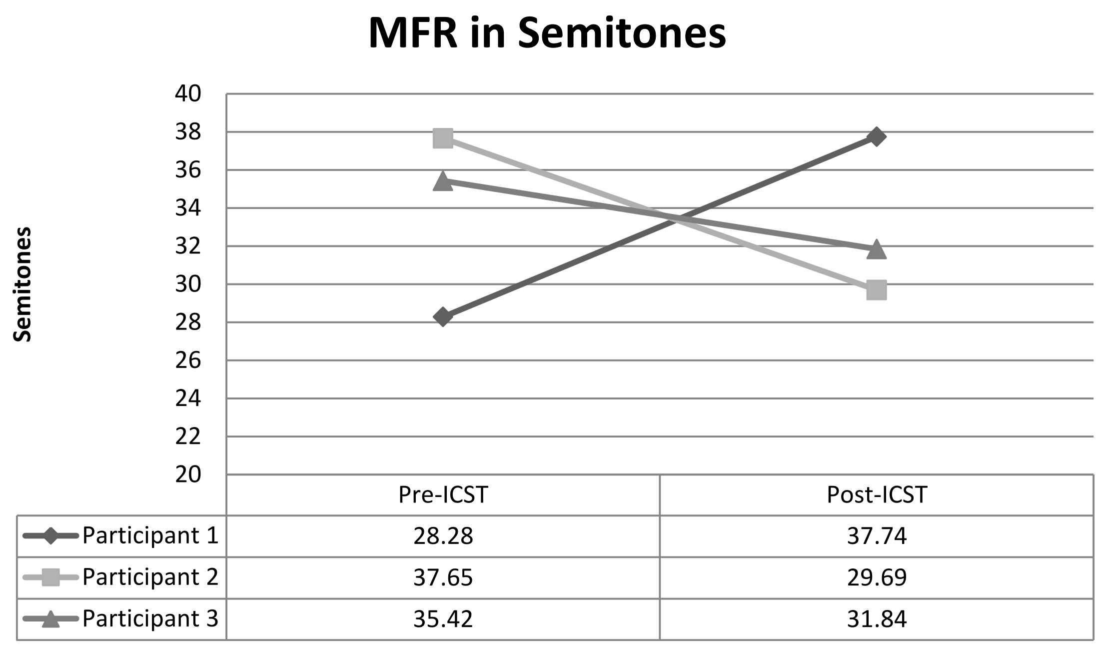
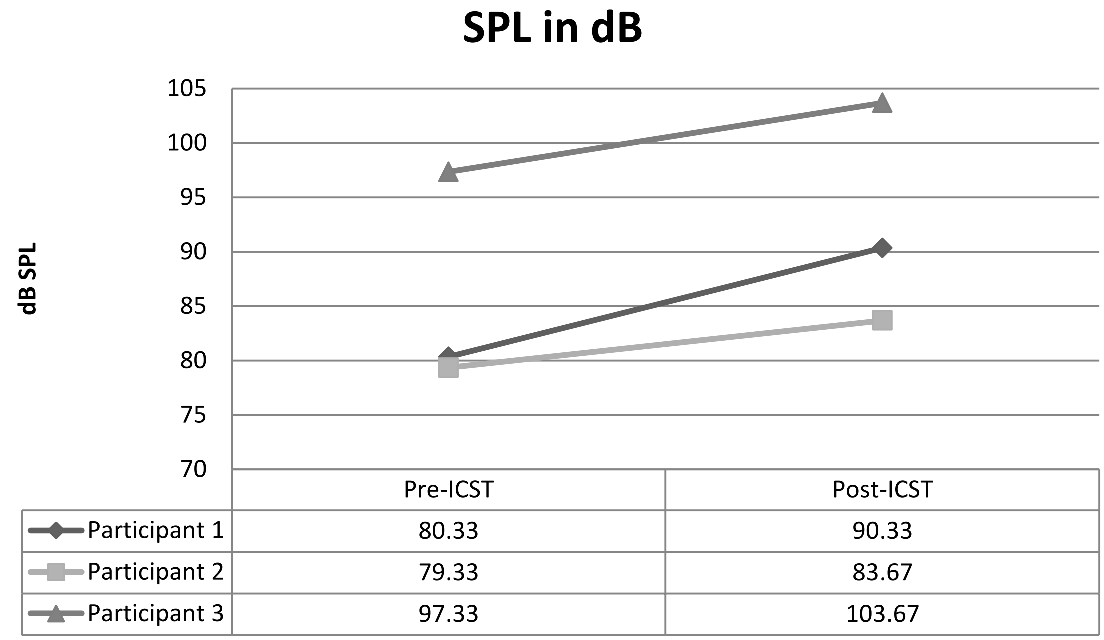


Figure 3-3. Individual MFR (in semitones) from pre-to-post treatment

SPL

After completing treatment, all three participants demonstrated greater SPL than from pre-treatment data collection. Participant 1 increased from pre-to post- by 10 dB, participant 2 increased and from pre-to –post treatment by 4.34 dB, and participant 3 increased from pre-to-post dB by 6.34 dB(Figure 3-4).

In addition to individual sound-pressure level scores recorded pre-and post-intervention, SPL measures were collected during each ICST intervention session as well. All three participants gradually increased their SPL during Messa di Voce exercises and singing in unison each week (Figure B-1 and B-2 in Appendix B).



	Pre-ICST	Post-ICST
Participant 1	80.33	90.33
Participant 2	79.33	83.67
Participant 3	97.33	103.67

Figure 3-4. Individual SPL (in dB SPL) from pre-to-post-treatment

MEP

After the completing ICST, MEP increased for all three participants (Figure 3-5). Participant 1 increased by 1.3%, participant 2 increased by 16.7%, and participant 3 increased by 6.5%. Overall, MEP increased improved by 8.2 % (pre = 74.6 cm H_20 ± 11.7, range = 54.0 – 94.7 cm H_20; post = 82.8 cm H_20 ± 13.4, range = 63.7 – 108.7 cm H_20).

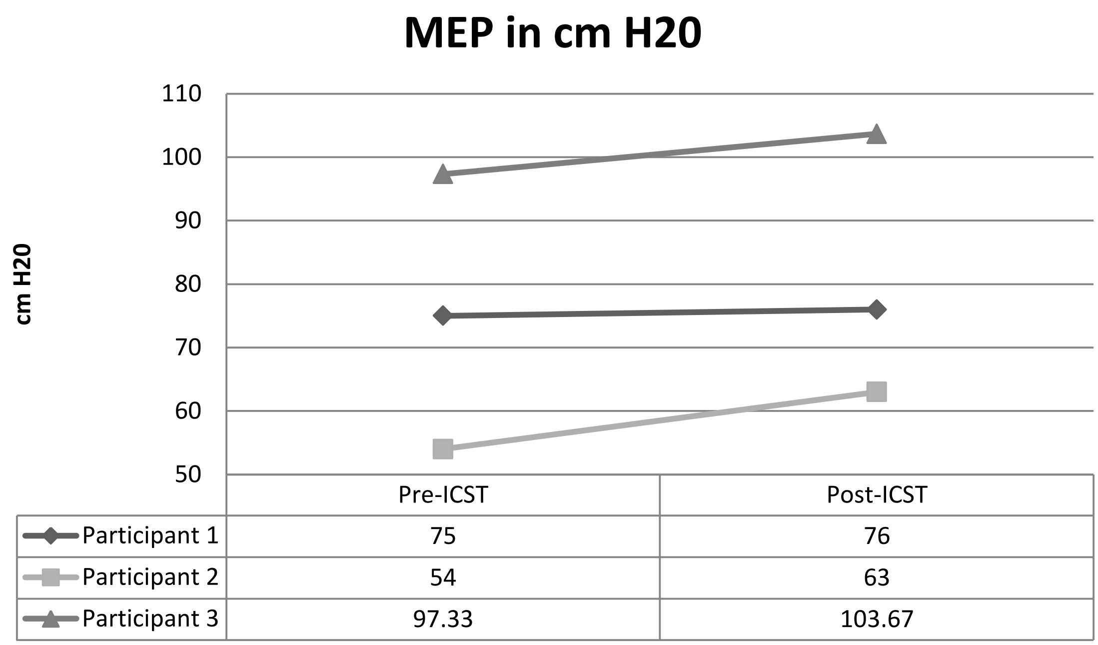
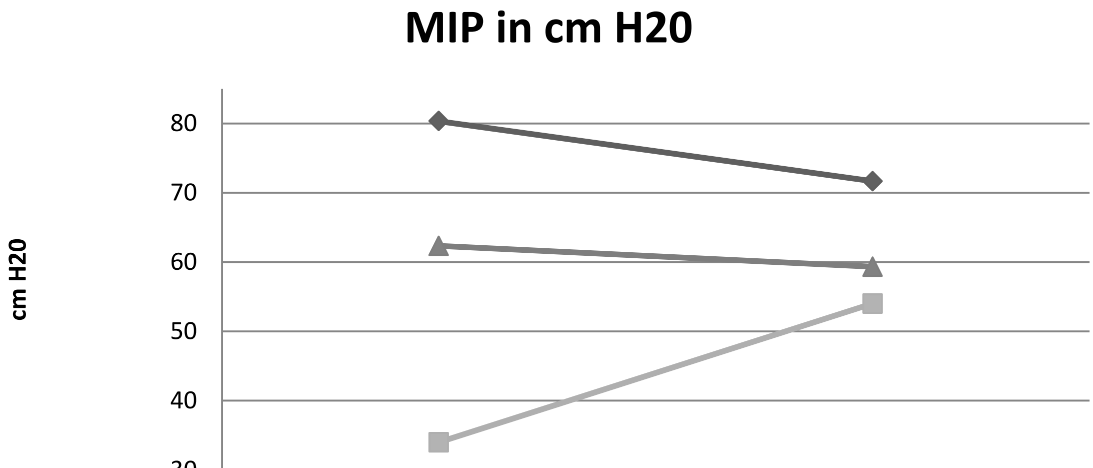


Figure 3-5. Individual MEP (in cm H_20) from pre-to post-treatment

MIP

Only one participant increased MIP after participating in ICST (Figure 3-6). Participant 1 decreased by 10.8%, participant 2 increased by 58.8%, and participant 3 decreased by 4.8%. Overall, MIP increased by 2.8% (pre = 58.9 cm H_20 ± 13.5, range = 34.0 – 80.33 cm H_20; post = 61.7 cm H_20 ± 5.2, range = 54.0 – 71.7 cm H_20).



	Pre-ICST	Post-ICST
Participant 1	80.33	71.67
Participant 2	34	54
Participant 3	62.33	59.33

Figure 3-6. Individual MIP (in cm H_20) from pre-to post-treatment

V-RQOL

Improvement in V-RQOL is indicated by a decreasing score, indicating a decrease in voice-related difficulties from during daily life, where as higher scores indicate an increase in frequency and extent of voice difficulties or problems (Hogikyan & Sethuraman, 1998). Only participant 2 displayed an improved V-RQOL score from pre- to post-intervention (Figure 3-7). When converting the raw score into a linear 0-100 metric, participant 1 only lowered perceived functioning by 8%, whereas participant 2 improved perceived functioning by 24% and participant 3 lowered perceived functioning by 20%. All participants perceived themselves as having a fair to excellent voice-related quality of life pre-and post-ICST, according to the perceptual descriptions found on the second page of the V-RQOL.

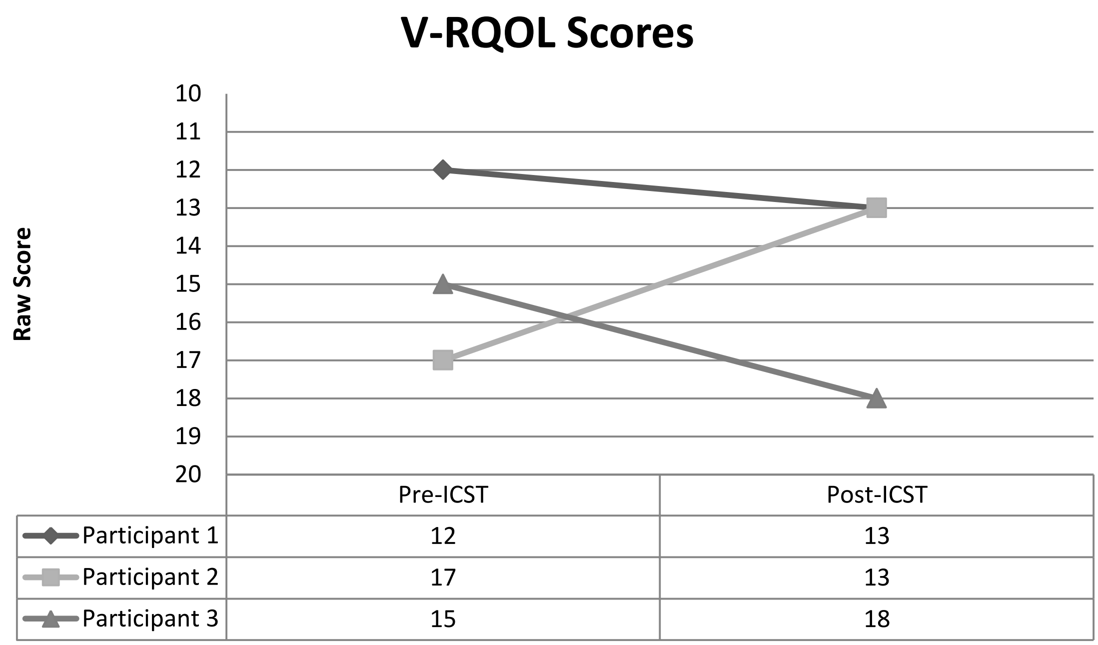


Figure 3-7. Individual V-RQOL scores from pre-to post-treatment

Swallowing Measures

Participant 1 was excluded from swallowing measures, due to a technical issue involving MBS recording. Increases in both angle of elevation and magnitude displacement of hyoid bone for 10 mL thin liquid and pudding thick barium swallows occurred for participant 2. Increases in angle of hyoid elevation occurred for participant 3. Increased angle reflects vertical movement of the hyoid bone during swallowing and increased magnitude indicates horizontal excursion of the hyoid bone during swallowing. Two graduate students in speech-language pathology (one independent and the author) marked the magnitude and angle between the hyoid bone and the third cervical vertebrae, frame-by-frame, in randomized order. The independent rater was a doctoral student who was licensed in speech-pathology for over two years. The author was a Master of Arts student in speech-language pathology, who was trained in MBS interpretation through clinical placements at the University of Florida over 3 academic semesters. Inter-rater reliability for hyoid bone displacement showed an agreement ranging between r=0.80 to r=1.00.

Hyoid Bone Displacement Measures

Hyoid bone angle of elevation

Both participants showed increases in hyoid bone angle of elevation pre-and post-ICST. Increases in participant 2 were the greater than in participant 3. Within participant 2, greater improvements were found when swallowing thin liquid barium than swallowing pudding thick barium (Figure 3-8). When swallowing thin liquid barium, A1 increased by 95%, A2 increased by 113%, and A3 increased by 95% from pre-to post-data collection (Table A-8 in Appendix A). During pudding thick barium swallows, A1 increased by 11%, A2 increased by 0.34%, and A3 decreased by 0.41% (Table A-9 in Appendix A).

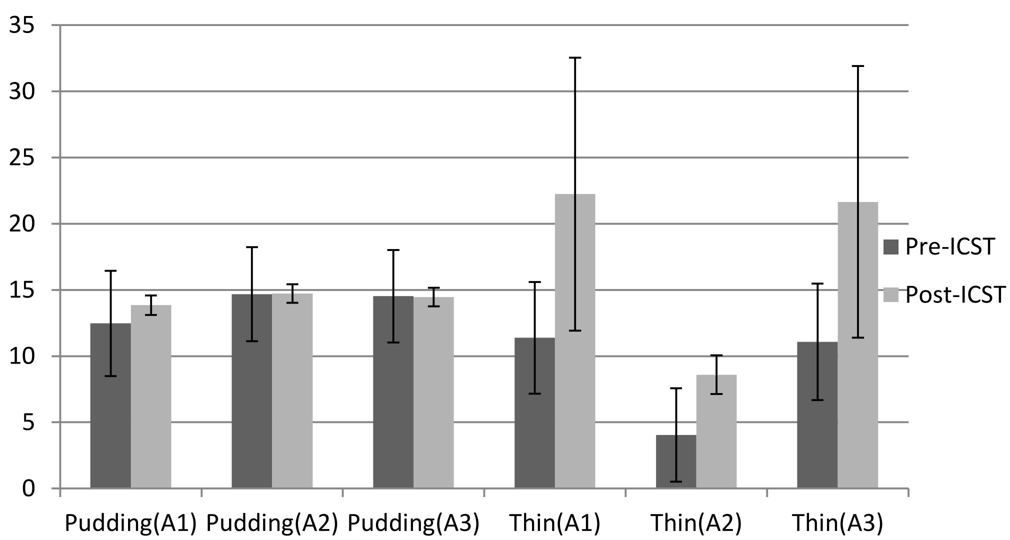


Figure 3-8. Participant 2* angle of elevation (in degrees) while swallowing thin liquid and pudding thick barium consistencies

Participant 3 demonstrated less angle of elevation increase from pre-to post- than participant 2. When swallowing thin liquid barium, the participant decreased angle of hyoid elevation on all three measures, whereas the participant increased all angle measures when swallowing pudding thick liquid barium (Figure 3-9). For thin liquid, A1 decreased by 43%, A2 decreased by 19%, and A3 decreased by 18% (Table A-10 in Appendix A). For pudding thick barium, A1 increased by 42%, A2 increased by 16%, and A3 increased by 16% (Table A-11 in Appendix A).

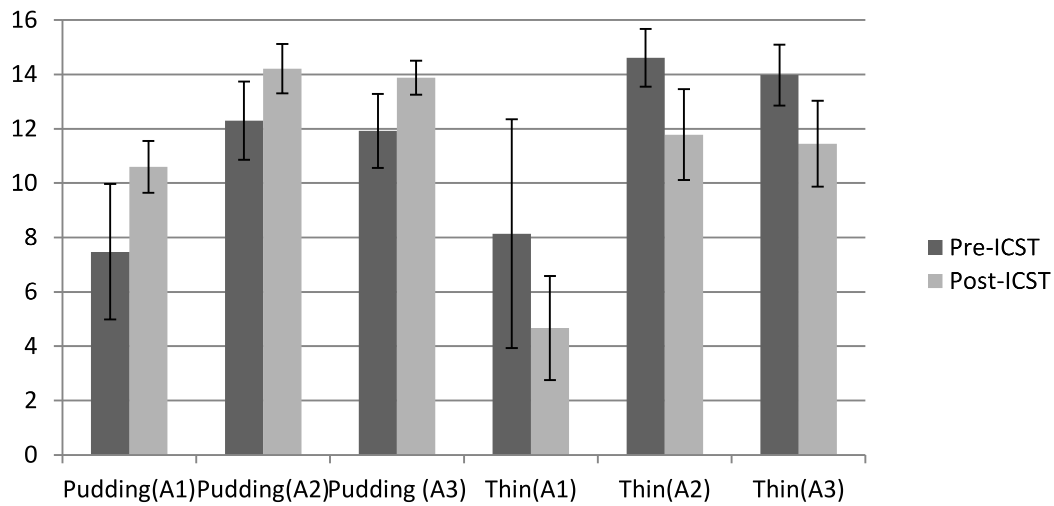


Figure 3-9. Participant 3* angle of elevation (in degrees) for thin and thick liquid swallows

Hyoid bone magnitude displacement

Only participant 2 showed improvements in magnitude hyoid bone displacement, which was calculated by the taking the ratio of length, in millimeters, between C3 and the hyoid bone of each frame to the length found at rest (first frame in sequence). This participant showed similar increases in all displacement measures when swallowing thin and pudding thick liquid barium (Figure 3-10). When swallowing thin liquid, D1 increased by 3%, D2 increased by 14%, and D3 increased by 9% from pre-to post-intervention data collection(Table A-12 in Appendix A). When swallowing pudding thick barium, D1 increased by 4%, D2 increased by 6%, and D3 increased by 20% from pre- to post-intervention data collection(Table A-13 in Appendix A).

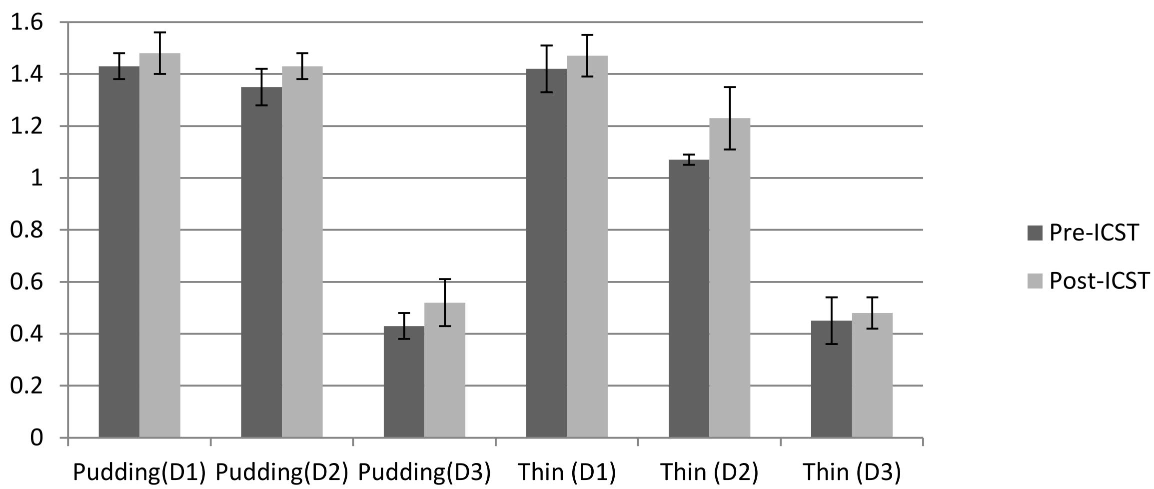


Figure 3-10. Participant 2* magnitude hyoid displacement (in millimeters) for thin and thick liquid swallows

Participant 3 demonstrated some decreases in hyoid magnitude displacements during thin liquid and pudding thick barium swallows. Small decreases in hyoid displacement were similar for both thin liquid and pudding thick barium consistencies (Figure 3-11). For thin liquid, D1 decreased by 0.1%, D2 decreased by 2%, and D3 decreased by 6% from pre-to post-intervention data collection(Table A-14 in Appendix A). For pudding thick barium, D1 decreased by 5%, D2 decreased by 3%, and D3 decreased by 12% from pre-to-post intervention data collection (Table A-15 in Appendix A).

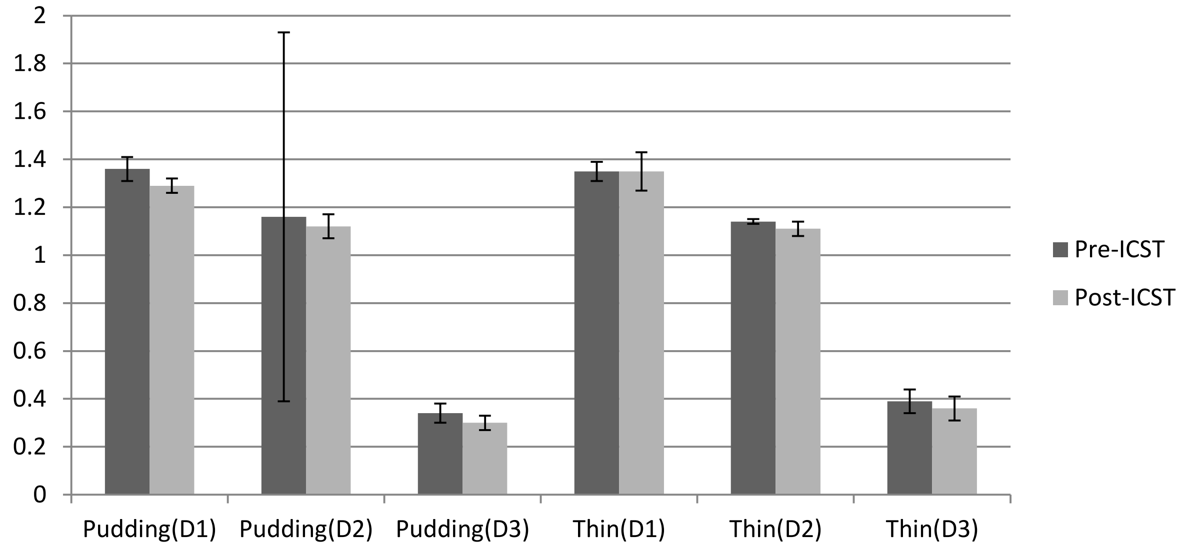


Figure 3-11. Participant 3* magnitude hyoid displacement (in millimeters) for thin and pudding thick liquid swallows

P-A Score

Three graduate student clinicians (two independents and the author), trained by the Center for Movement Disorders and Neurorestoration at UF for 3-6 months, rated participant 1-3 for swallows of thin liquid barium using the P-A scale. Swallowing sequences were displayed out of order. The independent raters were blinded to the order and the participant number. Inter-reliability range was r=.59 to r=.82 according to P-A scale criteria.

Participant 1 Showed penetration to the level of the vocal folds with visible residue on 1/3 swallowing sequences pre-ICST and showed less deep penetration without visible residue on 2/3 swallowing sequences post-ICST. That marks an improvement in P-A score. Participant 2 displayed penetration to the level of the vocal folds with some visible residue on 1/3 swallowing sequences pre-ICST, and 1/3 swallowing sequences post-ICST, signifying no change from pre-to-post intervention. Participant 3 increased in P-A score during post-ICST data collection. This participant displayed penetration above the vocal folds with visible residue post-ICST (Table 3-1).

Table 3-1. Penetration-Aspiration Scale scores pre-and post-intervention for thin liquid barium swallows

Participant	Pre-ICST	Post-ICST	Change
1	5	2.67	Improvement*
2	4.67	4.67	No change*
3	3.33	3	Mild improvement*

SWAL-QOL

Participant 1 and 3 worsened in their overall score by >10 points. Participant 2 increased the overall score by one, thus representing no measurable change from pre- to post-intervention in perceived swallowing day-to-day functioning(Figure 3-11) .

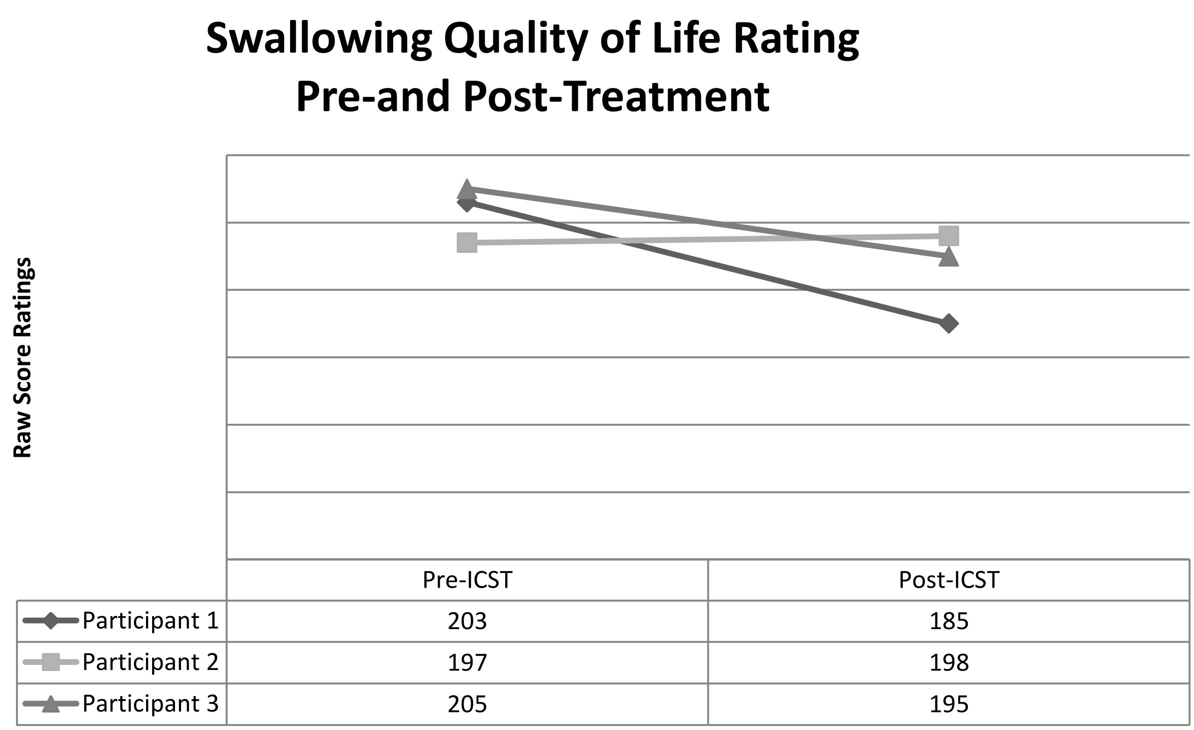


Figure 3-12. SWAL-QOL overall score pre-and post-treatment

CHAPTER 4
DISCUSSION

Voice Outcomes

As hypothesized, increases were found for MPT of /a/ and /i/. Maximum phonation time depends on respiratory volume, specifically vital capacity, and laryngeal airflow, or the time derivative of the volume of air moving through the larynx during phonation for each individual (Kent, Kent, & Rosenbek, 1987). Ptacek et al. (1966) reported the mean maximum phonation duration (time) on /a/ for healthy men between the ages of 68-89 years as 18.1 seconds, with a standard deviation (SD) of 6.6. Increases in MPT for the vowel /a/ have been reported in both singing intervention studies Haneishi (2001) and Di Benedetto and colleagues (2009). A case study integrating MT and speech/voice therapy also improved this measure in an individual with pseudo-Parkinsonian vascular disease (Magee et al., 2006). The study by Di Benedetto and colleagues (2009), investigating VCST, found significant increases to this measure (n=20, P=0.000). Haneishi (2001), investigating an individual singing therapy, MTVP, reported non-statistically significant increases in part due to a low sample size (n=4, P=.311) after a paired t-test. A difference between the current study and past research investigating singing therapy in PD is that the patients involved in VCST (Di Benedetto et al., 2009) received approximately 4 hours per week of speech therapy and choral singing separately over 10 weeks, whereas the current study provided 1 hour per week of combined speech/voice and choral singing therapy, over 8 weeks.

It was surprising that although increases were found for all participants in SPL, MPT, and MEP measures, only participant 1 increased in MFR. The previous studies mentioned above (Haneishi, 2001; Di Benedetto et al., 2009) did not investigate MFR, but did find increased fundamental frequency variability or prosody during phonation of five consecutive words, sentences, and connected speech samples. Variability in MFR, also called fundamental frequency range (FFR) or phonatory frequency range has been reported (Hollien, Dew, & Philips, 1971). One study by Gelfer (1986) indicated a mean intra-subject variation of 2 semitones (ST) within a single day, and greater variation between 4-6 weeks, without intervention. In a study by Gamboa and colleagues (1997), 16 male healthy control subjects and 24 males with PD within a similar age group had a phonatory frequency range of approximately 20.9 ST and 18.4 ST during connected speech, whereas Ramig and Ringel (1983) reported that healthy geriatric adults had a mean pitch range of 31.4 ST with an SD of 4.4. During pre-testing of the current study, all participants scored within the normal range of their peers, 31.4+/- 4.4, as reported in Ramig and Ringel (1983). Participant 1 scored at the bottom of this reported range, however. Furthermore, participant 1 was the only participant who did not have previous singing experience via singing lessons, singing solos, or with choral singing. This may represent a ceiling effect for the other two participants, who displayed a higher frequency range during pre-testing.

As hypothesized, increases in SPL were discovered post-ICST for all three participants. Increases from pre- to post-intervention ranged from 4.3 to 10.0 dB with an average increase of 6.9 dB for the group. Ptacek et al. (1966) found that geriatric men on the vowel /a/ and at 30.48-cm. mike to mouth distance had an average SPL of 100.5 dB +/-5.9. Both participants 1 and 2 had pre-testing scores below the mean reported by Ptacek et al. (1996), but showed increases post-testing.

Haneishi (2001) found that four female subjects with PD showed increases in vocal intensity of 10 dB from pre- to post-treatment. The increases in SPL found in the current study are also similar to those found in studies investigating LSVT, although therapy sessions in the current study were much less intensive. Ramig and colleagues (2001) reported an average increase of 8 dB immediately post-LSVT and a maintained average increase of 6 dB from baseline at a 6 month follow-up for 14 participants. Additionally, in a study of 12 participants with PD, Spielman and colleagues (2007) found an increase of 8 dB immediately after an extended version of LSVT and maintenance of a 7.2 dB increase from 6 months later. Both the current study and LSVT research studies prompted and/or provided feedback to participants in order to increase participant SPL during the therapy sessions. One conclusion that could be made about SPL scores in the current study is that increases found pre- and post-intervention could be attributed to the practice effect. This effect was expected as dB scores from a sound pressure level meter were used as feedback for participants during all singing sessions (Figure B-1 & B-2 in Appendix B).

Moreover, MEP increased for all participants, while MIP scores showed improvement for only one participant. Statistically significant improvements in MEP were discovered in the study (n=20, P=0.006) by Di Benedetto and associates (2009). Normative MEP and MIP means for the age groups 60-69 years and above 69 years have been reported on by Britto, Zampa, de Oliveira, Prado, and Parreira (2009). This study found that between the ages of 60-69 years, the mean MEP value was 102.08 +/- 47.89 cm H_20 and the mean MIP value was 54.58+/-32.37 cm H_20. Participants 1 and 3 lay within this age range. Pre-ICST, the participants scored below the mean for MEP, but above the mean for MIP. This may have reflected a ceiling effect for the MIP scores of participants 1 and 3. Participant 3 improved MEP post-intervention to above the normal mean, whereas participant 1 showed less improvement. Above the age of 69 years, the mean MEP value was 87.92+/- 59.71 cm H_20 and the mean MIP value was 54.58 +/- 33.61 cm H_20 (Britto et al., 2009). Participant 2 was within this age range. During pre-testing, this participant scored below the mean for both MEP and MIP. After completing ICST, both MEP and MIP scores increased for participant 2. Maximum inspiratory post-testing scores were similar to those of norms, denoting a larger improvement than in MEP, although MEP increased by 16.7% post-testing.

In the current study, it was observed that two out of three participants showed more difficulty during pre-and post-data collection in completing the task to measure inspiratory versus expiratory pressure. Improvements to MEP cannot be entirely explained by the practice effect, although participants in the current study were asked to coordinate respiration by taking deep breaths, phonating while activating abdominal muscles, and maintaining loudness during voice therapy and singing tasks. Wilson and colleagues (1984) reported that the measurement of MEP and MIP can be a simple and reproducible measure of respiratory muscle functioning and the progression of weakness of the respiratory system (p. 538). Therefore, improvements in MEP may be due to improved respiratory strength or coordination from phonation tasks associated with ICST. Lack of average improvement for MIP scores was somewhat expected, because the treatment did not specifically target this outcome.

The V-RQOL measures were more variable between participants than hypothesized, as participant 2 improved scores, participant 3 worsened scores, and participant 1 did not show great change in scores post-treatment (Hogikyan & Sethuraman, 1998). When converting the raw score into a linear 0-100 metric, participant 1 only lowered perceived functioning by 8%, whereas participant 2 improved perceived functioning by 24% and participant 3 lowered perceived functioning by 20%. Group voice therapy by Searl et al. (2001) has shown increases to perceptions of vocal quality for 15 individuals with PD via the Voice Handicap Index (VHI), a questionnaire highly correlated with the V-RQOL (Portone, Hapner, McGregor, Otto, & Johns, 2007). Although using specific voice-related quality of life measures is useful, it has been shown to have no significant correlation to the Dysphonia Severity Index (DSI), a more objective measure of vocal functioning (Schneider, Plank, Eysholdt, Schutzenberger, & Rosanowski, 2011). Variability of this outcome, in the current study, may be due to increased awareness of vocal deficits for some patients in this study. Participant 3 reported increased awareness of vocal deficits during a singing session conducted prior to post-testing. Supporting this, it has been documented that those with PD experience sensorimotor deficits that may cause them to overestimate vocal function when lacking feedback from the listener, particularly in regard to vocal loudness (Ho, Bradshaw, & Iansek, 2000). During the ICST intervention, feedback concerning vocal functioning was frequently given to the participants.

Swallowing Outcomes

Data showed increases to hyoid bone superior and anterior displacement within the participants from pre- to post- testing. Increases in angle of elevation were found for both participants and increases in magnitude displacement for one participant. Results from this study are most similar to results from EMST investigations by Troche and colleagues (2010), in that hyoid bone magnitude displacement (anterior excursion) increased due to a non-swallowing specific intervention for those 55-85 years of age with moderate PD (n=60). Hyoid bone displacement duration and other measures related to displacement, analyzed using “mainrand” routine, were also reported by Troche et al. (2010). Like the current study, this study also found improvements in P-A scores as well as other measures related hyolaryngeal functioning. There is currently no normative data on the specific angle and magnitude displacement included in this study for healthy older adults; however, pre-testing scores of A1, A2, D1, and D2 with thin liquid barium for both participants were similar to the data of younger individuals in a study by Wheeler-Hegland and associates (2008). In the previously mentioned study (Wheeler-Hegland et al., 2008), the mean hyoid elevation for A1 and A2 was reported as 7.49 degrees and 10.39 degrees respectively. The mean hyoid magnitude displacement for D1 and D2 was 1.42 millimeters and 1.22 millimeters respectively.

Differences were observed between the current study population and the normative data on younger adults (Wheeler-Hegland et al., 2008) for swallows of 10 mL thin liquid barium. Participant 2 had an A1 below the mean reported by Wheeler-Hegland and associates (2008) during pre-testing of thin liquid barium, but increased to have an A1 above the reported mean, which indicates improvement. Participant 2 also exhibited a post-testing score for A2 much greater than the mean reported in Wheeler-Hegland and associates (2008). This could reflect a difference between the age groups, as seen in a previous study by Kendall, and Leonard (2001). This study reported that older adults (67-83 years) compared with younger adults (18-62 years) showed greater extent of hyoid displacement but a shorter duration of hyoid elevation. The researchers hypothesized that greater extent of hyoid displacement found in the older adult group may be a compensation for a shorter duration of hyoid maximal elevation and thus shorter duration of UES opening. Participant 3 showed a mild decrease in the angle of elevation from pre-to-post testing for thin liquid barium consistency. The ceiling effect could have contributed to this outcome, with consideration that this participant exhibited higher pre-testing scores of A1 and A2 when compared to normative data from young adults (Wheeler-Hegland et al., 2008).

In reference to magnitude displacement (D1 and D2) for swallows of 10 mL of thin liquid barium, both participants displayed lower pre-testing scores than the young healthy adult data (Wheeler-Hegland et al., 2008), with the exception of D1 for participant 2. A ceiling effect was observed in this measure for participant 2, as pre-testing scores for magnitude displacement were closer to the mean reported by Wheeler-Hegland and associates (2008). Participant 2 also exhibited a smaller amount of change from pre-to post-data collection session for this measure. Participant 3 exhibited decreases to magnitude of hyoid bone displacement for 10 mL thin liquid barium bolus.

It should be noted that the study by Wheeler-Hegland and associates (2008) did not investigate swallowing displacement during swallows of pudding-thick barium consistency. Both participants showed increases to both angle and magnitude hyoid displacement for swallows of pudding-thick consistency, however, it was observed that the frequency of piecemeal swallowing, also called piecemeal deglutition, for pudding-thick liquid consistency increased from pre-to post-data collection sessions. Piecemeal swallowing is an early swallowing problem for individuals with PD (Potulska et al., 2003;

Groher & Crary, 2010). This difference may affect further comparisons to younger subjects and to individuals with PD, who do not exhibit piecemeal deglutition.

Penetration-Aspiration scores from pre- to post-ICST were more variable than hypothesized. This is surprising as Troche and associates (2010) found significant improvement to P-A scores in addition to hyoid bone magnitude displacement in a study of the swallowing-related task of EMST, which also has been shown to improve MEP, another finding of the current study. Participant 1, who was not included in hyoid bone displacement measures made the most dramatic improvement in P-A score from pre-to-post data collection session. Participant 2 increased both vertical elevation and anterior excursion of the hyoid bone, but did not show change in P-A score from pre-to post-ICST. Participant 3 demonstrated slight increases in hyoid bone angle and magnitude of displacement and showed a similar mild improvement in P-A score. This mild improvement may be due to the ceiling effect, as participant 3 displayed the mildest pre-testing scores out of the three participants, indicating greater airway protection during pre-testing (Rosenbek et al., 1996). Statistical analysis is needed in order to conclude the extent of positive correlation between P-A scores and hyoid displacement measures within the current study.

Lastly, all participants either showed little change or worsened overall scores of the SWAL-QOL questionnaire, thus reflecting little change or worsening of perceived swallowing function and an increase in perceived swallowing problems. All participants showed pre-testing scores reflecting mild-moderately diminished swallowing-related quality of life (McHorney et al., 2000, McHorney et al., 2006). When converting raw overall score using the Likert method to a linear metric scale of 0-100, percentage of change of the participants from pre-to post-testing may be considered minimal, ranging between 0.5% to 8.9% change (Likert, 1932). It is interesting that all three participants scored very little change or lower in perceived swallowing function, while two out of three of the participants demonstrated physiologic improvements to swallowing function either in P-A score or hyoid bone displacement measures.

This outcome, in addition to discrepancies observed in V-RQOL scores, may be due to other factors not investigated by the current study, such as increased awareness of swallowing problems. Also, disease progression detrimentally affects the SWAL-QOL scores, according to Leow, Huckabee, Anderson, and Beckert (2010). Another study, by Plowman-Prine et al. (2009) found that swallowing-specific quality of life was highly correlated with general health-related quality of life and depression. Additionally, this phenomenon could be partly attributed to sensory changes. Discrepancies in patient perception of swallowing function and actual physiologic changes to the swallowing mechanism are evidenced by the prevalence of subclinical physiologic changes in swallowing function in earlier stages of PD, such as undetected piecemeal deglutition and smaller and more variable tongue movements (Potulska et al., 2003; Van Lieshout et al., 2011).

CHAPTER 5
CONCLUSIONS AND FUTURE RESEARCH

The results of this investigation indicate that a choral singing program, such as ICST, integrating both speech-language therapy and music therapy components, may lead to positive changes in voice and swallowing measures for individuals with PD. As this pilot study utilized a small sample size, more research needs to be completed in order to determine the effectiveness and efficacy of ICST in improving voice and swallowing measures in individuals with PD.

In the current study, data collection sessions were 2.5-3.0 hours in duration due to the recording of measures of speech and cognition not discussed in this paper. This long duration could have caused an effect of fatigue, waning concentration, and diminished motivation throughout the data-collection session. A future study investigating ICST should include measures of SPL, MEP, MPT, hyoid bone displacement and angle measures, and P-A scores, due to the suggestive increases or improvements found in the current study. Measures of functional outcomes such as V-RQOL and SWAL-QOL, as well as generalization to daily speech tasks, such as outcomes of intelligibility during conversation or reading, should be included in a future study. These measures were included in the study of MTVP by Haneishi (2001), and yielded positive results. Furthermore, the optimum duration, frequency, and procedure of home practice and singing sessions should be investigated. ICST singing sessions occurred once per week, with 2-3 hours of home practice, but other successful programs, namely LSVT, showed greatest change when clients were treated more intensively at 4 therapy sessions per week (Spielmann et al., 2007). The VCST study by Di Benedetto et al. (2009) also showed similar improvements to the current study but with a more intensive therapy program.

Future ICST interventions should also include more of a variety of songs for home practice, in order to keep participants highly motivated and challenged. The effectiveness of the ICST home program could be investigated in isolation from the ICST singing sessions, as participants showed high compliance of 100%, and commonly individuals with PD experience mobility and transportation issues, which prevent them from attending highly intensive therapy programs(Uc et al., 2011;Spielman et al.,2007). The possible long-term impact and outcomes of ICST should be investigated as well as the possible impact of using ICST in combination with a more established voice or swallowing therapy. Correlations between age, sex, and duration of disease from onset and outcomes should be analyzed. In a future study, the relationships between extent and duration of hyoid bone displacement, P-A score, and UES opening should be investigated as positive results to these measures have been found from EMST (Troche et al., 2010). Finally, hyoid bone displacement and elevation should be measured under videofluroscopy during vocal exercise and singing employed during ICST sessions, in order to compare to hyoid bone movement during swallowing events.

APPENDIX A
VOICE MEASURE AND HYOID DISPLACEMENT CHANGE SCORE TABLES

Table A-1. Maximum phonation time for /a/ (in seconds) from pre-to-post treatment

Participant Number	Pre-CST	Post-CST	Change Score
1	24	23	-1.0*
2	13	34	21.0*
3	18	24	6.0*

Table A-2. Maximum phonation time of /i/ (in seconds) from pre-to post-treatment

Participant Number	Pre-CST	Post-CST	Change Score
1	22	21	-1.0*
2	18	26	8.0*
3	20	26	6.0*

Table A-3. Maximum frequency range (in semitones) from pre-to post-treatment

Participant Number	Pre-CST	Post-CST	Change Score
1	28.28	36.74	8.46*
2	37.65	29.69	-7.96*
3	35.42	31.84	-3.58*

Table A-4. Maximum sound pressure level (in dB SPL)

Participant Number	Pre-CST	Post-CST	Change Score
1	80.33	90.33	10*
2	79.33	83.67	4.34*
3	97.33	103.67	6.34*

Table A-5. Maximum expiratory pressure (in cm H_20) from pre-to post-treatment

Participant Number	Pre-CST	Post-CST	Change Score
1	75	76	1*
2	54	63	9*
3	97.33	103.67	14*

Table A-6. Maximum inspiratory pressure (in cm H_20) from pre-to post-treatment

Participant Number	Pre-CST	Post-CST	Change Score
1	80.33	71.67	-8.66*
2	34	54	20.00*
3	62.33	59.33	-3.00*

Table A-7. V-RQOL scores pre-and post-ICST

Participant Number	Pre-CST	Post-CST	Post-CST descriptive score
1	12	13	good-excellent*
2	17	13	good-excellent*
3	15	18	fair-good*

Table A-8. Participant 2 average angle of elevation (in degrees) for thin liquid

Measure	Mean(Pre)	Mean (Post)	Change Score
A1	4.04	8.60	4.56*
A2	11.38	22.24	10.85*
A3	11.08	21.64	10.57*

Table A-9. Participant 2 average angle of elevation (in degrees) for pudding thick liquid

Measure	Mean(Pre)	Mean (Post)	Change Score
A1	12.47	13.85	1.38*
A2	14.68	14.73	0.05*
A3	14.53	14.47	-.06*

Table A-10. Participant 3 average thin liquid angle of elevation (in degrees)

Measure	Mean(Pre)	Mean (Post)	Change Score
A1	8.14	4.67	-3.47*
A2	14.61	11.78	-2.83*
A3	13.97	11.46	-2.52*

Table A-11. Participant 3 average pudding thick angle of elevation (in degrees)

Measure	Mean(Pre)	Mean (Post)	Change Score
A1	7.47	10.60	3.13*
A2	12.30	14.21	1.91*
A3	11.92	13.88	1.96*

Table A-12. Participant 2 average thin liquid magnitude displacement (in millimeters)

Measure	Mean(Pre)	Mean (Post)	Change Score
D1	1.42	1.47	0.05*
D2	1.07	1.23	0.15*
D3	0.45	0.48	0.04*

Table A-13. Participant 2 average pudding thick magnitude displacement (in millimeters)

Measure	Mean(Pre)	Mean (Post)	Change Score
D1	1.43	1.48	0.05*
D2	1.35	1.43	0.08*
D3	0.43	0.52	0.09*

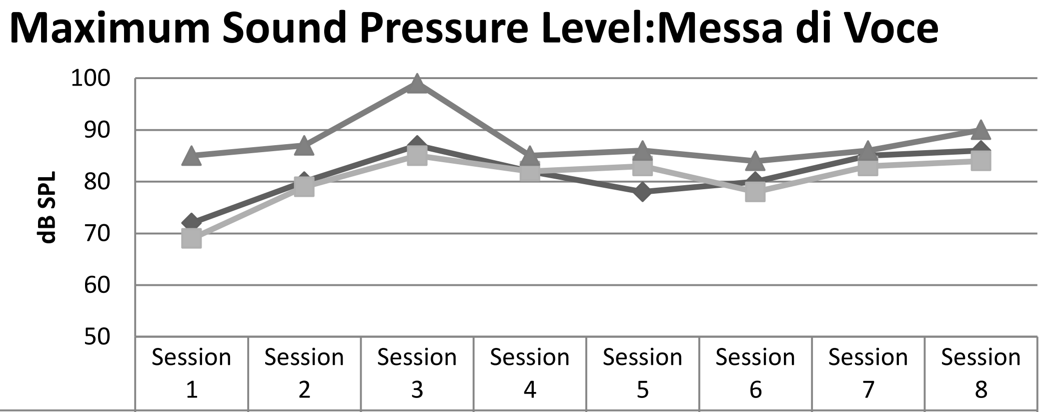
Table A-14. Participant 3 magnitude displacement (in millimeters) for thin liquid barium swallows

Measure	Mean(Pre)	Mean (Post)	Change Score
D1	1.35	1.35	-0.001*
D2	1.14	1.11	-0.03*
D3	0.39	0.36	-0.02*

Table A-15. Participant 3 magnitude displacement (in millimeters) for pudding thick barium swallows

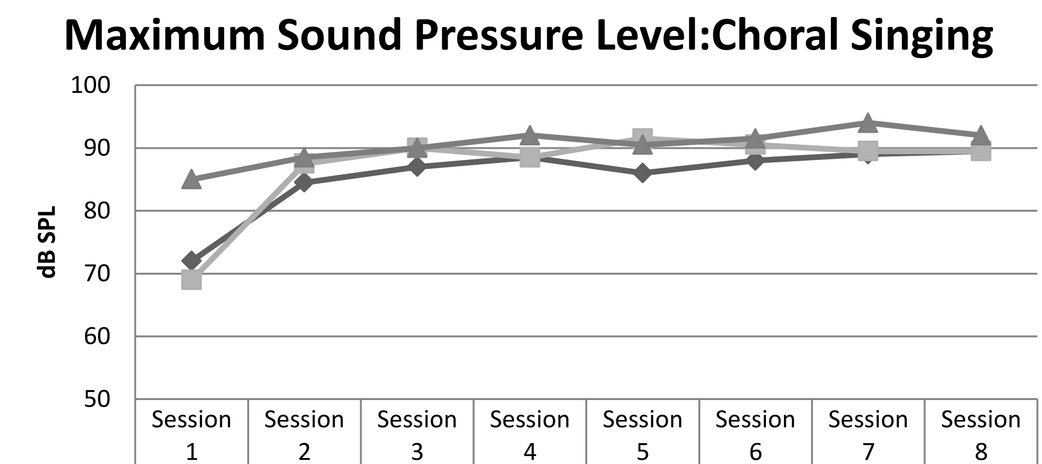
Measure	Mean(Pre)	Mean (Post)	Change Score
D1	1.36	1.29	-0.07*
D2	1.16	1.12	-0.04*
D3	0.34	0.30	-0.04*

APPENDIX B
WEEKLY INTERVENTION SPL FIGURES



	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7	Session 8
Participant 1	72	80	87	82	78	80	85	86
Participant 2	69	79	85	82	83	78	83	84
Participant 3	85	87	99	85	86	84	86	90

Figure B-1. Weekly individual SPL during Messa di Voce exercises



	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7	Session 8
Participant 1	72	84.5	87	88.5	86	88	89	89.5
Participant 2	69	87.5	90	88.5	91.5	90.5	89.5	89.5
Participant 3	85	88.5	90	92	90.5	91.5	94	92

Figure B-2. Weekly individual SPL during choral singing

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BIOGRAPHICAL SKETCH

Sarah Katherine Funderburke was born in Atlanta, GA to Janice and Danny Funderburke. She has one younger brother named Daniel. Sarah grew up in various cities across the Southeastern United States, until her graduation from middle school, upon which her family settled and has remained in Merritt Island, FL. Sarah began her college career at UF as a vocal performance major with an interest in Pre-Health. She sang in Mr. Ron Berichter's vocal studio and the UF Concert Choir. After her first semester at UF, she decided to pursue speech-language pathology as her career and soon developed a passion for this subject that merged both her love of the voice and the medical sciences. Sarah graduated in Communicative Sciences and Disorders in 2010 and continued at UF in the Speech-Language Pathology Master of Arts program. In this program, she has worked as a student in a variety of both adult and pediatric setting and has worked as speech-language pathology assistant part-time. Her adult experiences include Voice Clinic in Shands Hospital, in-patient Speech and Language Services at Shands Hospital, and the Center for Movement Disorders and Neurorestoration at the University of Florida, in which her interests in voice, motor-speech, and language disorders grew. She helped to treat children with craniofacial abnormalities at the Shands Craniofacial Clinic and served as a camp counselor and student therapist at a craniofacial camp. Lastly, she gained experience both as a student and an assistant working with children 3-21 years of age with language delay, articulation, and pragmatic deficits. In the future, she plans to become a certified medical speech-language pathologist.