SKILL TRAINING FOR SWALLOWING REHABILITATION IN INDIVIDUALS WITH PARKINSON'S DISEASE

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science

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Abstract

The primary aim of this pilot study was to evaluate the effects of a novel dysphagia rehabilitation approach: skill training on swallowing in individuals who have dysphagia secondary to Parkinson's disease. The secondary objective was to assess skill retention following treatment termination. This within-subject study involved 10 patients with Parkinson's disease who met the inclusionary criteria.

All participants underwent two baseline data collection sessions, conducted two weeks apart. Data collected included the water swallow test, Test of Mastication and Swallowing Solids (TOMASS), ultrasound measurement of hyoid movement and cross-sectional area of submental muscles, surface electromyography (sEMG) of submental muscles, and swallowing-related quality of life questionnaire (SWAL-QOL). Patients then underwent 10 sessions over two weeks of skill training therapy using custom-designed sEMG software. The focus of the treatment was producing swallowing tasks with defined and adjustable temporal and amplitude precision. The skill training treatment phase was followed by an immediate post-intervention assessment session and two weeks later by a retention assessment session. All outcome measures were administered at each data collection point. The study consisted of a total of 14 laboratory sessions, conducted over a six-week period per subject.

Results revealed significant improvements in swallowing efficiency for liquids, reduced durational parameters on sEMG, such as pre-motor time (PMT), pre-swallow time (PST), and duration of submental muscle contraction. There was a functional carry-over effect seen from dry swallows, which were the focus of training, to water swallows, which were not directly trained. Additionally, improvements in swallowing-related quality of life were demonstrated.

In conclusion, the skill training approach evaluated in this research is able to produce functional, biomechanical, and swallowing-related quality of life improvements in patients with Parkinson's disease. This indicates the potential effectiveness of this novel approach for dysphagia rehabilitation in this population. However, replication with a larger number of patients with Parkinson's disease is needed before findings can be generalised to the larger population

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Preface

This MSc thesis conforms to the referencing style recommended by the American Psychological Association Publication Manual (6^{th} the edition) and spelling in New Zealand English.

The research was carried out between March 2011 and February 2012 at the New Zealand Brain Research Institute, Christchurch, New Zealand. The research was supervised by Dr. Maggie-Lee Huckabee and Professor Richard Jones, of the Department of Communication Disorders at University of Canterbury.

Preliminary and final results from the MSc research have been presented at the following conferences:

- BioMouth 2011 (Palmerston North, New Zealand, 2011).
- New Zealand Speech-language Therapists' Association conference (Auckland, New Zealand, 2012).

Abbreviations

PD	Parkinson’s disease
UPDRS	Unified Parkinson’s disease rating scale
TOMASS	Test of mastication and swallowing of solids
sEMG	Surface Electromyography
RT	Reaction Time
PMT	Pre-motor time
PST	Pre-swallow time
SWAL-QOL	Swallowing quality of life
CSA	Cross-sectional area
H-Y	Hoehn and Yahr score
VFSS	Videofluoroscopic study of swallowing

Chapter 1. Introduction

Swallowing difficulties or dysphagia is a common consequence of Parkinson's disease. Approximately 90% of this patient cohort is reported to have dysphagia (Sapir, Ramig & Fox, 2008) and deficits may be evident in all stages of swallowing (Logemann, 1983). Studies revealed that dysphagia in these individuals may result in medical complications and have a negative impact on quality of life (Plowman-Prine et al., 2009; Robbins, Logemann & Krishner, 1986). Current rehabilitative treatment methods for dysphagia with and/or without Parkinson's disease focus on increasing muscle strength to alter biomechanical features of swallowing pathophysiology (Lazarus, Logemann, Huang, & Rademaker, 2003; Lazarus, 2006; Robbins et al., 2007). These techniques include: the head-lift exercise (Shaker et al., 1997), effortful swallow (Kahrilas, Logemann, Lin & Ergun, 1992; Kahrilas, Lin, Logemann & Ergun & Facchini, 1993), Masako manoeuvre (Fujiu, Logemann & Pauloski, 1995), and Mendelsohn manoeuvre (Logemann & Kahrilas, 1990).

However, neurological injuries may produce dysphagia that is not due to weakness, but results from impaired motor planning and/or temporal deficits such as neuromuscular discoordination and slowness. This is the case in Parkinson's disease, where muscle rigidity, tremor, and bradykinesia (Johnston, Li, Castell J & Castell D, 1995; Logemann, 1983; Potulska, Friedman, Królicki & Spychala, 2003) have been attributed to some of the common swallowing deficits such as lingual festinations, temporal deficits in bolus transfer, initiation of swallowing, and/or incoordination between pharyngeal swallowing and glottic closure (Logemann, 1983; Love & Webb, 1996; Shaker et al., 2003). Thus, strength training for swallowing rehabilitation in this population may not always be the most appropriate approach. Indeed, it may exacerbate deficits resulting from muscle rigidity (Clark, 2003) or could be ineffective for impairments due to temporal deficits. Effective swallowing requires improved neuromuscular coordination, precision, timing, speed of reaction, and planning of motor movements (Ludlow et al., 2008). Hence, an alternative approach of skill training is proposed.

The approach to treatment has different effects on the underlying neuromuscular system (Adkins, Boychuk, Remple & Jeffrey, 2006). Strength training, as is common in swallowing rehabilitation, results in peripheral myogenic changes such as hypertrophy and fibre type shifts (Folland & Williams, 2007; Moritani, 1993). However, skill training results in adaptive changes in the central nervous system such as increased synaptogenesis (Kleim et al., 2002) and reorganisation of movement representation (Kleim, Barby & Nudo, 1998; Remple, Bruneau, VandenBerg, Goertzen & Kleim, 2001). Nudo (2003) has identified that many of the mechanisms evident in skill training are also involved in relearning of motor skills and functional recovery. The findings of Buonomano and Merzenich (1998) and Duffau (2006) are congruent with the findings of Nudo (2003) and demonstrate that the cortex has the ability to compensate for damaged areas by modifying its neural networks through plasticity. Buonomano and Merzenich (1998) and Duffau (2006) suggest that plasticity can be influenced by environmental and rehabilitative inputs. Moreover, evidence from the studies of Kleim et al. (2000) and Plautz et al. (1999) revealed that the functional reorganisation of cortical areas resulting from skill training remains even in the absence of practice.

This research was undertaken to investigate the effects of a novel swallowing rehabilitation procedure, “skill training,” on individuals with dysphagia secondary to Parkinson’s disease. It is hypothesised that a skill-training approach in dysphagia rehabilitation will yield substantial long-term improvements in functional physiology of swallowing even when practice is discontinued. No research has been conducted in skill training related to swallowing rehabilitation in individuals with dysphagia secondary to Parkinson’s disease. However, evidence from gait rehabilitation in this population can be used to draw inferences, which provide support for this hypothesis (Fisher et al. 2008; Petzinger et al., 2010).

Thus, this proposed exploratory pilot study was developed to answer the questions:

1. What effects (biomechanical, muscular and patient’s perception) will skill training have on swallowing impairments in individuals with Parkinson’s disease?
2. Do these effects and/or improvements remain even in the absence of training?

The proposed skill training task aims to improve conscious control of timing and strength of muscle contraction. This task is expected to result in improved neuromuscular coordination, precision, speed of reaction, range of motion, and planning of motor movements. In addition, improvements are expected in cognitive aspects such as awareness of, and attention to, swallowing movements. These in turn are anticipated to promote safe and efficient swallowing in patients with Parkinson’s disease. Furthermore, skill training is anticipated to change swallowing-related quality of life in these individuals. These benefits might in turn improve long-term patient outcomes and reduce health care costs.

In the chapters following the literature review (chapter 2), research methods employed in this study are described (chapter 3), the results of 10 individuals with dysphagia secondary to Parkinson's disease who underwent the skill training treatment protocol are presented (chapter 4). Finally, discussion and concluding remarks are explained (Chapter 5).

Chapter 2. Literature Review

2.1 Swallowing and Dysphagia

Swallowing is the process of delivering food and liquid from the mouth to the stomach (Miller, 2008). This complex neurophysiological motor task involves coordination of 31 paired striated muscles (Dodds, Stewart & Logemann, 1990), six cranial nerves (Donner, Bosma & Robertson, 1985), several areas in the cerebral cortex, sub-cortical structures (Daniels & Huckabee, 2008), and the brainstem (Dodds et al., 1990). Difficulty in swallowing or dysphagia can occur due to various reasons in adults. Among these include: neurogenic aetiologies (e.g., stroke, degenerative neuromuscular diseases) (Buchholz, 1987), head and neck cancers and treatment for cancer, gastroesophageal reflux disease (GERD) (Logemann, 1983), and aging (Logemann, 1990; Tracy et al., 1989).

2.2 Stages of swallowing

The dynamic process of swallowing occurs rapidly with several interdependent events. Daniels and Huckabee (2008) conceptualises this in four phases: pre-oral, oral, pharyngeal and esophageal phase (Figure 2-1).

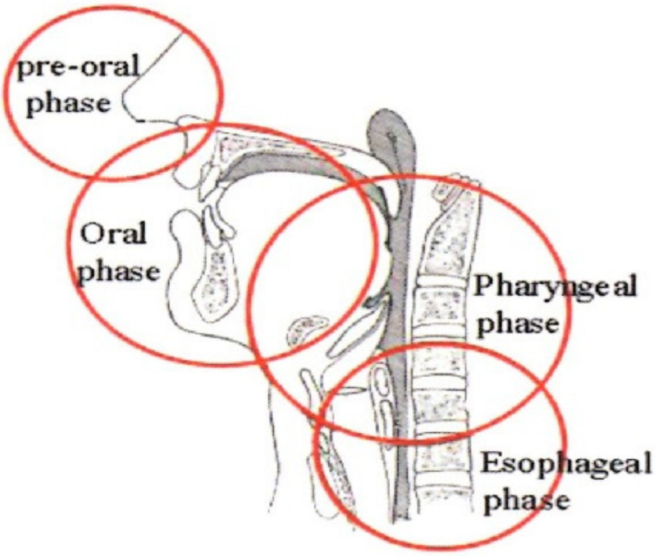

Figure1: Interdependence of the four stages of swallowing. Bass, N., & Morrell, R. (1992, pp. 2). The Neurology of Swallowing. In M.Groher (Eds.), *Dysphagia: Diagnosis and Management* (2 ed.). Massachusetts: Butterworth-Heinimann.

Pre-oral (Anticipatory) stage

The parameters involved in this phase include physiological effects that occur when one anticipates food and first smells and/or sees the food (Leopold & Kagel, 1997). According to Leopold and Kagel, (1997, p.203) "cortex-driven stimuli of food and meal-time environment" may influence the subsequent stages of swallowing. Additionally, external factors such as state of hunger and thirst, milieu of the meal, attention, societal influences, emotional state and motor skills may also influence the pre-oral stage (Leopold & Kagel, 1997).

Oral stage

This phase begins when liquid or food reaches the oral cavity. The tongue tip grooves to form a basin for the bolus to be positioned when it enters the oral cavity (Perlman & Christensen, 1997). Bolus preparation involves mastication, mixing food with saliva by tongue and jaw movements (Daniels & Hukabee, 2008). During bolus preparation the posterior part of the tongue remains elevated against the soft palate (glossopalatal seal) and prevents pre-mature spillage of bolus (Dodds et al., 1990). Once a cohesive bolus is formed, it is propelled into the oropharynx by volitional tongue movements, following relaxation of the glossopalatal seal (Perlman & Christensen, 1997). When the bolus reaches the oropharynx the base of the tongue drops to push the bolus into the hypopharynx (Dodds et al., 1990). Sensory information detected by sensory receptors embedded in the base of the tongue and in the pharynx goes to the nucleus tractus solitarius in the medulla which triggers the swallowing reflex (Daniels & Huckabee, 2008). For detailed descriptions of neural control of swallowing see Dodds et al. (1990) and Miller (2008). This phase ends when the bolus head reaches the ramus of the mandible.

Pharyngeal stage

During this phase, several biomechanical events occur simultaneously and rapidly, within less than 1 second (Kahrilas, Lin, Chen & Logemann, 1996). These include: hyolaryngeal excursion, velopharyngeal closure, base of tongue to posterior pharyngeal wall approximation, pharyngeal peristalsis and shortening, epiglottic deflection, laryngeal closure, and opening of the upper oesophageal sphincter (UES) (Logemann, 1983). Temporal coordination of these events is important for safe and efficient bolus propulsion through the pharynx (Daniels & Huckabee, 2008). The velum remains elevated during the pharyngeal stage, preventing nasal regurgitation (Perlman & Christensen, 1997).

On videofluoroscopy study of swallowing (VFSS) the first anatomical movement that marks the onset of pharyngeal swallowing is elevation of the hyoid and laryngeal complex (Cook et al., 1989). Hyolaryngeal excursion is achieved by contraction of the submental (mylohyoid, geniohyoid, and anterior belly of digastric) and strap muscles (Cook et al., 1989; Logemann, 1988; Vaiman, Eviatar & Segal, 2004c). During hyolaryngeal excursion the hyoid moves up and forward (Ekberg, 1986). Anterior hyoid movement causes deflection of the epiglottis and thereby covers the laryngeal vestibule (VanDaele, Perlman & Cassell, 1995), protecting the airway. The airway closure involves several processes. Following true and false vocal fold adduction, the arytenoids move medially, then anteriorly to approximate the epiglottis (VanDaele, McCulloch, Palmer & Langmore, 2005). The epiglottis deflects to cover the arytenoids (VanDaele et al., 2005). These mechanisms along with the compression of the quadrangular membrane, further protect the airway (Daniels & Huckabee, 2008). Airway closure for swallowing takes approximately 0.6-0.7 s to complete (Dodds et al., 1990; Langmore, 2001), suggesting that the airway is vulnerable to an oncoming bolus for approximately half a second after swallowing has begun (Langmore, 2001). Hence, precise timing of airway closure and bolus movement is integral for keeping the airway protected and preventing aspiration.

The literature on amount of hyolaryngeal excursion is debatable, with some researchers documenting 1.1 cm superior and 0.9 cm anterior (Perlman, VanDaele & Otterbacher, 1995) while others reporting as much as 2.5 cm superior movement (Sundgren, Maly & Gullberg, 1993). However, anterior displacement is reported to be greater than superior by 8 mm which is seen consistently regardless of food consistency, suggesting that forward displacement is more important (Ishida, Palmer, Hiiemae, 2002). This anterior hyoid movement also acts as the traction force to pull the UES open (Cook et al., 1989). Hyolaryngeal excursion is accompanied by pharyngeal shortening, where the pharyngeal muscles contract from superior to inferior (Palmer, Drennan & Baba, 2000). Several factors contribute to the propulsion of the bolus through the pharynx: tongue driving force, stripping action of the pharyngeal constrictors, the presence of negative pressure in the laryngopharynx, and gravity (Donner et al., 1985; Logemann, 1983). However tongue driving force, which provides direct pressure on the descending bolus, is considered to be the main driving force for bolus propulsion as opposed to contraction of pharyngeal walls, which acts as a clearing wave (McConnel, Cerenko, Jackson & Guffin, 1989). This stage ends with the cricopharyngus muscle relaxing, combined with the traction force of hyolaryngeal excursion resulting in UES opening, allowing the bolus to enter the UES (Perlman & Christensen, 1997).

Esophageal stage

Similar to the pharyngeal phase, the esophageal stage is involuntary. Following relaxation of the cricopharyngus muscle, the bolus enters the esophagus through the UES. The bolus is then propelled to the stomach via the esophageal peristaltic waves (Donner et al., 1985). This phase ends when the tail end of the bolus passes through the lower esophageal sphincter, which closes after the bolus enters the stomach, thus, preventing reflux of gastric contents (Palmer et al., 2000). This stage lasts between 8-15 s (Miller, 1982).

2.3 Parkinson's Disease

2.3.1 Parkinson's disease: Overview

Parkinson's disease (PD) is a progressive neurodegenerative disorder that affects approximately one in five hundred New Zealanders (The Parkinsonism Society of New Zealand, n.d). Even though this disorder is of idiopathic origin, studies suggest that it could be caused by a combination of environmental and genetic factors (Guttman, Kish, & Furukawa, 2003; Wirdefeldt, Adami, Cole, Trichopoulos & Mandel, 2011). PD is more prevalent in men than women and generally occurs in middle and/or late life. The motor deficits in PD are associated with degeneration of dopaminergic neurons in the pars compacta of the substantia nigra in the basal ganglia (Wirdefeldt et al, 2011). The primary motor deficits in PD are rigidity, resting tremor, bradykinesia (slowness of movements), and postural abnormalities (Jankovic, 2008; Shumway-Cook & Wollacott, 2001). Other symptoms include dementia, depression, disturbance in normal sleep, anxiety, constipation, urinary problems, and speech and swallowing difficulties (Adler, 2005; Duffy, 1995).

Currently Levodopa (L-DOPA), together with a peripheral decarboxylase inhibitor (e.g., carbidopa) or DA agonist, is considered the most effective drug for reducing signs and symptoms of PD (Martin & Wieler, 2003; Nicholson, Pereira & Hall, 2002). However, prolonged use of L-DOPA may lead to motor fluctuations, dyskinesias, and psychiatric problems (Munchau & Bhatia, 2000; Schapira et al., 2006). Furthermore, L-DOPA treatment is reported to be ineffective for influencing symptoms such as cognitive impairments, gait, and postural disturbances, which are considered to have the most long-term disabling effects in this population (Hely, Morris, Reid & Trafficante, 2004).

2.4 Parkinson's disease and dysphagia

2.4.1 Dysphagia in Parkinson's disease

Dysphagia in Parkinson's disease is frequently seen in individuals at an advanced stage of the disease (Nagaya, Kachi, Yamada & Igata, 1998; Nagaya, Kachi & Yamada, 2000). Even though Johnston et al. (1995) provide a review of possible causes for dysphagia in this cohort, the exact pathophysiology is not clear (Potulska et al., 2003). Rigidity, bradykinesia (Johnston et al., 1995; Robbins et al., 1986), and tremor (Potulska et al., 2003) of the oral musculature are considered to be plausible causes for the abnormalities in the oral and oral preparatory phases. Additionally, research suggests that reduced somatosensory perception, delayed/dyscoordinated oral delivery may result in pharyngeal dysphagia in PD (Jonhnston et al., 1995; Potulska et al., 2003).

Dysphagia in PD is mainly evident in the oral and pharyngeal phases of swallowing (Bushmann, Dobmeyer, Leeker, Perlmutter, 1989). The oral dysphagia is characterised by distinctive features such as repetitive lingual pumping (Logmann, 1983; Nagaya et al, 1998), slowness in chewing (Leopold & Kagel, 1996), poor lip seal resulting in anterior leakage, and piecemeal deglutition (Nagaya et al., 1998). Also, Nagaya et al. (2000) measured pre-motor time (PMT) to describe the oral phase of dysphagia in PD. They defined PMT as the time difference between presentation of a stimulus to the first detectable change in the EMG waveform. Results from their study revealed longer PMT in patients with PD as compared to healthy controls. This finding is congruent with previous limb literature which has shown that PMT tends to be prolonged in individuals with PD (Pullman, Watts, Juncos, Chase & Sanes, 1988; Sheridan, Flowers & Hurrell, 1987; Yokochi, Nakamura & Narabayashi, 1985). Furthermore, oral transit times were reported to be prolonged compared to pharyngeal transit times (Stroudley & Walsh, 1991).

Characteristics of pharyngeal phase dysphagia in PD include reduced pharyngeal peristalsis (Ali et al., 1996; Leopold & Kagel, 1997), reduced laryngeal elevation (Bushmann et al., 1989), delayed swallow response (Love & Webb, 1996), impaired epiglottic deflection, valleculae and pyriform sinus bolus retention, penetration, and aspiration (Leopold & Kagel, 1997). Patients with PD are reported to have greater difficulty swallowing liquids than semi-solids and/or solids resulting in greater penetration/aspiration (Eadie & Tyrer, 1965; Stroudley & Walsh, 1991). This may be due to increased pharyngeal stimulation provided by solids (Dodds, 1989) and reduced cohesiveness of the liquid bolus (Stroudley & Walsh, 1991). Additionally, some abnormalities in the esophageal phase have been reported (Johnston et al., 2005; Potulska et al., 2003). These include incomplete UES relaxation and reduced UES opening during swallowing (Ali et al., 1996).

There are discrepancies in the literature regarding the correlation between the severity of PD and the presence and severity of dysphagia. Some studies have found no relationship (Ali et al., 1996; Flexi, Corréa & Soares, 2008) while others have found worsening of dysphagia with increasing disease severity (Lam et al., 2007; Leopold & Kagel, 1997). These discrepancies could be due to differences between the Hoehn & Yahr stages (disease severity) of the patients examined. For example, Leopold and Kagel (1997) study had patients who belonged to both stages, mild/moderate (II & III) and advanced (IV & V). However, the majority of the patients in Ali et al. (1996) study belonged to mild/moderate (II & III) and had only one patient from the advanced stage (V). Sample sizes also varied across studies, ranging from four (Flexi et al., 2008) to 71 (Leopold & Kagel, 1997). Additionally the assessment tools varied from dynamic videofluoroscopy (Leopold & Kagel, 1997) to symptom questionnaire, 50 ml water swallow test, and VFSS (Lam et al., 2007). Hence, future replicated studies with larger, homogenous samples and stronger research designs are needed to clarify this discrepancy.

2.4.2 Prevalence and patient's perception of dysphagia

Estimates of the prevalence of dysphagia in PD range from 18.5% (Mutch, Strudwick, Roy & Downie, 1986) to 100% (Robbins et al., 1986). Coates and Bakheit (1997) suggested that this wide degree of variation in dysphagia occurrences could be due to different assessment approaches (postal surveys versus radiological assessments) used by researchers to identify dysphagia, which may have led to underestimation. Furthermore, several researchers found that PD patients were unaware of their swallowing difficulties (Bushmann et al., 1989;

Logemann, Fisher, Boshes & Blonsky, 1978; Robbins et al., 1986), which could also lead to underestimation of prevalence.

Reports of reduced perception of dysphagia in PD come from several studies. In a study by Bird, Woodward, Gibson, Phyland and Fonda (1994), of the 16 PD patients who had reported no symptoms of dysphagia, all were found to have had swallowing abnormalities on VFSS. Similarly, several other studies revealed that PD patients who did not complain about dysphagia displayed physiologic abnormalities on radiological assessments, whereas, those who complained were found to be non-dysphagic (Ali et al., 1996; Bushmann et al., 1989). Hence, physiological abnormalities are likely to be present before the symptoms of dysphagia are noticed by the physician or patient (Ali et al., 1996; Bushmann et al., 1989). This may make it difficult to diagnose dysphagia in individuals with PD. Other reasons for reduced perception of dysphagia in this patient population include: cognitive deficits and use of self-learnt compensatory strategies (Aarsland, Tandberg, Larsen & Cummings, 1996; Miller, Noble, Jones & Burn, 2006). Positive coping/compensatory strategies such as taking smaller bites/sips, use of modified cutlery, and avoidance helped lessen dysphagia symptoms temporarily (Miller et al., 2006) resulting in dysphagia symptoms being unnoticed.

Bird et al. (1994) urged that self-reports of dysphagia in this patient population need to be viewed with caution due to patient's poor awareness of the disorder. This raises an important issue that swallowing-related questionnaires such as SWAL-QOL (Mc Horney et al., 2002), which investigates the patient's perception of the swallowing problem, needs to be interpreted cautiously as these questionnaires maybe under-scored or over-scored depending upon the patient's self-awareness of the disorder. Despite this limitation, quality of life questionnaires are considered to be psychobehavioural and psychosocial markers, and therefore may provide complementary information to the clinician (McHorney, Martin-Harris, Robbins & Rosenbek, 2006). Additionally, quality of life measures provide valuable information regarding the effectiveness of the treatment on their lifestyle; this is beneficial when assessing the efficacy of novel treatment (Guyatt, Feeny & Patrick, 1993).

2.4.3 Effects of dysphagia in Parkinson's disease

Dysphagia may cause malnutrition, dehydration, and respiratory infections such as aspiration pneumonia (Marks & Rainbow, 2001). Generally, aspiration pneumonia results in increased length of recovery, longer duration of hospitalisation, and higher risk of death (Langmore et al., 1998). Similarly in this cohort, pneumonia has been identified as a leading cause of death, specifically six times higher than that of the normal population (Fall, Saleh, Fredrickson, Olsson & Granérus, 2003). This is further supported by the finding that patients with PD have reduced cough reflex and therefore are at higher risk of silent aspiration resulting in development of aspiration pneumonia (Ebihara et al., 2003). The high mortality rates following pneumonia in PD suggests the significant need to develop and/or improve effective and long lasting rehabilitation options for dysphagia in this population.

Eating is frequently considered a social event and hence, swallowing is also important for an individual's emotional wellbeing and quality of life (Morgan & Ward, 2001). Studies have shown that dysphagia can have a negative impact on the quality of life among individuals with PD such as anxiety during meals, decreased self- esteem and social withdrawal (Miller et al., 2006; Plowman-Prine et al., 2009). A study by Leow, Huckabee, Anderson and Beckert (2010) revealed that individuals with PD with dysphagia had reduced scores on all the subsections of a swallowing quality of life questionnaire (SWAL-QOL), thus implying that dysphagia affects the quality of life in this patient group. Apart from Leow et al. (2009) and Plowman-Prine et al. (2009) studies on swallowing-related quality of life in this cohort, there are no published studies done to measure patient's perception following swallowing treatment using SWAL-QOL in PD.

2.5 Dysphagia rehabilitation and strength training

2.5.1 Overview

Most of the current rehabilitative treatment methods for dysphagia with and/or without PD focus on increasing muscle strength to alter biomechanical features of swallowing pathophysiology (Lazarus et al., 2003; Lazarus, 2006; Robbins et al., 2007). These techniques may be broadly categorised as *'techniques outside the context of swallowing'* and *'techniques performed within the functional context of swallowing'*. The exercises outside the context of swallowing include the head-lift exercise (Shaker et al., 1997), lingual exercises (Robbins et al., 2005; Robbins et al., 2007), expiratory muscle strength training-EMST (Kim & Sapienza 2005) and Lee Silverman Voice Treatment-LSVT (Ramig, Countryman, Thompson & Horii, 1995). Manoeuvres within the functional context of swallowing include the effortful swallow (Kahrilas et al., 1992; Kahrilas et al., 1993), tongue-hold/Masako manoeuvre (Fujiu et al., 1995), and the Mendelsohn manoeuvre (Logemann & Kahrilas, 1990). Exercises outside the context of swallowing can be considered as non-task-specific strengthening exercises. A task-specific exercise is one in which the technique replicates the desired task, that is swallowing (Burkhead, Sapienza & Rosenbek, 2007). Hence, techniques such as effortful, tongue-hold and Mendelsohn, are task-specific strength-training techniques.

2.5.2 Strengthening exercises outside the context of swallowing

The head-lift exercise is a commonly-used technique in dysphagia rehabilitation. It is purported to increase UES opening through strengthening of the submental muscles (Shaker et al., 1997). This consists of 30 brief raising and lowering of head (isokinetic) followed by three sustained head raisings (isometric) for one minute in supine position (Shaker et al., 1997). Shaker et al. (2002) studied the effects of this technique in 26 chronic dysphagic, tube-fed patients and found significant improvements in anterior hyoid movement, UES opening, and post-swallow aspiration. All patients were also reported to have resumed oral feeding. Despite these positive outcomes, changes in hyoid displacement were not reported in a study which compared head-lift with traditional exercise involving 19 oropharyngeal dysphagic patients (Logemann et al., 2009). Moreover, another study revealed that only 68% of the healthy participants were able to attain the isometric goal by week five and that 27% dropped out during the first two weeks of the programme (Easterling, Grande, Kern, Sears & Shaker, 2005). Likewise, in Logemann et al. (2009) study 26% of the patients dropped out during the head-lift exercise protocol. This raises a concern for patient compliance and attainment of goals with the head-lift exercise. Additionally, this technique may not be appropriate for patients with poor head and neck control as it requires an individual to lie down and lift their head up and down 30 times.

Another strength training technique used outside the context of swallowing, which reported changes in swallowing biomechanics, is the lingual resistance exercises (Robbins et al., 2005; Robbins et al., 2007). Robbins and colleagues used the Iowa Oral Pressure Instrument (IOPI), which measures tongue to palate pressure in an eight week treatment programme. This programme consisted of compressing the air filled bulb between tongue and hard palate using the IOPI as a biofeedback device. These studies revealed significant increases in both isometric and swallowing pressures in 10 healthy elderly (Robbins et al., 2005) and 10 stroke patients (Robbins et al., 2007). Results revealed decreased oral transit time, post-swallow pharyngeal residue, and improved SWAL-QOL scores for all 10 stroke patients. Furthermore, tongue hypertrophy was noted in two patients following treatment. However, further replicated studies of lingual exercises with larger patient samples, adequate placebo groups, and longer post-treatment follow-ups are required to understand the cumulative and lasting effects of lingual exercises on functional swallowing.

The Lee Silverman Voice Treatment (LSVT) programme is another example of a non-swallowing-related strengthening exercise (Ramig et al., 1995). This intensive voice rehabilitation programme focuses on improving communication by increasing the loudness in patients with PD (Ramig et al., 1995). Besides the improvements on communication, LSVT has been found to have benefits on swallowing, such that it improved swallowing efficiency in PD (Sharkawi et al., 2002). Similarly, expiratory muscle strength training (EMST), which consists of blowing into a calibrated device with a mouthpiece and a one-way spring loaded valve, is reported to have a positive influence on swallowing biomechanics (Kim, Devenport & Sapienza, 2009; Sapienza & Wheeler, 2006). This is further supported by positive findings from a study by Pitts et al. (2009) reviewed in section 2.6. Furthermore, increased submental muscle activity following EMST has been reported (Wheeler, Chiara & Sapienza 2007). The influence of these non-swallowing related tasks on swallowing efficiency suggests an interaction between the respiratory and laryngeal subsystems related to swallowing (McFarland & Tremblay, 2006). Thus, intervention aimed to improve one system may have a complementary (transference) effect on another (Burkhead et al., 2007; McFarland & Tremblay, 2006).

2.5.3 Strengthening exercises with in the functional context of swallowing

Muscle strengthening tasks in isolation have as reviewed above shown to produce mixed effects on swallowing biomechanics. A more efficient approach to rehabilitation may include implementation of task-specific exercises, in which the techniques replicates the desired task, i.e. swallowing (Burkhead et al., 2007). Effortful swallow is a commonly-used, task-specific strength training exercise. Swallowing with effort results in increased pressure on the bolus and thereby decreases pharyngeal residue (Huckabee, Butler, Barclay & Jit, 2005; Kahrilas et al., 1992; Kahrilas et al., 1993). In the long term, with repeated execution the effortful swallow manoeuvre may strengthen striated pharyngeal musculature. Numerous studies have been conducted to assess the effects of effortful swallow on swallowing biomechanics. These include effects on hyoid movement, ranging from no effect (Wheeler-Hegland, Rosenbek & Sapienza, 2008), to decreased hyoid excursion (Bülow, Olsson & Ekberg, 1999) and to increased superior but decreased anterior movement (Hind, Nicosia, Roecker, Carnes & Robbins, 2001). Therefore, when prescribing effortful swallow one should be cautious of potential negative effects on hyoid movement. This can be counterbalanced by pairing it with techniques, such as head-lift exercises, which specifically focus on increasing anterior hyoid movement. Researchers have also found that effortful swallow can result in longer UES opening (Hind et al., 2001; Hiss & Huckabee, 2005). However, no change in aspiration and penetration in patients with moderate-to-severe dysphagia (Bülow, Olsson & Ekberg, 2001) and adverse effects such as increased pyriform sinus residue with increasing age were noted (Hind et al., 2001). Of additional concern is a case report which revealed that long-term use of effortful swallow resulted in nasal redirection in a 12 year old patient with post-surgical removal of a brainstem tumour (Gracia, Hakel & Lazarus, 2004). Considering these findings it is evident that effortful swallow can have positive, or negative effects on swallowing biomechanics. Hence, prescribing it maybe contra-indicatory for certain patient populations.

Another strengthening technique in functional context is the tongue-hold manoeuvre, in which the tongue is stabilised anteriorly between the teeth (Fujiu et al., 1995). This technique, considered a resistance exercise, is found to result in a greater anterior movement of the posterior pharyngeal wall (Fujiu & Logemann, 1996). This notion was supported by Lazarus, Logemann, Song, Rademaker and Kahrilas (2002) in a study of three patients with base-of-tongue resection. Doeltgen, Witte, Gumbley and Huckabee (2009) evaluated the amplitude and duration of upper, middle, and lower pharynx using pharyngeal manometry in 40 healthy participants using the tongue-hold manoeuvre. Results suggested reduced pharyngeal peak pressure, shorter pharyngeal pressure durations, and significantly lower UES relaxation pressures. It can be postulated that repeated execution of this technique would strengthen posterior pharyngeal wall contraction. However, stronger posterior pharyngeal wall may impose a higher force on the hyoid bone, pulling it back. Therefore, when prescribing the tongue-hold exercise, head-lift needs to be prescribed as a prophylactic treatment. Another limitation of the approach is that it cannot be used with a bolus.

The Mendelsohn manoeuvre is another commonly used task-specific strength training technique. Execution of the Mendelsohn manoeuvre involves an individual initiating a swallow, and at the peak of hyolaryngeal excursion, maintaining suprahyoid contraction before relaxing and completing the swallow (Logemann & Kahrilas, 1990). Prolonging the swallow results in prolonging of UES opening, but does not increase in the diameter of the

UES (Kahrilas, Logemann, Krugler & Flanagan, 1991). Additionally, Mendelsohn in healthy subjects increased the duration of anterior-superior excursion of the larynx and hyoid, thereby delaying UES closure (Kahrilas et al., 1991). However, there was no measurement of bolus flow parameters. A Manofluorographic study by Boden, Hallgren and Witt Hedström (2006) found that the Mendelsohn technique not only increased duration but also the amplitude of pharyngeal contraction. Hence, repeated execution of this technique is thought to strengthen pharyngeal muscle contraction. These researchers also documented that Mendelsohn manoeuvre can significantly result in longer bolus transit time. A concern with conducting the Mendelsohn technique with a bolus is an increased possibility of aspiration. It can be postulated that during holding of the swallow (when performing the manoeuvre), the bolus might descend towards the valleculae and remain instead of going through the UES and result in aspiration. Thus, in patients with poor airway protection performing the Mendelsohn manoeuvre may be contraindicated. As reviewed above, some of the rehabilitation techniques have documented adverse effects on swallowing biomechanics. Therefore, strength training may not always be the appropriate approach of treatment, as it may be contraindicated at worst or be ineffective at best. This indicates the need to further document the efficacy of swallowing manoeuvres on swallowing biomechanics either by improving and/or modifying the current techniques and/or investigating alternative treatment approaches.

The aforementioned techniques, within the context (e.g., effortful, tongue-hold, and Mendelsohn) or outside the context of swallowing (e.g., head-lift, EMST, lingual) aim at strengthening the swallowing muscles by increasing the force, effort and duration of muscle contraction. Behavioural plasticity of swallowing has been evidenced following strength-training techniques, such as, lingual exercises (Robbins et al., 2005, 2007), head-lift (Shaker et al., 2002), LSVT (El Sharkawi et al., 2002), and effortful swallowing (Bülow et al., 2001; Hiss & Huckabee, 2005). Furthermore, literature from limb rehabilitation documents that peripheral myogenic changes such as hypertrophy and fibre-type shifts (Folland & Williams, 2007; Moritani, 1993) take place following strength training. Studies of orolingual exercise by Robbins et al. (2005, 2007) provide support for this in the realm of dysphagia rehabilitation. Despite these positive attributes of strength training, it may have inherent shortcomings as an approach itself.

2.5.4. Drawbacks with strength training

Some of the disadvantages of strength training include muscle fatigue (Clark, 2003; Moldover & Borg-Stein, 1994), increased muscle tone (Clark, 2003), and an inability to retain newly-acquired skills (Clark, O'Brien, Calleja, & Corrie, 2009). Muscle fatigue, is described as weakness that occurs during prolonged "force production or over repeated trials" (Clark, 2003, p.400). In most individuals, this weakness is related to exercise-induced tiredness and lasts only for a short time. With adequate rest, fatigue can be overcome (Moldover & Borg-Stein, 1994). However, in certain degenerative diseases like multiple sclerosis and amyotrophic lateral sclerosis, fatigue can considerably hinder or restrain the recovery and reduce the functional strength levels (Clark, 2003). According to the swallowing literature, one study reported muscle fatigue before and after the head-lift exercise (White, Easterling, Roberts, Wertsch & Shaker, 2008). These researchers reported that the sternocleidomastoid (SCM) muscle fatigued as fast as or faster than the supra-hyoid and infra-hyoid muscles initially. However following completion of the protocol, SCM became more resistant to fatigue while supra-hyoid and infra-hyoids showed increased fatigue. Further research is required to understand the adverse effects of fatigue of swallowing muscles and its translation into functional swallowing.

A further effect of strength training is that it can also adversely increase muscle tone (Clark, 2003). For patients with rigidity (e.g., Parkinson's disease) or spasticity (e.g., cerebral palsy), strengthening exercises may further increase muscle tone and as a consequence cause distress, reduce the range of motion, and be contra-indicatory (Clark, 2003). However, there is no documented literature on the effects of disrupted tone on swallowing following strengthening exercises. Another limitation following strength-training paradigms is detraining (Baker, Davenport and Sapienza 2005; Clark et al., 2009). Detraining may be defined as the progressive decline of improvements to pre-treatment levels when training is terminated (Clark et al., 2009). A study by Clark et al. (2009) revealed that lingual strength increased after nine weeks with directional tongue strengthening exercises but these improvements (tongue strength) decreased significantly during the detraining period.

Furthermore, no neural changes have been documented in dysphagia rehabilitation following strength training. However, evidence from the limb literature indicates that strength training resulted in minimal changes at the central neural level in humans (Carroll, Riek & Carson, 2002; Jensen, Marstrand & Nielsen, 2005). Similarly, it may be assumed that strength training paradigms in the area of dysphagia might not yield neural plasticity but this speculation warrants investigation. Neurological diseases like stroke and Parkinson's disease result from changes of brain activation in the cortex or sub-cortical areas, rather than peripheral muscle function directly. Therefore, rehabilitation should logically focus on changes at the neural level instead of the peripheral level. This suggests the need for a treatment approach which would enhance cortical changes and neural plasticity.

2.5.5 Task-specific exercises with biofeedback

There are also several studies in which task-specific exercises were used in combination with biofeedback using surface electromyography (sEMG). Surface EMG biofeedback is not a behavioural treatment in itself but is a means to improve the existing treatment in a novel manner. Some of the early studies using sEMG biofeedback as an adjunct treatment provided positive results. Crary (1995) and Huckabee and Cannito (1999) reported significant improvements in swallowing physiology in patients with chronic dysphagia secondary to brainstem injury, when effortful and Mendelsohn techniques were used along with sEMG as a biofeedback tool. The positive outcomes reported as a result of biofeedback-assisted treatment may not be solely attributed to muscle strengthening through effortful swallowing and the Mendelsohn manoeuvres per se as the use of biofeedback provides potential benefits to recovery outside the realm of muscle strengthening. Conscious effort or challenge during an exercise adds a skill-learning component to the task. Therefore, it can be assumed that when an individual performs a task in a novel way or completes an activity with increasing levels of difficulty skill learning occurs. Utilising biofeedback modalities to master the task-specific exercises enhances the 'skill' component likely through recruitment of cognitive modulation of biomechanical performance. This raises the question of whether improvements in the patients reported by Crary (1995) and Huckabee and Cannito (1999) were solely due to the strengthening aspect of treatment or solely due to the cortical modulation at executing the skilled behaviour or a combination of both.

Another justification for the need of an alternative treatment approach comes from the fact that dysphagia may result from other neuromuscular deficits other than muscle weakness. An assumption underlying application of strength training has been that dysphagia results from muscle weakness. Weakness is frequently cited as a characteristic of dysphagia (Dworkin & Hartman, 1979; Clark, Henson, Barber, Stierwalt, & Sherrill, 2003; Weijnen et al., 2000) and hence, it is not surprising that strength training has been the focus of treatment. Unfortunately current primary diagnostic tools such as endoscopy and videofluoroscopy, do not give insight into underlying muscle function (Huckabee & Kelly, 2005). Thus, neuromuscular deficits such as muscle dyscoordination (Daniels, 2000; Huckabee & Kelly, 2005) and spasticity (hypertonia) (Huckabee & Kelly, 2005) may not be easily identified. In addition, healthy individuals have substantial physiologic muscle reserve that is not used in ingestive swallowing (Burkhead et al., 2007). Hence, swallowing may depend more on precision and speed of movement than on strength. Finally, it has not been documented that an increase in neuromuscular strength transfers to functional swallowing (Steele, Bailey, Molfenter & Yeates, 2009). Therefore, improving strength alone may not be adequate to execute safe and efficient swallowing. Even though strengthening exercises would suit dysphagia resulting from weakness (Daniels & Huckabee, 2008), these exercises may not be appropriate for dysphagia resulting from temporal deficits and impaired motor planning.

2.6 Current rehabilitative treatment for dysphagia in Parkinson’s disease

Studies on the effects of swallowing rehabilitation in PD are quite sparse, despite dysphagia being highly prevalent and resulting in adverse medical and psychosocial consequences among this population (Baijens & Speyer, 2008). Interestingly, all of the studies on dysphagia rehabilitation in PD have focused on strengthening of the swallowing muscles (Felix, corrêa & Soares, 2008; Nagaya et al., 2000; Pitts et al., 2009; Sharkawi et al., 2002). A pilot study by Felix et al. (2008) evaluated the effects of the effortful-swallow manoeuvre, reinforced with biofeedback, on swallowing function. They examined four patients with PD with moderate oropharyngeal dysphagia. Two consecutive weeks of swallowing training was conducted with a custom-designed biofeedback instrument. Each session consisted of four saliva swallows and four solid (biscuit) swallows using the manoeuvre. All treatments and testing were carried out during the “on” phase of L-dopa. Results revealed that all four patients had improved oral transit time for swallowing water and three for swallowing biscuit. Also, none of the patients showed overt signs of aspiration. Hence, Felix et al. (2008) concluded that effortful swallow reinforced with biofeedback may be a potential swallowing rehabilitation method for this patient cohort. However, this study has several weaknesses. The swallow targets consisted of saliva and biscuit swallows, hence it is difficult to determine whether the reported improvements were a result of the effortful manoeuvre coupled with biofeedback or merely due to a practice effect of having the patients swallow biscuits, several times, every session. Similarly, the use of effortful swallowing with biofeedback can be considered a form of skill training, thus, it is difficult to ascertain whether the improvements in these patients were due to increased peripheral muscle recruitment or due to improvements in strength. Thirdly, no objective instrumental assessments was conducted pre and post-therapy to validate the reported improvements in their patients swallowing. The study also lacked a control group, had a small sample size, and the authors did not document whether the two swallowing conditions were randomised within and across sessions, within and between patients.

A study by Sharkawi et al. (2002) examined the effects of the Lee Silverman Voice Treatment (LSVT) on swallowing and voice function in eight patients with Parkinson's disease with dysphagia. Each patient received 16 sessions of LSVT over a four week period, with each session lasting 50-60 min. VFSS was conducted pre- and post-treatment along with several voice assessments. Post-therapy assessment revealed reduction in oral and pharyngeal transit times. Thus, Sharkawi et al. (2002) concluded that, in addition to the benefits of LSVT on speech, it might also improve neuromuscular control of oral-tongue and tongue-base during swallowing. These swallowing observations may be considered in light of a study by Ward, Theodoros, Murdoch and Silburn (2000), which suggest that patients with PD following LSVT had significantly increased tongue strength. Some of the strengths in Sharkawi et al. (2002) study include blinding of ratings. Outcome parameters consisted of both temporal and qualitative measures of swallowing. Statistical analysis and disease severity according to the Hoehn-Yahr (H-Y) scale were noted. Additionally, the time and medication cycle were controlled for each patient. Despite these strengths, the Sharkawi et al. (2002) study lacked a placebo group. Also, the reported improvements in swallowing were determined from a single tool (VFSS). As a result, several other important aspects of swallowing such as neuromuscular changes, quality of life, and the sensory component of swallowing were not evaluated. The use of multiple assessment tools is very important in treatment studies as they provide various information regarding the efficacy and effectiveness of treatment (Baijens & Speyer, 2009).

The effects of swallowing training were investigated by Nagaya et al. (2000). They measured the pre-motor time (PMT) in 10 patients with Parkinson's disease with dysphagia using videofluoroscopy (pre-training only) and sEMG pre- and post-training. The PMT value was calculated from the time between the presentation of the stimulus (green light) to the first detectable change in the EMG waveform. Swallowing training involved five strength training exercises: "range of tongue motion exercises, [tongue] resistance exercises, exercises to increase the adduction of vocal cords, the Mendelsohn manoeuvre and range of motion exercises in the neck, trunk and shoulder joints" (Nagaya et al., 2000, p. 12). These were conducted five times, in a single session of 20 min. Post-therapy assessment revealed a significant reduction in the PMT of the submental muscles, faster initiation of the swallowing reflex and improved swallowing performance. All evaluations were conducted during the "on" phase with time of medication controlled for each patient. Disease severity was documented with the H-Y scale and there were 12 healthy control participants. However, a limitation of the study was that they did not evaluate pre-swallow time (PST), which is indicative of the motor-execution component of the reaction time. Hence, it is difficult to determine whether the reported improvements in swallowing occurred as a result of improved cognitive preparation (visual cue-green light) or due to improved neuromuscular coordination, improved speed of reaction and ROM or a combination of both. Another limitation is that only the immediate effects following training was assessed and not long-term retention and carry-over to functional swallowing. Additionally, only one outcome tool was used to assess the efficacy of treatment. Also there was no mention of whether pre-and post-training measures of sEMG were scored blinded by the raters.

Another study conducted by Pitts et al. (2009) examined 10 individuals with Parkinson's disease with dysphagia. They assessed the effects of expiratory muscle strength training on voluntary cough and swallowing function, as measured by the Penetration/Aspiration (P/A) scale using VFSS pre- and post-training. After four weeks of training (five days per week, performing five sets of breaths, with a total of 25 breaths per day), the voluntary cough volume increased and P/A scores decreased significantly. The authors concluded that this was partly due to strengthening of the submental muscles which are responsible for hyolaryngeal excursion, and in turn is necessary for airway protection and upper esophageal sphincter (UES) opening. The raters were blinded to the experimental condition and the disease severity was rated according to the H-Y scale. All VFSS and cough productions were conducted during the "on" phase of medication and time of medication taken was controlled. However, there was no placebo group.

2.7 Dysphagia rehabilitation and skill training

2.7.1 Introduction

Skill training is a relatively new area construct in swallowing rehabilitation and its effects on swallowing in individuals with dysphagia secondary to Parkinson's disease have not yet been investigated. Current literature on skill training comes from sports medicine, neuroscience, and physiotherapy and has proven to be effective in functional rehabilitation of limb and trunk (Perez, Lungholt, Nyborg & Nielsen, 2004).

Skill training is defined crudely as the process of learning and fine-tuning new sequences of movements (Adkins, et al., 2006). In other words, when an individual does a novel task and/or challenging activity, skill learning occurs. When the task introduces a 'challenge' component it requires an individual to problem-solve the movement each time it is practised rather than memorising and replaying the sequences of muscle/joint contractions (Krakauer, 2006). This learning effect can be thought of as when one tries to shoot a ball through a ring (e.g., netball, basketball); we may do so differently each time, due to the differences in body position, advancing opponent players, differences between the distances relative to the ring, etc. Therefore, learning of novel postures and/or new combinations of muscle control takes place during a task that challenges the system (Nudo, 2007). This concept is further supported by studies done on gait rehabilitation in PD (Cakit, Saracoglu, Genc, Erdem & Inan, 2007; Fisher et al., 2008; Herman, Giladi, Gruendlinger & Hausdroff, 2007; Miyani et al., 2002; Petzinger et al., 2010). All of these studies used treadmill training, which involves mastery of walking with increasing levels of difficulties and allowing the patient with PD to have more awareness and control over the task (Herman et al., 2007). Post-treadmill training in PD revealed not only increased gait speed, cadence, step-stride distance, balance, and hip and ankle joint excursion but also increased corticomotor excitability (Fisher et al., 2008) and cortical reorganisation in the motor areas (Miyani et al., 2002). This may suggest that treadmill training in PD may induce neuroplasticity (Herman, Giladi & Hausdroff, 2008). This finding is not surprising given the fact that novel task-specific learning, which takes during skill learning, have been shown to result in cortical changes (Bayona, Bitensky, Salter & Teasell, 2005).

The literature suggests that adaptive changes occur in the central nervous system following skill training. These include changes in the area of motor representation (Karni et al., 1995), increased synaptogenesis and intracortical connections (Adkins et al., 2006; Kleim et al., 2002; Kleim, Monfills & Plautz, 2005). These cortical areal expansions are shown to parallel improvements in motor performance (Nudo, Plautz, Frost, 2001). However, just mere repetition of motor activity alone does not cause changes in the cortical representation, instead functional reorganisation of cortex occurs when there is task-oriented skill motor learning (Plautz, Milliken & Nudo, 2000) . Moreover, evidence from several studies revealed that functional reorganisation of cortex occurs when there is take-oriented skill motor learning (Kleim et al., 2000; Plautz et al., 1999). This has a significant implication on designing and conducting treatment. The ultimate goal of swallowing rehabilitation is to have the patients swallowing ability to return to as near normal as possible (Langmore, 2001). Therefore, a treatment approach such as skill training may result in permanent neural changes and be maintained.

Cortical changes, such as synaptogensis and reorganisation, have been associated with relearning of motor skills and functional recovery following damage to the cortex (Buonomano & Merzenich, 1998; Duffau, 2006). These cortical changes compensate for the damaged areas by modifying neural networks through plasticity (Nudo, 2003). Hence, skill training approach may be more appropriate for patients with neurogenic impairments as it may mimic the biological recovery. Similarly in the swallowing literature, Hamdy et al. (1996) reported that during spontaneous recovery of swallowing there was an increase in the cortical excitability of the undamaged hemisphere or a shifting of cortical representation for swallowing. Therefore, any future therapies targeted at improving swallowing recovery should be aimed at influencing reorganization of the cortex (Hamdy, Rothwell, Aziz & Thompson, 2000). This is further supported by Buonomano and Merzenich (1998) and Duffau (2006) who reported that plasticity can be influenced from environmental and rehabilitative inputs. Evidence from several studies, support the notion that intensive rehabilitation training is able to produce experience-dependent recovery of motor function (Liepert, Bauder, Miltner, Taub & Weiller, 2000; Mark & Taub, 2004). Therefore, it can be postulated that a task-specific treatment regime which provides adequate load (challenge/increasing levels of difficulty) may bring about optimal swallowing rehabilitation (Burkhead et al., 2007). Thus, traditional swallowing techniques like effortful swallow, Masako and Mendelsohn (task-specific) manoeuvres, when used differently or used with a challenge may introduce a skill component to swallowing.

2.7.2 Biofeedback in rehabilitation

No study has evaluated skill training in the context of swallowing. Moreover, none have examined the effects of skill training in individuals with dysphagia secondary to PD. Work from several studies provides support for improvements in swallowing when sEMG biofeedback was used with existing treatments (Bryant, 1991; Crary, 1995; Crary, Caranaby Mann, Groher & Helseth, 2004; Huckabee & Cannito, 1999). As mentioned previously skill learning may occur when the system is challenged or different/difficult-to- perform tasks are introduced. Therefore, traditional swallowing techniques like effortful swallow, tongue-hold, and Mendelsohn manoeuvres when paired with sEMG biofeedback may introduce a skill component to swallowing.

Biofeedback is a technique which immediately indicates to the individual the internal physiological events that are taking place either in the form of a visual or auditory modality (Basmajian, 1989). It allows the individual to gain voluntary control over the physiological activities (Olson, 1995) by making the abstract motor behaviour into a more concrete concept (Barofsky, 1995). Biofeedback modalities are used in several other fields, such as physical rehabilitation (e.g., gait training) (Nelson, 2007), psychology (e.g., anxiety disorders) (Moore, 2000), medicine (e.g., urinary incontinence) (Burgio, et al., 1998) and speech language therapy (e.g. stuttering, dysarthria and dysphagia) (Bryant, 1991; Craig & Cleary, 1982; Crary, 1995; Rubow & Swift, 1985). Biofeedback may provide valuable information to the patient which otherwise cannot be provided due to the difficulty of directly observing the small muscles in the mouth, throat, and neck region involved in swallowing (Nelson, 2007). Ultrasound, endoscopy, oxygen saturation, auscultation, and sEMG are some of the biofeedback modalities used in dysphagia rehabilitation (Huckabee & Pelletier, 1998). Out of these, sEMG is used frequently. EMG measures the electrical activity of muscles, specifically the duration and amplitude of muscle activation and gives immediate visualisation of these features of movement (Crary & Groher, 2000).

Biofeedback has proven to be more effective during learning of novel and/or different tasks (Mulder & Hulstyn, 1984). Wolf and Binder-Macleod (1989) postulated three possible mechanisms involved in augmentation of motor learning with the use of biofeedback. First, they state that it could be due to an over-ride effect, where information may activate the somatosensory cortex by entering at a level higher than the level of damage. The second mechanism involves bypassing, in which an appropriate motor-sensory feed-forward system is established via the brainstem motor nuclei. The third possibility is that previously unused central synapses maybe activated by visual and auditory feedback enabling execution of the motor command. Following continuous biofeedback training, the patient becomes less reliant on the external feedback and relies more on intrinsic feedback (Wolf, 1994), such as “sensory information provided by joints, skin receptors, and the visual and auditory systems of the individual during a movement” (Tse & Spaulding, 1998, p.28). Therefore, for patients with inadequate proprioception, biofeedback may provide an alternative form of sensory input, allowing the individual to re-calibrate the movement and understand the movement pattern (Wolf, 1994). Apart from being able to judge and modify the performance, biofeedback allows patients to monitor their progress and maintain focus (Basmajian, 1989). In short, biofeedback takes the emphasis off the therapist and empowers the patient to take a more active role in the recovery leading to efficient mastering of the task. Since biofeedback facilitates the learning of controlling individual muscles/physiologic activities at a cognitive level, it may also increase the individual’s awareness of complex motor tasks, such as, swallowing (Fitzgerald, Huckabee, Lin, Coombes & Bryant, 2004). Even though there are no published studies documenting enhancement of cortical activity with biofeedback, it can be speculated that biofeedback training facilitates cortical activity and results in better motor planning and control of movement. However, this concept needs to be investigated.

Despite the need for biofeedback during motor skill learning (Mulder & Hulstyn, 1984; Wolf, 1994), motor relearning which occurs after a neuromuscular insult, is considered to be different from initial learning of the task (Fitzgerald et al., 2004). However, this view has been opposed by Mulder and Hulstyn (1984), suggesting that after injury individuals need to learn a new/different task in order to gain voluntary control over muscles/functions that were not previously impaired/lost. Hence, it can be inferred that novel motor learning may take place following a neurological insult and that the learning may be augmented with biofeedback. Similarly, in the context of swallowing following a neurological injury, the movement pattern of swallowing may become an unfamiliar/new task to the patient, thus requiring the individual to learn and gain voluntary control over swallowing activity (Crary & Groher, 2000). Furthermore, Crary et al. (2004) stated that biofeedback may augment the rate of motor learning and enhance functional outcomes in chronic dysphagic patients. Also, it is reported that biofeedback can improve neuromuscular strength and coordination of swallowing muscles (Crary & Groher, 2000).

Biofeedback for muscle relaxation is also commonly used in patients with spasticity (Basmajian, 1989). Biofeedback inhibits abnormal antagonistic muscle synergies resulting in an increased range of movement and efficient recruitment of muscle fibres (Basmajian, 1989). Despite the many applications and benefits of biofeedback, the use of biofeedback in swallowing rehabilitation for PD has not been investigated, other than in a case report which revealed improvements in swallowing of a patient with PD when biofeedback was used for muscle relaxation (Huckabee & Pelletier, 1998).

Biofeedback can be used to introduce a challenge component to the task. This can be achieved by adjusting the parameters on the device and so as to offer more difficult goals, which challenge the system resulting in skill learning. Therefore, it can be postulated that sEMG biofeedback with a novel swallowing task, which provides increasing levels of difficulty (challenge), might result in skill learning. Several case series studies of dysphagic patients secondary to head and neck cancer, brainstem injuries, and cortical stroke have documented functional improvements in swallowing using sEMG biofeedback as an adjunct treatment modality (Bryant, 1991; Crary, 1995; Crary et al., 2004; Huckabee & Cannito, 1998). Following an intensive course of strength-training swallowing treatments (effortful and/or Mendelsohn) paired with sEMG biofeedback, these researchers documented significant improvements in diet levels of patients with severe pharyngeal phase dysphagia. Additionally, Huckabee and Cannito (1999) reported improved pulmonary functions in six out of the 10 dysphagic patients secondary to brainstem stroke sample.

Despite the reported improvements, these studies have several limitations. The Crary (1995) study did not use videofluoroscopy to objectively evaluate patients post-treatment. Hence, it is unclear whether the improvements reported were due to a change in biomechanics or due to compensatory techniques developed over the course of treatment. However, Huckabee and Cannito (1999) study sort to this limitation by conducting pre and post-treatment videofluoroscopy. Also, they controlled the duration and frequency of treatment given to the patients and duration from the post-treatment until when the feeding tubes were removed. In spite of these strengths in the Huckabee and Cannito (1999) study, the time post-onset of dysphagia differed substantially between patients (8-84 months). In addition, the small sample sizes in all the aforementioned studies fail to provide adequate statistical support for evidence-based practice. Another study conducted by Reddy et al. (2000) on five acute dysphagic patients with different aetiologies was treated with computerised biofeedback using dynamic acceleration measurements. Improvements in swallowing were reported in all five patients post-treatment. However, this study comprised of acute patients, who were treated several days/weeks post onset and hence, it is unclear whether these improvements were a result of spontaneous recovery or due to the effect of biofeedback (Reddy et al., 2000).

Despite the significant improvements reported in the above studies, several questions remain unclear: were these improvements a result of strength training and/or due to the intensity of the treatment protocol and/or an effect of increased peripheral muscle recruitment (skill in swallowing) or a combination of all three? Unfortunately, most studies conducted on sEMG biofeedback as an adjunct treatment tool were retrospective (Crary et al., 2004) or methodologically limited as mentioned above. Even though there is great potential in implementing biofeedback for swallowing rehabilitation, its efficacy needs to be further validated by experimental studies containing larger sample sizes with randomised controlled trials.

2.8 Conclusion

In summary, based on the literature appraised above, current swallowing rehabilitation has focused primarily on strength training. However, this approach may not be appropriate for dysphagic patients secondary to PD. Most of the oral and oral-preparatory symptoms in PD result from muscle rigidity and/or bradykinesia (Johnston et al., 1995; Robbins et al., 1986). Strength training for rigidity has been postulated by Clark (2003) to cause further distress and reduce the range of motion and therefore may be contraindicated. Likewise, strengthening the oropharyngeal muscles for dysphagia symptoms resulting from bradykinesia (slowness of movement) could be ineffective. Additionally, a treatment approach which focuses on enhancing neural changes may be more beneficial, as PD manifests pre-dominantly from sub-cortical changes rather than peripheral myogenic changes. Therefore, it is logical to shift the focus of treatment of dysphagia for this cohort from strength training towards skill training, which will enhance neuromuscular coordination, precision, timing, speed of reaction and planning of motor movements. As reviewed above, central neural adaptations occur during a repetitive goal-oriented skilled task (Adkins et al., 2006; Karni et al., 1995; Kleim et al., 2002; Kleim et al., 2005) which results in permanent functional changes (Kleim et al., 2000; Plautz et al., 1999). Likewise, swallowing treatment should be aimed at influencing neural changes (Hamdy et al., 2000). Following an injury, many of the neural mechanisms associated with skill training have been reported to take place during the recovery process (Buonomano & Merzenich 1998; Duffau 2006; Nudo, 2003). This is further supported by the evidence that neural plasticity can be influenced by environmental and rehabilitative inputs (Buonomano & Merzenich, 1998; Duffau, 2006). Since there were cortical changes associated with skill training in the limb literature, it can be hypothesised that a skill training rehabilitation paradigm in the context of swallowing for patients with PD will result in similar permanent functional changes. However, a question to keep in mind is: will training paradigms used for limbs have a similar effect on swallowing, which in some stages is brainstem controlled?

2.9 Questions and Hypotheses

Question 1: What are the effects of skill training for swallowing rehabilitation in individuals with dysphagia secondary to PD?

Hypothesis 1: Skill training will result in significant improvements to swallowing function of patients with dysphagia secondary to PD on one or more of the outcome measures in the timed water swallow test, TOMASS, surface EMG, ultrasound, and SWAL-QOL.

Hypothesis 1a: In the timed water swallow test (Hughes & Wiles, 1996) the average time per swallow will reduce, total volume per swallow will increase, and swallowing capacity will increase.

Rationale: The timed water swallow evaluates the swallowing efficiency for liquids and provides valuable information regarding the sequential swallowing abilities (Hughes & Wiles, 1996). Several studies have shown that on timed continuous water drinking tasks (100 ml, 150 ml, 200 ml) dysphagic patients with PD demonstrated reduced swallowing speed, increased number of swallows, reduced swallowing capacity, reduced bolus volume and longer duration per swallow when compared to healthy controls (Aydogdu, Tanriverdi &

Ertekin, 2010; Miller et al., 2009; Nilsson, Ekberg, Olsson & Hindfelt, 1996). Similarly, three out of the five patients with PD in Nathadwarawala, McGroary and Wiles (1994) sample were reported as "abnormal" on the 150 ml timed water swallow test. In addition, Van Lieshout, Steele and Lang (2011, p.1728) found "shorter durations and smaller [tongue] movement amplitudes" in PD patients during sequential swallowing when compared to age-matched controls.

Evidence from limb literature on gait training in individuals with PD using skill training has shown significant improvements in gait speed, cadence, step-stride distance, hip and ankle joint excursion and improved weight distribution during sit to stand (e.g., Fisher et al., 2008; Petzinger et al., 2010). Improvements in these gait parameters were attributed to increased speed, timing, ROM and neuromuscular coordination of movement patterns following skill training. Taking inference from these studies it is anticipated that skill training will increase neuromuscular coordination, speed, ROM and timing of swallowing movements. This will thereby improve the aforementioned measures in the timed water swallow test, which would be indicative of improved efficiency for swallowing liquids.

Hypothesis 1b: In the Test of Mastication and Swallowing of Solids (TOMASS), the average time per bolus will reduce, the number of swallows per bolus will increase, and the number of chewing cycles per bolus will increase.

Rationale: TOMASS is based on the timed water swallow test (Hughes & Wiles, 1996) and was developed specifically for this research project to assess the efficiency of swallowing for solids. Similar to the parameters on the timed water swallow test, skill training is expected to improve the above mentioned measures on the TOMASS. This is due to improved neuromuscular coordination, precision, speed of reaction, timing and planning of motor movements enhanced with the skill training approach. Inference from Fisher et al. (2008) and Petzinger et al. (2010) studies in limb literature in PD population provide support for this hypothesis.

Hypothesis 1c: The pre-motor time of swallowing, pre-swallow time of swallowing, and duration of submental muscle contraction will reduce as measured by surface EMG.

Rationale (pre-motor time): Reaction time has been fractionated into two sub-components using sEMG: pre-motor time (PMT) and motor time (Rose, 1997). PMT is indicative of the central or cognitive processing component of reaction time and represents the time taken to receive and process the sensory stimuli, develop a motor plan and transfer it to the relevant muscles (Rose, 1997). PMT is prolonged in patients with PD compared to healthy controls, as documented in swallowing and limb literature (Nagaya et al., 2000; Pullman et al., 1988; Sheridan et al., 1987; Yokochi et al., 1985). Furthermore, practice can decrease PMT and overall RT in these patients (Behrman, Cauraugh & Light, 2000; Rostami et al., 2009). Study by Nagaya et al. (2000) revealed that after a single session of swallowing training PMT significantly reduced and swallowing performance improved in PD. Hence, it can be inferred that swallowing skill training will reduce premotor time of swallowing due to increased neuromuscular coordination, timing, speed or reaction and planning of movement. Additionally, improved cognitive preparation and increased attention may improve initiation of swallowing. Moreover, this might subsequently improve the timing of the initiation of the pharyngeal swallowing.

Rationale (pre-swallow time): Motor time is the second sub-component of reaction time (as described above). This indicates the peripheral component of reaction time and reflects the neuromuscular and physiological processes involved in initiating and executing the movement (Behrman et al., 2000). In the context of swallowing, motor time can be referred to as pre-swallow time (PST). PST is indicative of the motor component of reaction time, evaluates initiation of swallowing specific movement and provides valuable information regarding the oral phase of swallowing. A limitation of Nagaya et al.'s (2000) study was that they had not assessed pre-swallow time (PST). Furthermore, no study has evaluated PST in the context of swallowing in PD. Therefore, to fill the gap in literature PST was assessed. Similar to PMT, PST will decrease due to improved neuromuscular coordination, speed of reaction, timing and planning of motor movement. Inference for this is supported by limb rehabilitation studies in PD (e.g., Fisher et al., 2008; Petzinger et al., 2010).

Rationale (duration of submental muscle contraction): Surface EMG can be used to measure the amplitude and the duration (onset and offset) of the of the submental muscle contractions during swallowing (Vaiman, Eviatar, & Segal, 2004a, 2004b). Surface

EMG amplitude and duration parameters in the context of swallowing have not been studied in PD patients. However, normative data for sEMG provided by Vaiman et al. (2004a), (2004b) suggested longer sEMG durations for single "normal" swallows in elderly individuals (70+). Furthermore, several studies have reported longer oral and pharyngeal durations in PD (Stroudley & Walsh, 1991). Hence, it can be inferred that sEMG durations of submental muscle contraction will be longer in these individuals. However, since skill training produced significant improvements in gait parameters in PD (e.g., Fisher et al., 2008; Petzinger et al., 2010), skill training in the context of swallowing is anticipated to improve neuromuscular coordination, speed of reaction, timing, ROM and planning of motor movements. Additionally, quicker muscle contraction will take place due to changes in the brain activity that results in faster recruitment of neurons. All of this will result in a decrease of the duration of the submental muscle contraction.

Hypothesis 1d: The displacement of hyoid bone will increase, but the cross-sectional area of submental muscles, namely geniohyoid and anterior belly of digastric, as recorded by ultrasound, will *not* change after skill training.

Rationale (movement of hyoid bone): Drawing inferences from limb rehabilitation studies skill training in the context of swallowing is anticipated to improve neuromuscular coordination, speed of reaction, timing and planning of motor movements. Inhibition of co-activation of antagonistic muscle contraction will result in more efficient range of movement, resulting in greater hyoid bone movement. Additionally, quicker muscle contraction will take place due to changes in the brain activity that results in faster recruitment of neurons. All of these factors may result in an increase in the displacement of hyoid bone movement.

Rationale (cross sectional area): Strength training brings about changes pre-dominantly at the muscular level, such as fibre type shifts, and hypertrophy (Folland & Williams, 2007; Moritani, 1993). Hypertrophy or enlargement of the muscle fibres can result in an increase in the cross- sectional area of the muscle undergoing the training. This is evident from Narici, Roi, Landoni, Minetti and Cerretelli (1989)'s study on human quadriceps with strength training. Similar findings were gained in Robbins et al. (2005)'s study on tongue muscles following strength training. This same inference can be made with respect to geniohyoid and anterior belly of digastric muscles with strength training. However, skill training brings about changes predominantly at the cortical and subcortical levels

(Remple et al., 2001) and does not result in hypertrophy. Hence, the cross-sectional area of these muscles will not change with skill training.

Hypothesis 1e: Patient's perception of swallowing problem will change as measured by swallowing quality of life questionnaire (SWAL-QOL).

Rationale: Studies have shown that dysphagia can have a negative impact on the quality of life among individuals with PD (Miller et al., 2006; Plowman-Prine et al., 2009). The SWAL-QOL outcome tool indicates patient's perspective of the swallowing problem (McHorney et al., 2002). A study by Leow et al. (2010) found that patients with PD had significantly reduced SWAL-QOL scores, confirming that dysphagia adversely affected the quality of life in patients with PD. Patients with PD are reported to have poor perception about their swallowing problem (Bird et al., 1994). Hence, swallowing related questionnaires such as SWAL-QOL, which investigates the patient's perception of the swallowing problem, may be underscored or over scored depending upon patient's self-awareness of the disorder.

Question 2: Will the changes that take place following skill training remain in the absence of therapy?

Hypothesis 2: Improvement in swallowing following skill training will not decline at two weeks post-treatment.

Rationale: Detraining following strength training has been evidenced in the swallowing literature (Baker et al., 2005; Clark et al., 2009). However, evidence from neuroscience literature has documented that the cortical reorganisations that occur following skill training remains even when practice is discontinued (Kleim et al., 2000; Plautz et al., 1999). Therefore, the biomechanical changes that are anticipated to take place following skill training will remain during the retention period, at the same level/values as at post-treatment, despite termination of treatment.

Overall Significance:

Skill training will promote safe and efficient swallowing in patients with dysphagia secondary to PD by:

1. Improving swallowing efficiency for liquids, leading to fewer aspirations and silent aspiration events and, in turn, improved pulmonary status.
2. Reducing possibility of dehydration by increased volumes of liquid intake.
3. Improving swallowing efficiency for solids, leading to fewer aspirations and silent aspirations and in turn, improved pulmonary status. Increased intake of solids will also help prevent malnourishment and weight loss.
4. Improving cognitive aspects such as awareness, attention, and conscious control of swallowing movements will help patients be more sensitive to their problems and seek early swallowing intervention when required instead of waiting for the dysphagia to progress.

In addition, skill training leading to long-term improvements in functional swallowing in patients with PD is likely to reduce patient admissions and, hence, lead to low health care costs for subsequent patient management.

Chapter 3. Methodology

3.1 Participants

Ten patients with Parkinson's disease (mean age of 67.4 years), comprising three females (mean age of 64.6 years) with a mean post-onset of PD (8.3 years), and seven males (mean age of 68.5 years) with a mean post-onset of (5.8 years) were recruited for the study. Patients were recruited from the Van der Veer clinic, New Zealand Brain Research Institute database, The Parkinsonism Society of New Zealand, and Canterbury District Health Board (CDHB) hospitals. Additionally, an advertisement (Appendix A) was put in the monthly newsletter of the Parkinsonism Society of New Zealand for recruitment. Prior to recruitment, ethics approval was obtained from the Upper South B Regional Ethics Committee. Each recruitment centre was provided with the Eating Assessment Tool (EAT – 10) (Belafsky et al., 2008) (Appendix B) to be given to their patients with PD to complete and return to the respective centres. Patients who identified themselves as having swallowing difficulties due to Parkinson's disease were contacted and invited to undergo a clinical swallowing assessment at the Swallowing Rehabilitation Research Laboratory in the New Zealand Brain Research Institute.

Inclusionary criteria for this study included any patients who had been diagnosed by a neurologist as having PD, who complained of having swallowing difficulties for at least 3 months or more and who was identified as having dysphagia on clinical swallowing evaluation. Patients who reported having a history of dementia, stroke, head and/or neck injury/surgery, muscular disease (e.g., muscular atrophy) and who had Parkinsonism signs that were caused due to Multiple System Atrophy (MSA), Progressive Supranuclear Palsy (PSP) and side effects of medications (e.g., some antipsychotics) did not undergo clinical swallowing evaluation and were excluded from the study (Appendix C).

Patients who met the inclusionary criteria, identified as having dysphagia on the clinical swallowing assessment and who were interested in participating in the study were provided and/or mailed an information sheet (Appendix D) for review. Additionally all patients were given verbal information regarding the nature and scope of the project. Those patients who consented to participate in the study were given an appointment at the Swallowing

Rehabilitation Research Laboratory. Participation was voluntary and consent (Appendix E) from each participant was obtained prior to commencement. Some key characteristics on each of the patients are shown in Table 3-1.

Table 3-1. Patient characteristics

Patient ID	Age/ Sex	Onset of PD (diagnosed)	Other medical conditions	Onset of dysphagia	Complaints
RN84	84/M	5-6 years	Depression, on anticoagulants - for? heart condition	3 years	Coughs on food/liquid, takes longer time to chew, food sticking in throat & mouth, drooling
JC76	76/M	10 years	High blood pressure, foot neuroma, skin carcinoma, on anticoagulants for arterial blockage	3 years	Loss of weight, difficulty swallowing pills, longer time to chew, food sticking on mouth/throat
PD71	71/F	16 years	Arthritis, high blood pressure, ptosis of both eyes,	9-10 months	Difficulty swallowing solids>liquids, coughs on food/liquid daily, food sticking in mouth and throat, uses straw to drink liquid
RW69	69/M	6-7 years	Scoliosis	2-3 years	Coughs on liquid/food, drooling, food sticking in mouth/throat
JT66	66/M	2 years	High blood pressure, on anticoagulants - ? heart condition	10-11 months	Coughs on food/liquid, food sticking in mouth/throat

LB66	66/F	5-6 years	Osteoarthritis, polymyalgia, depression, small hiatus hernia	1year	Coughs on food/liquid, food sticking in mouth/throat, drinks a lot of thickened liquid, struggle to swallow, pain while swallowing
DC67	67/M	5 years	Cholesterol, diabetes, asthma, on anticoagulants	6-7 months	Difficulty swallowing pills, cough on liquid, solids>liquid
JN64	64/M	4 years	H/o Prostate cancer, High blood pressure, cholesterol	2 years	Food sticking in mouth/throat, difficulty swallowing pills, coughs on liquid>solids, drooling
SR57	57/F	3 years	Diabetes- II, cholesterol, osteopenia	3 years	Loss of weight, longer time to chew-eating un pleasurable, uses bottle/straw, swallowing solids>liquid
PS54	54/M	6-7 years	High blood pressure, cholesterol, H/o heart attack, depression	2 years	Food sticking in mouth/throat, needs to swallow hard

Additionally, four patients were diagnosed with Mild Cognitive Impairment (MCI) (SR57, JC76, JN64 and?RN84). Three patients had an unexpected change of medication during the experimental period: PS54 (pre-treatment), LB66 (treatment), and JC76 (post-treatment).

3.2 Procedures

All subjects underwent an initial clinical swallowing assessment session (baseline-1). Patients who were identified as having dysphagia within any phase of swallowing on this clinical swallowing assessment, who met the inclusionary criteria, and gave consent to take part in the study underwent a second baseline session two weeks from the initial assessment. The Unified Parkinson’s Disease Rating Scale developed by the Movement Disorders Society (MDS-UPDRS) (Goetz et al., 2008) was administered during the second baseline session for each participant. This was conducted to identify the disease severity/stage of PD. Thereafter, each patient received 10 skill training therapy sessions conducted over a two week period, using sEMG with custom-designed BiSSkiT software (Biofeedback in Swallowing Skill Training) (Han, 2009) as a biofeedback modality. The first post-therapy/outcome session was conducted after the final therapy session. Finally, the second post-therapy session was conducted two weeks from the last day of therapy to evaluate skill retention. Each subject attended a total of 14 laboratory sessions, which were carried out over a six week period. All assessments and treatments were completed during the “On” phase of patient’s medication, scheduled around the time of their best performance, and generally within one hour of their last dose of medication. Figure 3-1 presents a flow chart of the structure of the study.

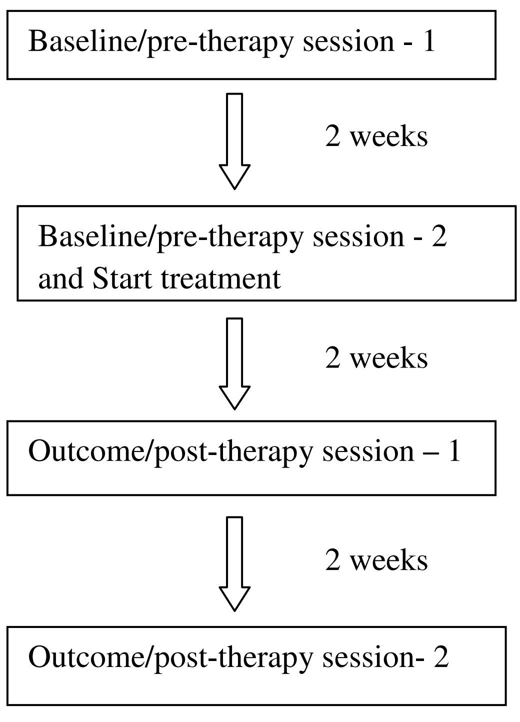

Figure 3-1. Overview of structure of the study

3.3 Assessment Procedures

During each baseline session and outcome session the following tests were conducted:

- Timed water swallow test (Hughes & Wiles, 1996)
- Test of Mastication and Swallowing of Solids (TOMASS)
- Surface Electromyography (sEMG)
- Ultrasound
- Swallowing related quality of life questionnaire (SWAL-QOL)

3.3.1 Timed water swallow test

This normed and validated clinical swallowing assessment (Hughes & Wiles, 1996) provides both quantitative and qualitative information regarding swallowing efficiency for liquids (Daniels & Huckabee, 2008). Quantitative observations include measures of volume consumed, time taken and number of swallows. Qualitative observations may include voice quality, coughing, breathlessness, and number of pauses. For this test, patients were seated comfortably on a chair and instructed to drink 150 ml of water from a plastic cup. The instructions given were: "[When you hear the 'go' signal drink this cup of water] as quickly and comfortably as possible" (Hughes & Wiles, 1996, p. 110). The go signal was given to the patients to avoid the confusion of when to begin drinking. Participants were observed from the side (Hughes & Wiles, 1996) and the complete test was video recorded to facilitate inter-intra rater reliability assessment.

3.3.2 Test of Mastication and Swallowing of Solids (TOMASS)

There is currently no validated and normed test of swallowing efficiency for solids. Therefore, based on the 150 ml water swallow test, the TOMASS was developed for this project at our research lab. At present, further research is underway to assess TOMASS's validity and reliability before it is used as a clinical bedside evaluation tool. Patients were seated comfortably on a chair facing away from the computer monitor. This was done to prevent any form of visual feedback to the patient, which could have biased data collection. Male patients were instructed to attend all sessions clean shaven under the chin and jaw areas.

When asked, six out of the 10 patients identified the left side as their preferred chewing side while the remaining reported that they habitually chewed bilaterally. Hence, to keep the recording site constant for all subjects, the left masseter was used as the recording site for sEMG. The skin surface overlying the left masseter muscle was cleansed using an alcohol swab. The masseter muscle was identified by palpation when asking the patient to "bite hard". A triode patch electrode (Thought Technology Triode ^{TM}) was placed, with active electrodes in line with the masseter muscle (Figure 3-2 & 3-3). The electrode patch was placed firmly on the skin to provide good contact between the skin surface and the electrodes. Surface EMG data were recorded during mastication using Kay Swallowing Signals Lab (Model 7120) which interfaced with the Digital Swallowing Workstation (DSW) Model 7200 (Kay Elemetrics Corp., Lincoln Park, NJ). The raw signal was amplified to 5 V, bandpass filtered between 50 Hz and 220 Hz, rectified, lowpass filtered at 3 Hz, then digitised at a sampling rate of 250 Hz.

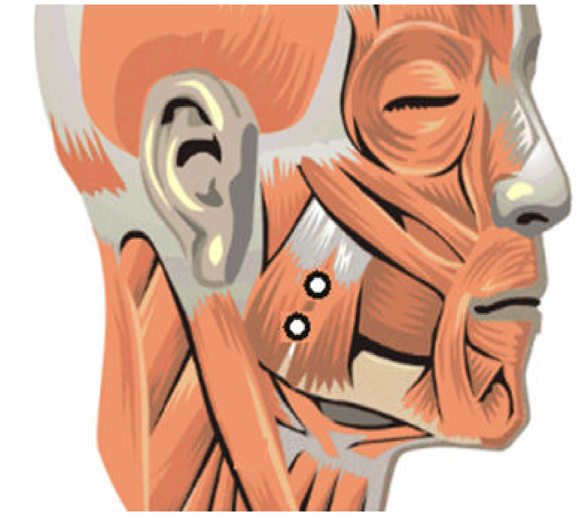

Figure 3-2. Location of the electrodes on the masseter site (Retrieved from Thought Technology Ltd, October, 2008).

Figure 3-3. Placement of triode electrode patch with active electrodes placed in line with the masseter (white leads) and ground electrode oriented 2 cm apart (black lead).

Patients were given a quarter (one portion) of an Arnotts^{TM} Salada cracker to chew using their preferred chewing side. The instructions given were "when you hear the 'go' signal eat this whole biscuit as quickly and as is comfortably possible". All patients were observed from the side and a video recording of the assessment were conducted to enable evaluation of inter-intra rater reliability. Masticatory cycles on observation were later correlated with the sEMG activity associated with chewing.

3.3.3 Submental surface electromyography

To avoid visual feedback, patients were seated comfortably on a chair facing away from the computer monitor. After preparing the skin surface underneath the chin, a triode patch electrode (Thought Technology Triode ^{TM}) was placed midline between the mental spine of the mandible and the superior palpable notch of thyroid cartilage (Figure 3-4). Patients were instructed to carry out five repeated trials of two different types of swallows: saliva swallows and 10 ml water swallows. Performance of swallow types was randomised within and between participants. They were given between 45-60 s to collect saliva for the saliva swallows. The instructions given were "hold water/saliva in your mouth and when you hear the go signal, swallow as quickly as possible". Surface EMG data was recorded as described in section 3.3.2. A red marker/tag was inserted by pressing a pre-determined key on the keyboard while simultaneously saying the "go" command. This tag was inserted to help measure the durational measurements on the sEMG waveform, described later. Prior to recording (during baseline 1 only) the patients was allowed one practice trial of each swallowing task.

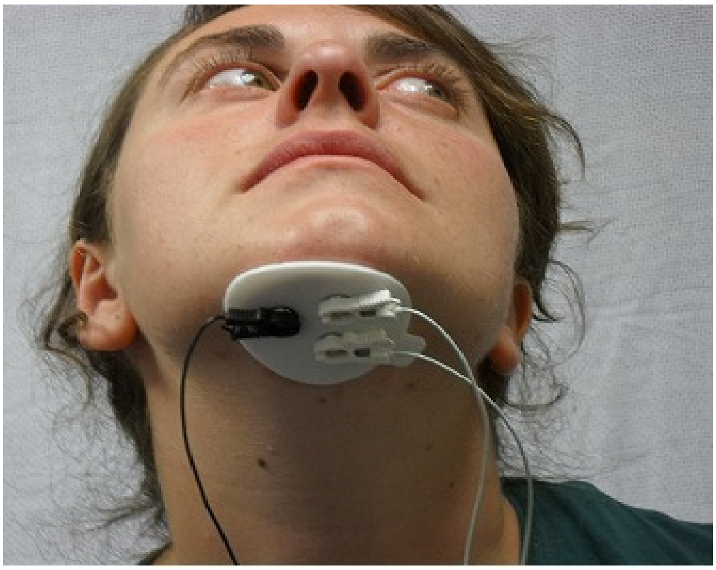

Figure 3-4. Anterior view of electrode placement on the submental area. The triode electrode patch was placed midline between the mental spine of mandible and superior palpable notch of thyroid cartilage.

3.3.4 Ultrasound

A Siemens Acuson Antares (Premium edition) ultrasonography device was used with a 13-5 MHz linear array transducer (Figure 3-5) to obtain cross-sectional area measurements of the submental muscles. Subjects were asked to sit in a comfortable position upright against the back of the chair to control movement (Yabunaka et al., 2011) and remain still as possible during the complete recording period. A generous amount of Aquasonic 100 ultrasound transmission gel (Parker Laboratories, INC, Fairfield, NJ) was put over the linear array transducer which was positioned in the coronal plane overlying the submental muscles. Ultrasound system parameters/settings (depth, frequency, contrast, etc.) were adjusted until a clear image of the target muscles was obtained. Subsequently, the two-dimensional (2D) area of the floor of the mouth muscles (geniohyoid and anterior belly of digastric) at rest was recorded five times. The ultrasound settings were documented for each subject and kept constant within subjects to control intra-individual variability. However, parameters were adjusted accordingly between participants to record the 'best' image.

Figure 3-5. Siemens 13-5 MHz linear array transducer used for coronal measures of the submental muscles

B-mode ultrasound video imaging of the hyoid bone was conducted using a curved 6-2 MHz array transducer (Figure 3-6). All video loops were 10 s in duration and consisted of 150 frames. Patients were seated comfortably and instructed to keep their head in a neutral position. They were asked to 'breathe as you would normally'. This was done to avoid extraneous movements of the larynx which may affect the position of the hyoid (Sonies, Parent, Morrish & Baum, 1988). A generous amount of Aquasonic 100 ultrasound transmission gel covered the curved array transducer. This was placed in the mid-sagittal plane overlying the floor of the mouth muscles with the bony spine of the mandible and the hyoid in frame view. Patients were instructed to perform five single secretion swallows, during which images were recorded. The instructions given were “swallow when you are ready”. Patients were given adequate time (45-60 s) to collect saliva and/or drink water to moisten the mouth as required to produce a swallow. Settings established as optimal for each patient were documented and used for subsequent scans.

Figure 3-6. Siemens 6-2 MHz curved array transducer used for mid-sagittal measures of hyoid bone.

All imaging was conducted free-hand, as previous studies have shown reduced equivalent variability among measurements when measured using a free-hand approach as opposed to a custom-designed head stabilization unit (Winkelman, 2010). Minimal pressure was applied on the submental area during all image recordings to prevent distortion of swallowing movements (Macrae, Doeltgen, Jones & Huckabee, 2012). All images were copied to CDs and imported on to a DICOM viewer (Osirix imaging software, standard 32-bit version) on an Apple Mackintosh computer for off-line data analysis.

3.3.5 Swallowing quality of life questionnaire (SWAL-QOL)

This tool was developed to assess the impact of dysphagia on quality of life (McHorney et al., 2000a; McHorney et al., 2000b). SWAL-QOL contains 44 items which looks at 10 quality of life domains (Apeendix E). These items are rated from one to five and a total SWAL-QOL score can be calculated (McHorney et al., 2002). Low scores are indicative of higher impairment while high scores indicate less or no impact of dysphagia on quality of life. All patients were mailed and/or given this questionnaire in person. They were asked to complete it one day prior to each data collection session (baseline sessions and outcome sessions) and bring it with them on the day of the assessments. Each patient was reminded (phoned/ e-mailed) one day prior to the expected SWAL-QOL completion day.

3.4 Biofeedback treatment device

The treatment was conducted using a sEMG biofeedback device (Myopace, Model NE-1, Niche Technology, 2002) which acted as the hardware platform for the *Biofeedback in Swallowing Skill Training* (BiSSkiT) software (Han, 2009). The sEMG device measured the electrical activity, picked up by the triode electrodes (Thought Technology Triode ™) which were attached to the patient's submental muscles. This electrical activity was rectified, low-pass filtered at 50 Hz, digitised, and sent to the computer via a USB serial port. The BiSSkiT software then processed the data from the EMG device and plotted it in real time as pressure by amplitude waveforms. This was displayed as a visual representation on the computer monitor. Figure 3-7 shows a flow chart of the system.

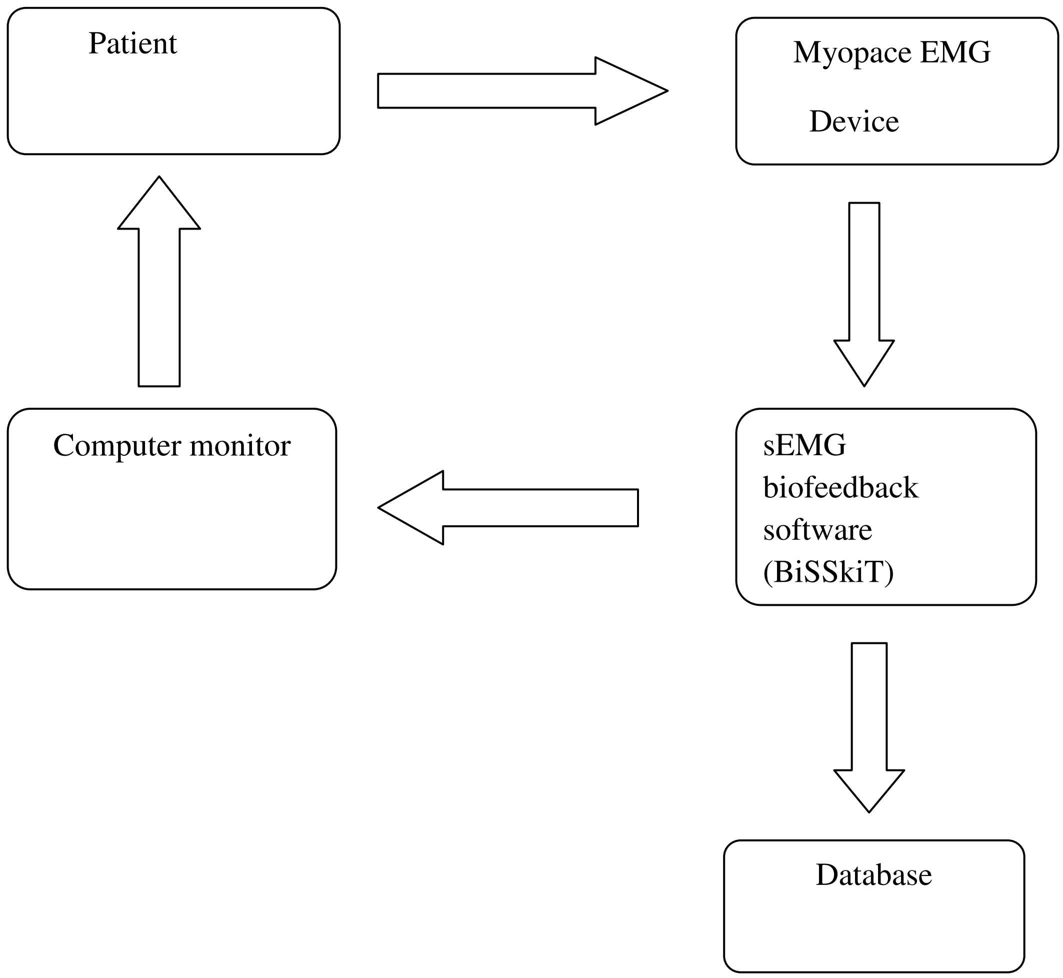

Figure 3-7. Overview of the biofeedback system (From Han, 2009)

The BiSSkiT software was designed to incorporate both a strength training approach (targeting maximal strength) and skill training approach (focusing on precision in sub-maximal muscle contraction during swallowing). However, only the skill training protocol was used for this project, discussed below.

The goal of skill training was to improve the precision of swallowing muscle contraction by developing conscious control over timing and strength of swallowing. Prior to commencing treatment, the software was calibrated such that the range of amplitude achieved by each individual during muscle contraction was optimally represented on the screen. Each participant's optimal swallowing range included a lower and an upper limit. The lower limit was calculated by taking 20% of the average amplitude of five effortful swallows and the upper limit was calculated by taking 70% of the average amplitude of five effortful swallows. Since the focus of this project was on precision/skill training and not strength, sub-maximal 20% and 70% levels were arbitrarily chosen as the lower and upper limits respectively. The swallowing target was a green square, which moved randomly within this amplitude range (20% - 70%) during the session. The target was represented in 2D: amplitude (height) and a duration (width) range. The ratio between the height and the width was fixed (1:1). The initial height of the green square was calculated by taking 50% of the average amplitude of five effortful swallows. Subsequent target sizes varied according to patient's performance. All of the above mentioned calculations were computed automatically by the BiSSkiT software and the green square was displayed on a graph with x and y axis indicating amplitude (microvolts) and time (seconds) respectively. The time scale on the x axis was 30 s, which was kept constant for all sessions. The calibration process was repeated at the beginning of each session for each patient. Figure 3-8 depicts a diagram of the skill training calibration.

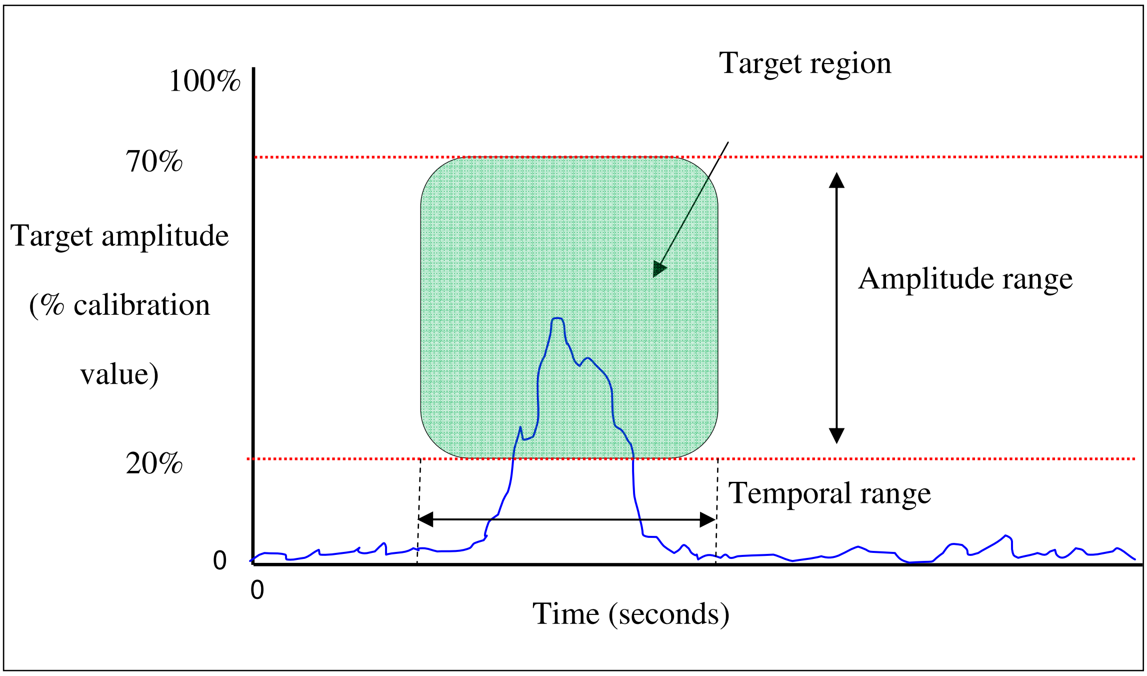

Figure 3-8. Skill training calibration display (From Han, 2009)

Patients were instructed to swallow such that the peak of the sEMG fell within the target area/green square (also referred to as a hit). This required precision of swallowing movements to meet the amplitude and temporal aspects of the target. The skill training protocol involved increasing levels of difficulty and required proficiency of a particular level before moving to the next. After every three consecutive hits, the size of the target/green square reduced in size, thus requiring greater amplitude and temporal precision of swallowing. However, with every three consecutive misses the size of the square became larger. Data from each session were saved to a patient database, which was accessible later for reviewing patient performances.

3.5 Biofeedback treatment procedures

Prior to commencement of therapy, patients were given instructions and rationale supporting the treatment. Next the submental area was cleansed with an alcohol swab and the triode electrode patch was attached in midline underneath the chin, between the mental spine of mandible and superior palpable notch of thyroid cartilage. EMG leads were clipped onto the triode electrode snaps which were connected to the sEMG electrode cable. The electrode cable was attached to the biofeedback device (Myopace, Model NE-1), which was connected to the computer via USB port. Patients were instructed to carry out five hard swallows to calibrate the swallowing range. Thereafter, they were instructed to swallow such that the peak of the waveform would fall within the green square. Participants were informed that the size of the square would reduce after every three consecutive hits and should they miss three in a row, the size would increase. Patients were given verbal feedback by the research clinician at the end of each 20 trials. Additionally, patients were encouraged to comment on their perception of swallowing performance. Figure 3-9 depicts skill training display.

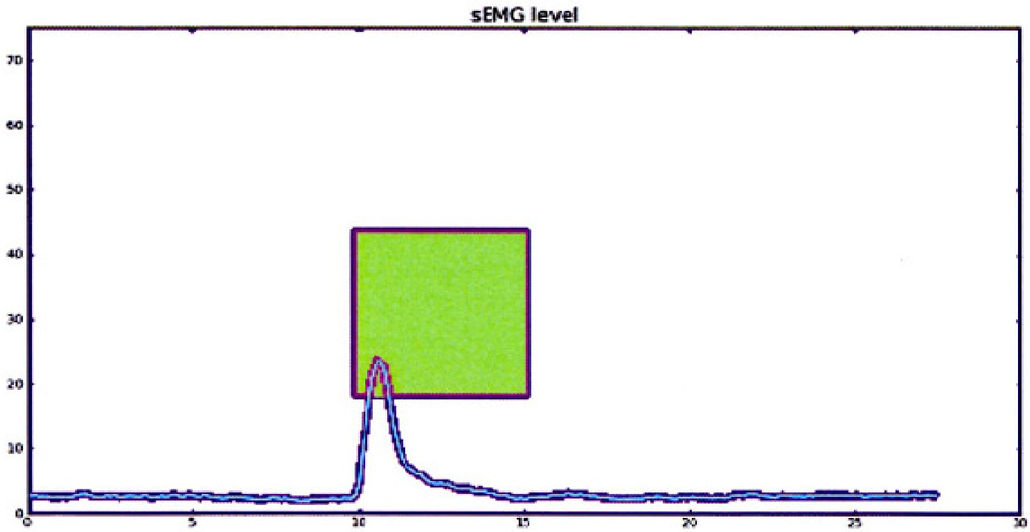

Figure 3-9. Skill training display (swallowing target) on BiSSkiT software (Han, 2009)

This intensive, task-specific treatment protocol was conducted for two weeks (five consecutive days per week). Each session lasted for one hour and consisted of 100 swallowing trials partitioned into five blocks. Each block consisted of 20 swallowing trials, followed by a brief break before the next block was commenced. All swallowing skill training sessions were conducted with saliva/dry swallows. However, each patient was given liquids (e.g., water, tea, coffee, juice etc.) when required, to avoid drying of oral mucosa and to facilitate saliva production.

3.5 Data Extraction

3.5.1 Timed water swallow test

The timed water swallow test was completed as described by Hughes and Wiles (1996). The number of swallows was counted by observing the rise and descent of the thyroid cartilage.

The time taken was measured from the time the water first touched the participant's bottom lip to the larynx returning to its rest position for the last time. The final swallow was determined by other behavioural cues such as mouth opening, phonation, head nod or exhalation. The total volume swallowed was calculated by measuring the remaining water in the cup and subtracting it from the initial amount. The following measures were calculated: time per swallow (T/S), volume per swallow (V/S), and swallowing capacity (V/T).

3.5.2 TOMASS

The number of swallows was counted by observing the rise and descent of the thyroid cartilage. The time taken was measured from the time the subject had their first bite to when the larynx returned to its rest position for the last time. This was determined by other behavioural cues such as, opening mouth, phonation, head nod, or exhalation. The numbers of masticatory cycles were determined by counting the upward and downward movement of the jaw (one cycle). The number of bites was identified by discrete segments of cracker taken to eat the whole.

A single masticatory cycle on sEMG was identified as a robust rhythmic regular upward and downward burst. Since there were irregular cyclic bursts in most patients, a measurement criterion was established to prevent measuring tremor movements (e.g., jaw dyskinesias). The criterion was determined by first selecting a segment of the waveform associated with a complete masticatory cycle and calculating the average amplitude (Figure 3-10). A horizontal cursor was then placed on this value. EMG peaks which fell below the horizontal cursor were excluded while rhythmic regular bursts which fell above were counted as masticatory cycles (Figure 3-11).

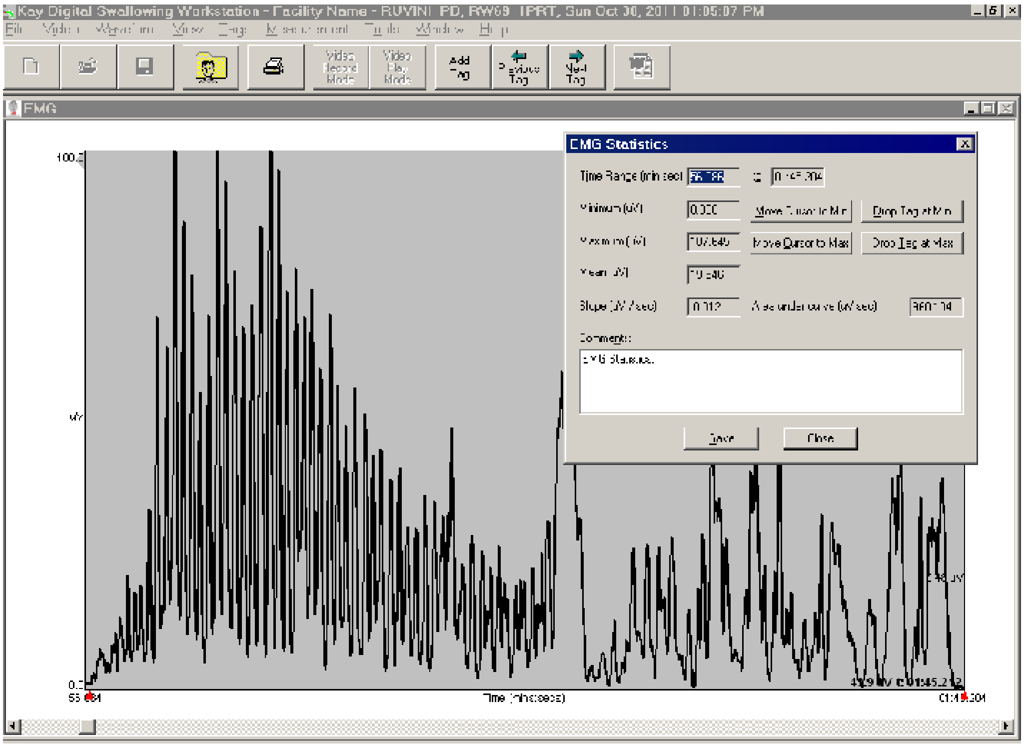

Figure 3-10. Calculation of the average amplitude of the chewing cycle. The first red tag depicts the "start" while the last indicates the "end" of mastication.

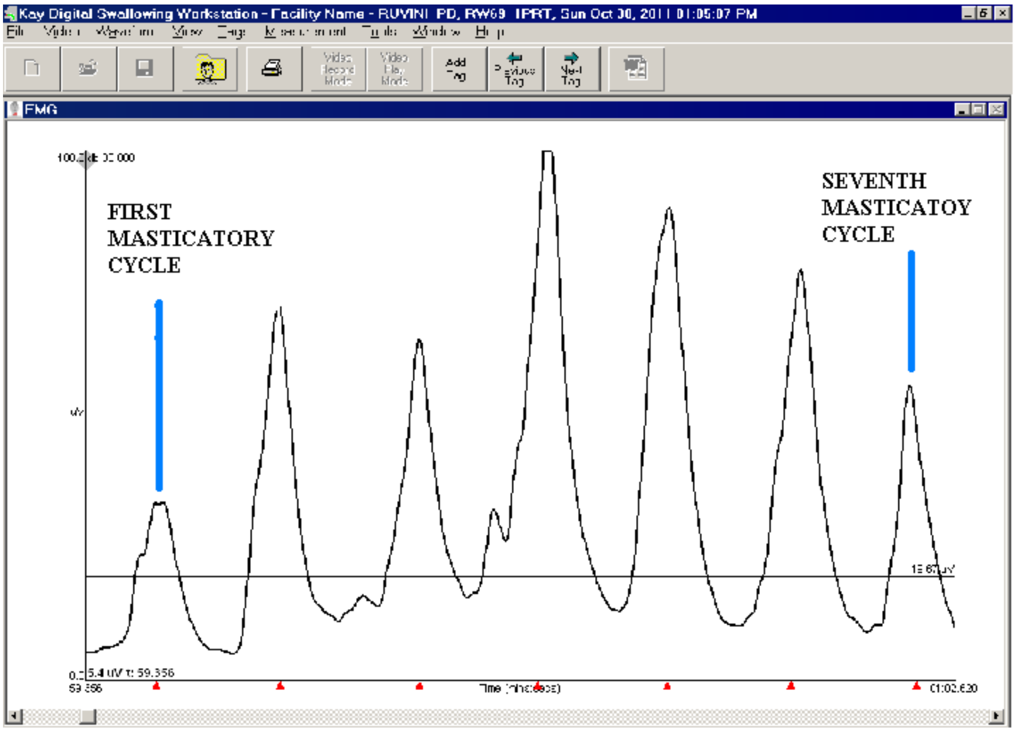

Figure 3-11. Masticatory cycles on sEMG.

3.5.3 Ultrasound

Movement of the hyoid bone was calculated as the percentage change in the distance between the mentalis of mandible and hyoid bone from rest to maximal swallowing contraction (Macrae et al., 2012). The reference point was defined as the “point at which the shadow cast by the spine of the mandible intersected with the brightly echogenic cortical surface of the mandibular bone” (Macrae et al., 2012, p. 76) as shown in figures 3-12A & 3-13A. The hyoid point was identified as the “point at which the shadow cast by the hyoid intersected with the geniohyoid muscle” (Macrae et al., 2012, p. 76) as shown by figures 3-12B & 3-12B. “A rest frame prior to any oral movements [...] and a maximal displacement frame, at which the hyoid bone was at maximal anterior displacement during each swallow’’ were identified. (Macrae et al., 2012, p. 76). The length between reference to rest and reference to maximal displacement positions were measured using electronic callipers on the Osirix imaging software.

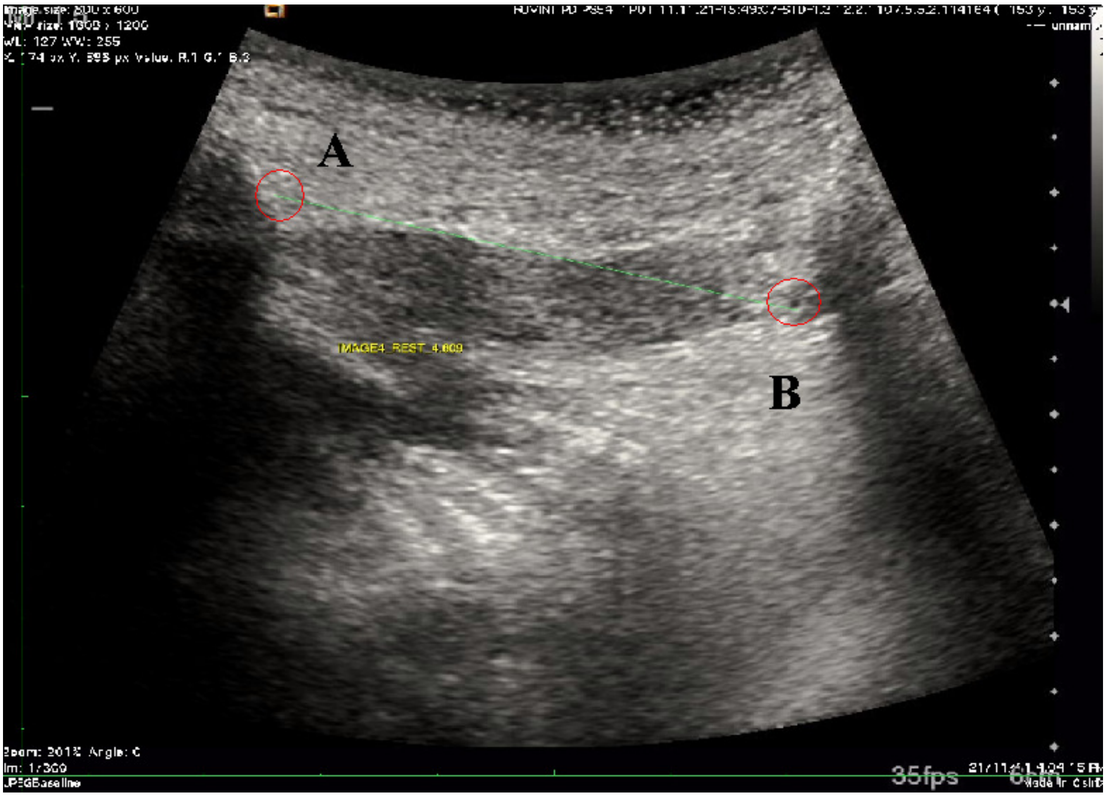

Figure 3-12. B mode ultrasound image of the hyoid and spine of mandible distance at rest. Electronic calipers mark the points at which the distance between mental spine of mandible shadow (A) and the intersection of the hyoid shadow with the geniohyoid muscle (B).

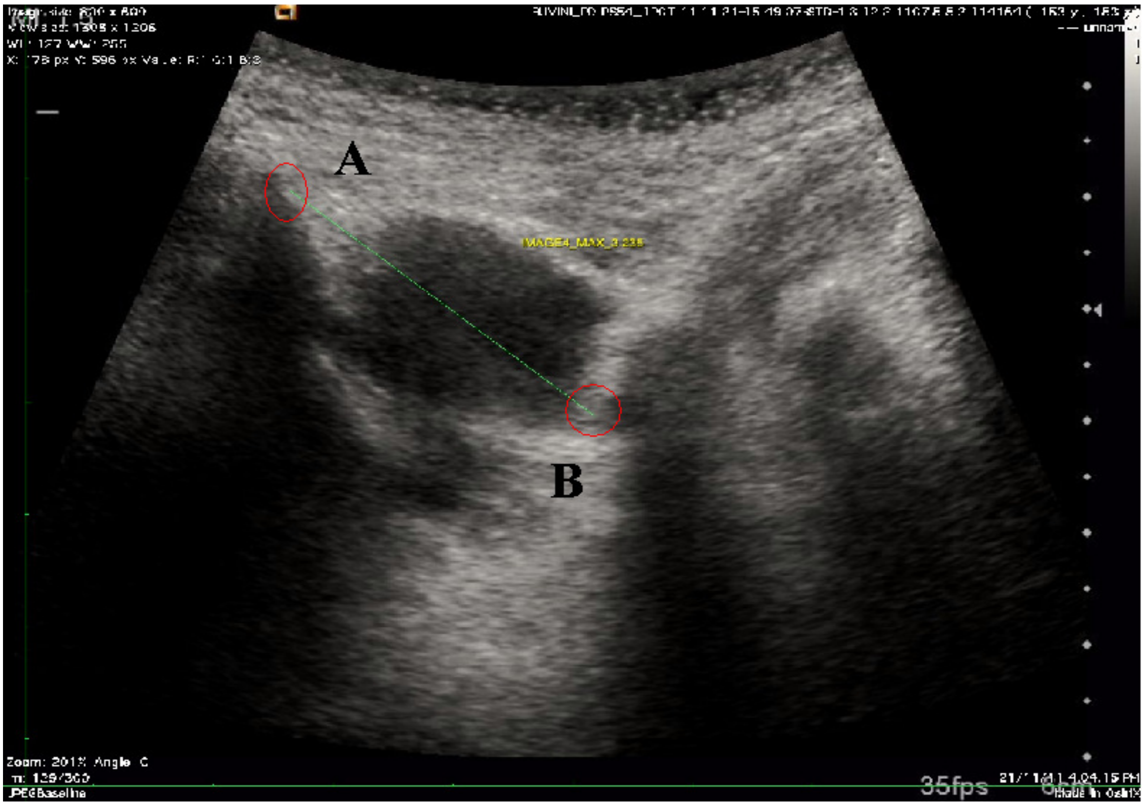

Figure 3-13. B mode ultrasound image of the hyoid and spine of mandible distance at the point of maximal displacement. The caliper mark at the mental spine of the mandible (A) and the caliper at the hyoid shadow (B). This has shifted anteriorly toward the mental spine of the mandible.

Hyoid displacement was calculated from the formula:

$$\frac{\text{Hyoid at max} - \text{hyoid at rest position X 100}}{\text{Hyoid at rest}}$$

Calculations were conducted on data taken from five hyoid bone images using the above mentioned formula and the average was taken.

The cross sectional area (CSA) of the geniohyoid muscle and of the anterior belly of digastric muscle were measured (Figure 3-14) using the continuous trace calliper tool of Osirix imaging software. Although five images of submental muscles were recorded, due to poor clarity for measurement the average of the four best images were taken per session. First, the CSA of the left and right anterior belly of digastric bellies were measured individually and then added together. Finally, the total CSA sum of both right and left muscles for the four best images were averaged. Likewise, the CSA of geniohyoid for the four best images was measured and averaged.

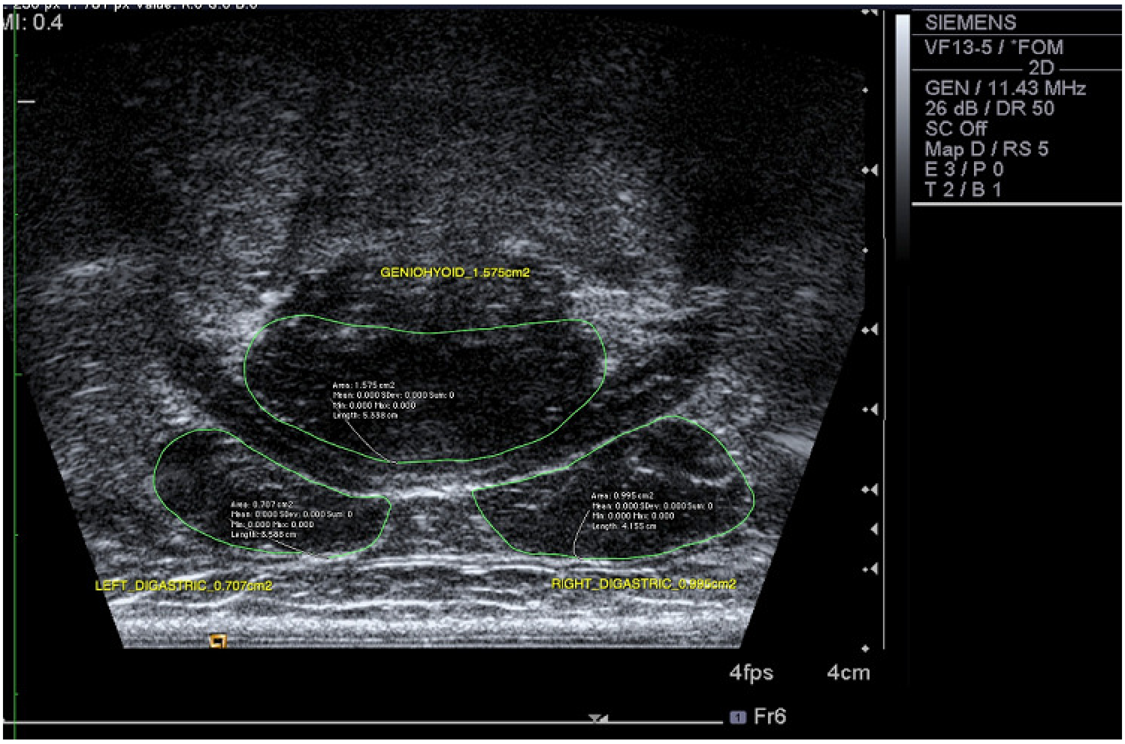

Figure 3-14. CSA of the two anterior bellies of digastric muscle, and the geniohyoid muscles measured using electronic callipers. Settings are displayed on the top right corner of the image and the respective CSA are displaced next to each muscle.

3.5.4 Surface EMG

Three durational measurements were extracted from the sEMG data. These were: pre-motor time (PMT), pre-swallow time (PST), and duration of submental muscle contraction. PMTs for saliva and 10 ml water bolus swallows were defined as the time duration between the first presentation of the stimulus ("go" signal - indicated with a red tag) to the first change in the EMG waveform. A criterion was established to determine the point of the first change in the EMG waveform. That is, the end of PMT point was identified by averaging the amplitude of one second of the EMG waveform prior to the 'go' marker (Figure 3-15), keeping the horizontal cursor on this average value and noting the point at which the vertical cursor intersected and remained above the horizontal cursor (Figure 3-16). This method was conducted for all five saliva and 10 ml water bolus swallows and average of each was taken.

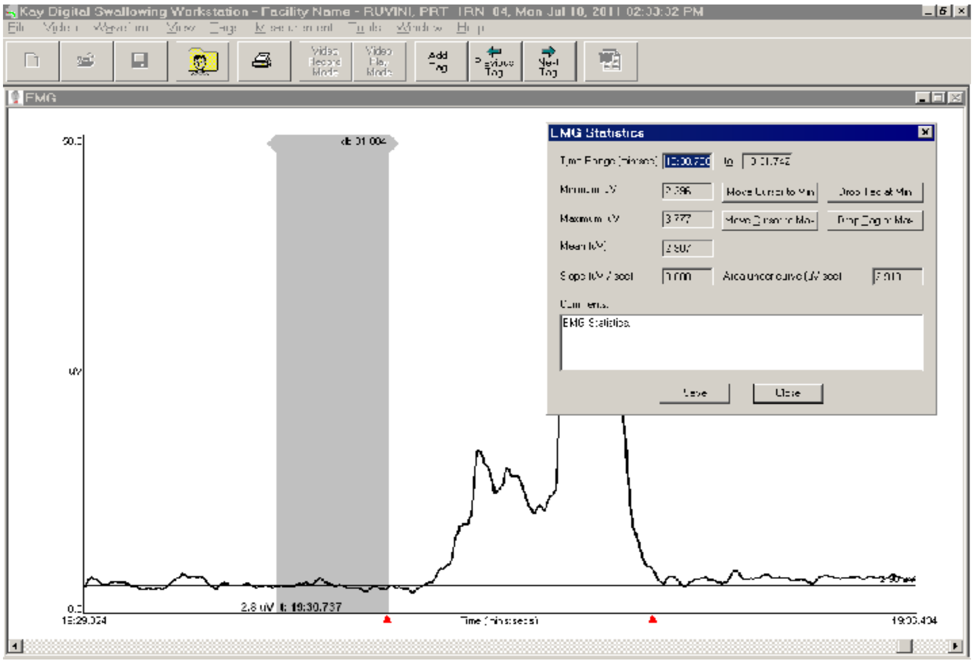

Figure 3-15. Calculation of the average for one second of the waveform from the first red tag (“go” signal). The red tag at the end depicts the type of swallow (e.g., 10 ml water).

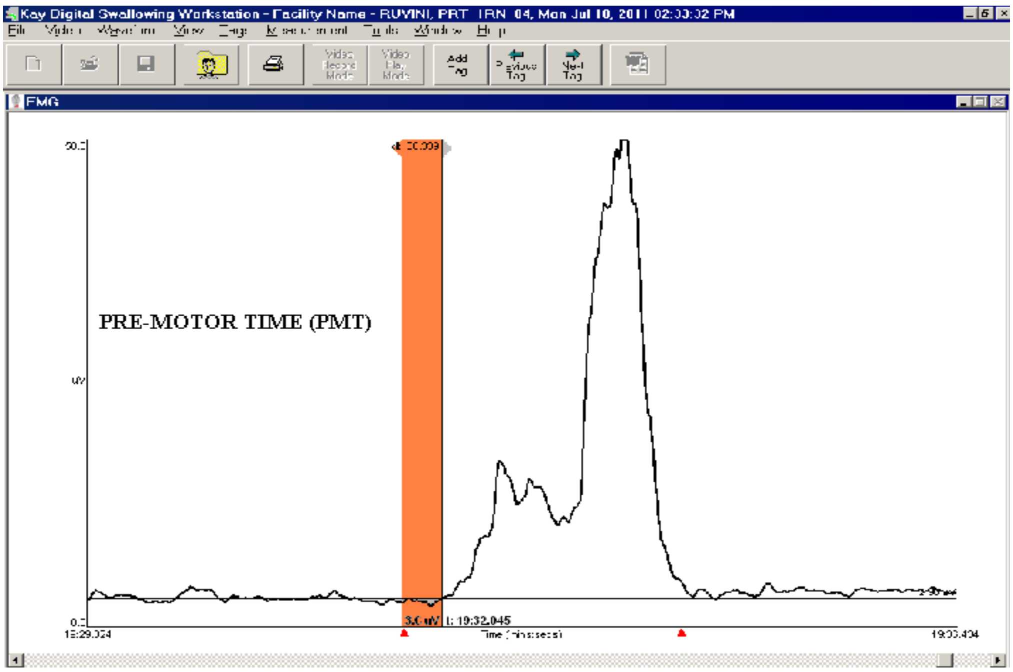

Figure 3-16. PMT of swallowing for 10 ml water bolus is shown. The first red tag indicates the “go” stimulus and the shaded area depicts the PMT. The red tag at the end depicts the type of swallow.

The pre-swallow time (PST) for dry/saliva and 10 ml water bolus swallows was defined as the time duration between the first change in the EMG waveform (described above) to the base of the onset of swallowing, which was identified as the highest peak of the overall event (Figure 3-17). In waveforms where there were double or multiple peaks the distance to the first peak was measured.

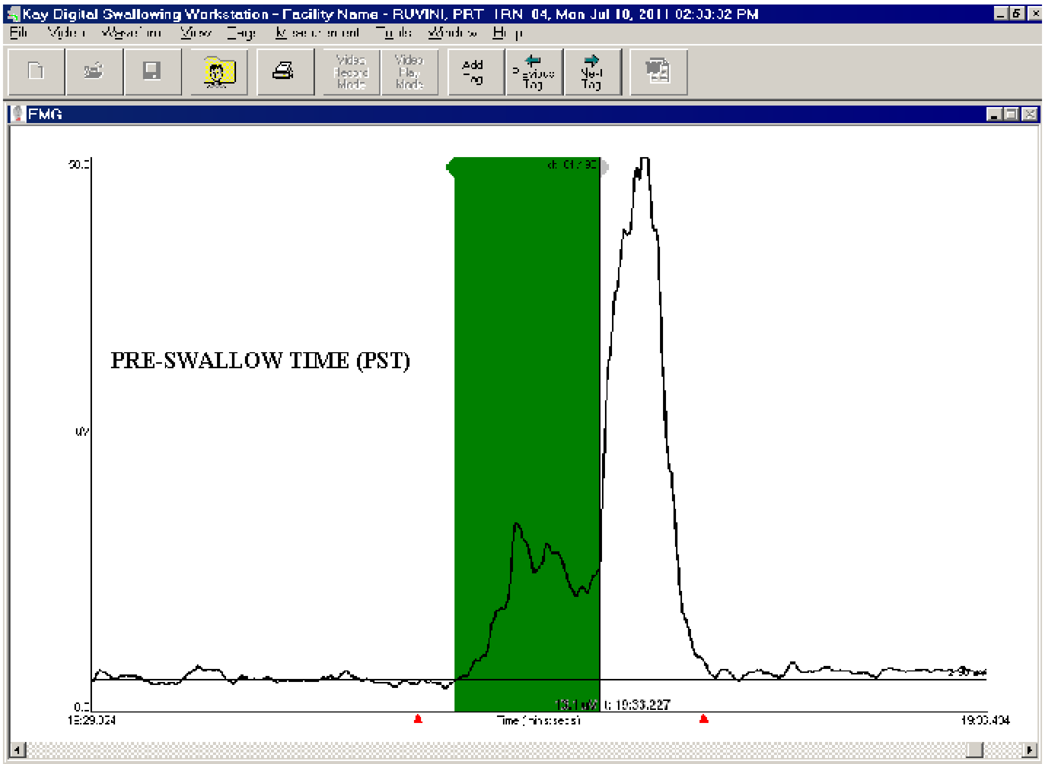

Figure 3-17. PST of swallowing for 10 ml water bolus is illustrated. The shaded area depicts the PST.

The duration of submental muscles contraction was assessed by determining the time between the onset and the offset of the EMG waveform. The last point of PMT (determined as mentioned above) was considered the onset of submental muscle contraction duration. The offset point was determined as the point at which the waveform dropped and intersected with the vertical cursor for the first time. The distance between these two points was measured (Figure 3-18).

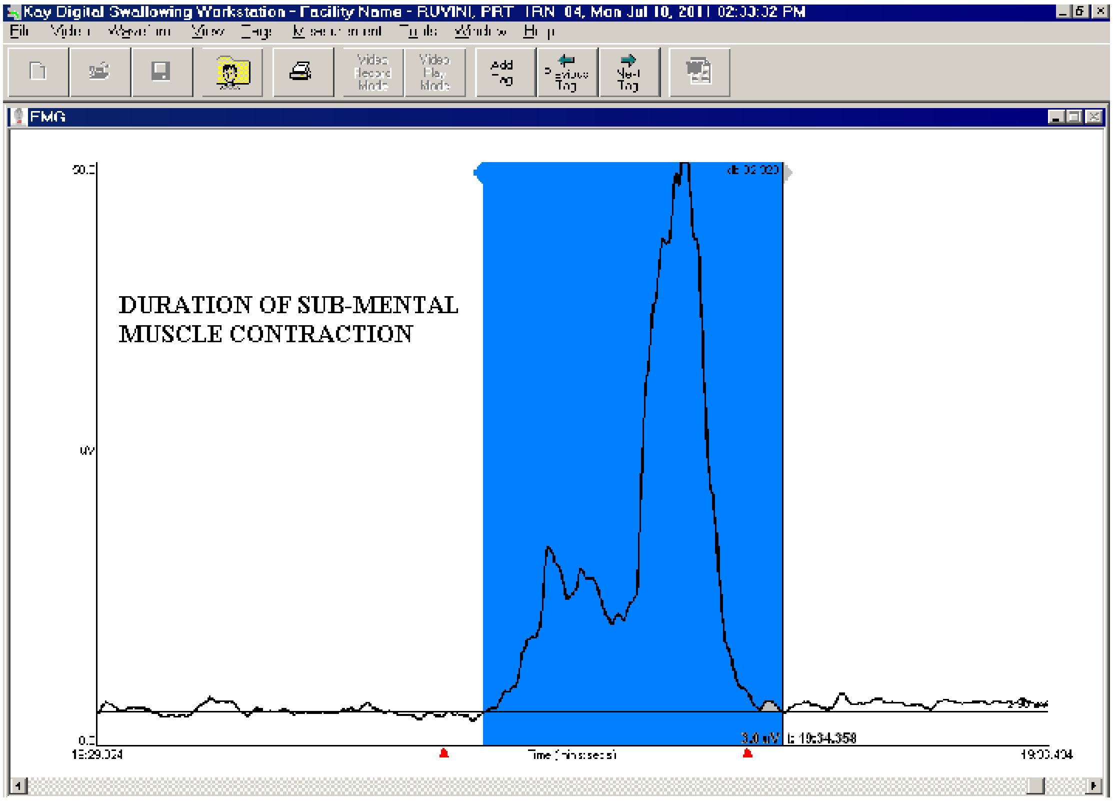

Figure 3-18. Duration of submental muscle contraction for 10 ml water bolus is illustrated in the shaded area.

3.5.5 SWAL-QOL

SWAL-QOL scores were calculated using the Likert method (Likert, 1932), in which, scores are totalled, with each item evenly weighted and added into an overall scale score (Leow et al., 2010). This allowed each question to be linearly converted into 0-100 metric, with '100' suggestive of no impairment and '0' with the greatest impairment and in-between scores indicating the possible percentage score achieved. The Likert method assumes that each component on the SWAL-QOL positively correlate with quality of life in dysphagia.

3.6 Data Analysis

All data were extracted and analysed by the primary researcher. To evaluate intra-and-inter-rater reliability, the primary researcher re-analysed and a second independent rater analysed a random sample of 20% of the total data set for each type of measurement. Single-measure intra-class correlation coefficients were calculated for each measure of intra-and inter-rater reliability using Statistical Package for the Social Sciences (SPSS, version 19, 2011). General Linear Model (GLM) repeated measures ANOVAs (one way) were performed using SPSS and an a priori *p* value < 0.05 was taken to indicate statistical significance. Maulchly's test of sphericity was assessed for all analyses. When this test was significant, Greenhouse-Geisser adjustment was applied to the *p* values. Planned comparisons (all two-tailed) were carried out between Baseline1 (B1) and Baseline2 (B2), Baseline2 (B2) and Outcome1 (O1), and Outcome1 (O1) and Outcome2 (O2).

As this was a pilot study of a novel intervention, none of the variables examined were corrected for multiple comparisons. Several researchers suggest that the Bonferroni method is inappropriate and too strictly conservative (Bland & Altman, 1995; Perneger, 1998) for exploratory studies, where data are being explored for patterns of change. In this case, a Type II error is considered a more critical risk than a Type I (Perneger, 1998) as true differences may be overlooked and findings from pilot studies may be interpreted and discarded. Therefore, patterns of change, effect sizes, and confidence intervals were critically analysed in this study.

Finally, Pearson's product-moment correlation coefficient was conducted to assess the relationship between masticatory cycles on observation and on sEMG. Additionally, descriptive statistics and effect sizes were used to assess within-subject treatment response patterns.

Chapter 4. Results

4.1 Disease severity

The male patients had a mean Hoehn & Yahr (H-Y) score of 2.4 and the female participants had a mean H-Y score of 2.6. Table 4-1 depicts the H-Y score for all ten patients.

Table 4-1. Hoehn & Yahr score of the patients.

Patient ID	H-Y score
RN84, JC76, PD71, RW69, LB66	3
JT66, DC67, JN64, SR57, PS54	2

4.2 Intra-and inter-rater reliability

The interclass-correlation coefficients for intra-and inter-rater reliability of each parameter in the outcome measures are as follows.

Variable	**ICC (95% CI)**	
	Within-rater	**Between raters**
1. Timed water swallow test		
Volume per swallow	.99 (.99 – 1.00)	.95 (.81 – .99)
Time per swallow	.99 (.96 – .99)	.90 (.67 – .98)
Volume per time	1.00 (1.00 – 1.00)	.86 (.50 – .97)

2. TOMASS (Test of Mastication and Swallowing of Solids)			
Time per swallow		1.00 (1.00 - 1.00)	.99 (.95 - .99)
Masticatory cycles per swallow		1.00 (.99 - 1.00)	.99 (.95 - .99)
swallows per bite		1.00 (1.00 - 1.00)	.96 (.83 - .99)
Number of masticatory cycles on surface EMG		.99 (.97 - .99)	.99 (.95 - .99)
3. Surface EMG			
Dry swallow PMT		.98 (.97 – .992)	.92 (.85 – .95)
Dry swallow PST		.92 (.85 – .95)	.80 (.66 - .89)
Dry swallow submental muscle contraction duration		.98 (.96 – .990)	.96 (.93 – .98)
Water swallow PMT		.95 (.91 – .97)	.93 (.87 – .96)
Water swallow PST		.94 (.90 -.97)	.92 (.85 – .95)
Water swallow submental muscle contraction duration		.99 (.98 – .99)	.94 (.86 – .97)
4. Ultrasound			
Cross sectional area (CSA) of anterior bellies of digastric		.99 (.99 - .99)	.89 (.83 - . 93)
CSA of geniohyoid		.98 (.96 - .98)	.81 (.65 - .90)
Displacement of hyoid bone	Hyoid at rest	.94 (.88 - .97)	.78 (.63 - .88)
	Hyoid at maximum	.98 (.97 - .99)	.87 (.76 - .92)

ICC can be interpreted as: 0.0-0.2 indicates *poor* agreement, 0.3-0.4 indicates *fair* agreement, 0.5-0.6 indicates moderate agreement, 0.7-0.8 indicates *strong* agreement, and >0.8 indicates *almost perfect* agreement while value 1.0 indicates *perfect* agreement and 0.0 indicates *no* agreement at all (Landis & Koch, 1977; Portney & Watkins, 2000).

In summary, there was ‘almost perfect’ agreement of intra-and inter-rater ratings for all parameters, indicative of high measurement reliability. However ultrasound measurements, especially, for hyoid at rest, were less reliable, albeit still with ‘strong’ agreement between raters.

4.3 Baseline and retention measures

There was no significant difference between B1 and B2 for any of the parameters on the outcome measures (p > .09), apart for SWAL-QOL which approached significance (p = .052). Likewise, there was no significant difference between O1 and O2 for any of the parameters on the five outcome measures (p > .09), with the exception of volume per swallow in the timed water swallow test (see section 4.4.1).

4.4 Timed water swallow test

Three variables were evaluated in this test: volume (ml) per swallow, time (s) per swallow and volume per time (ml/s). The individual scores for each parameter are represented in a line graph and attached as Appendix G.

4.4.1 Volume per swallow

There was a significant main effect of time [F (3, 27) = 3.000, p = .048]. Therefore, post-hoc pair-wise comparisons between B1 and B2, B2 and O1, and O1 and O2 were conducted. This revealed a significant difference between O1 and O2 (p = .032, d = 0.34, Δ = 15%), as shown in Figure 4-1, indicating an improvement in the retention period for this parameter.

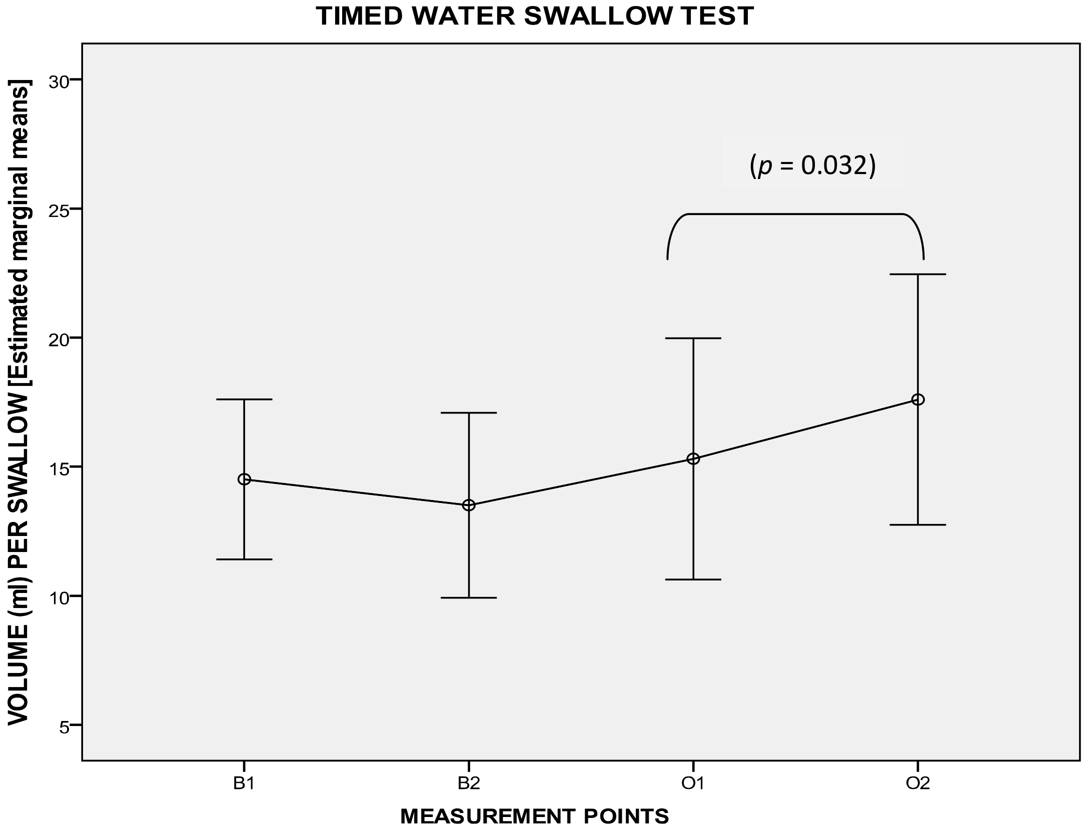

Figure 4-1: Means and confidence intervals for volume per swallow.

4.4.2 Time per swallow

There was a significant main effect of time [F (3, 27) = 5.552, p = .020]. Therefore, post-hoc pair-wise comparisons were conducted. As shown in Figure 4-2, there was a significant improvement from pre-treatment to post-treatment, B2 and O1 (p = .034, d = 0.72, Δ = 17%).

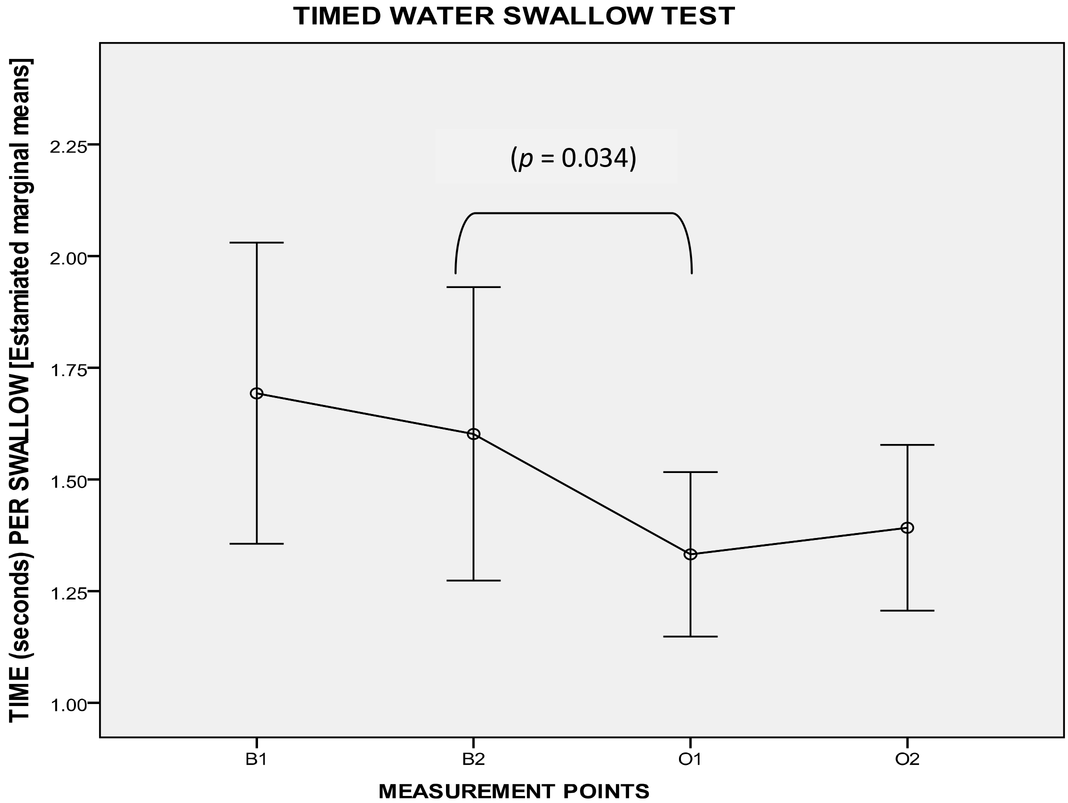

Figure 4-2: Means and confidence intervals for time per swallow.

4.4.3 Volume per time

There was no significant main effect of time [F (3, 27) = 3.690, p = .070] as shown in Figure 4-3. Therefore, post-hoc pair-wise comparisons were not conducted between B1 and B2, B2 and O1 and O1 and O2.

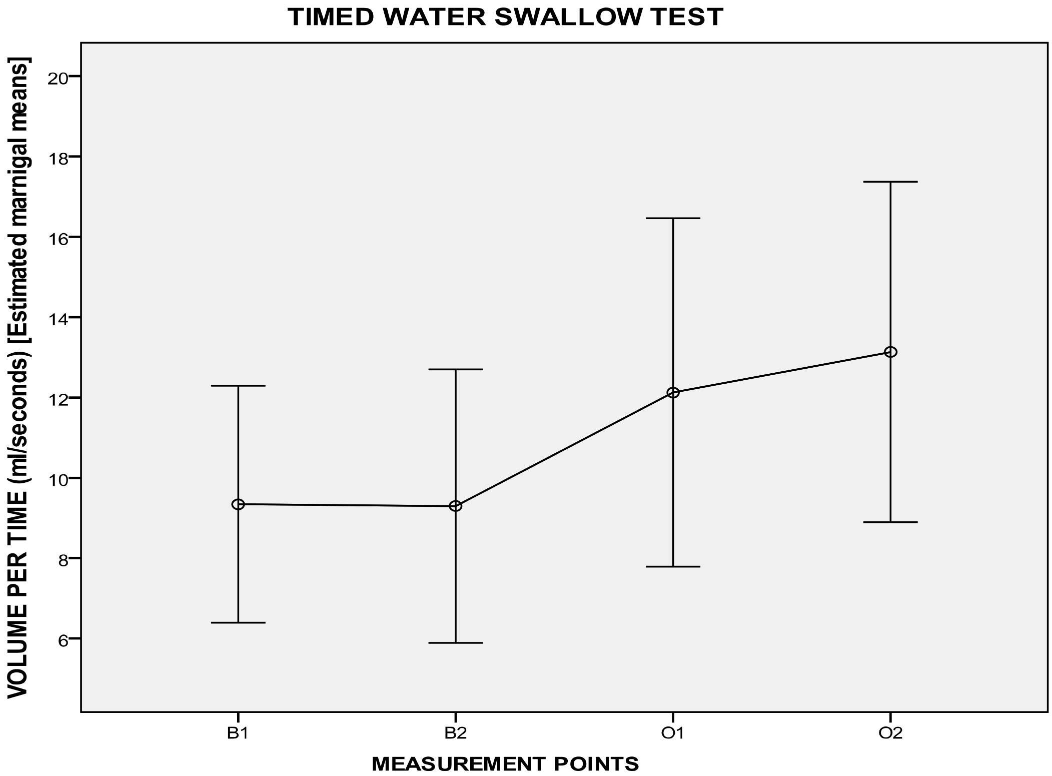

Figure 4-3. Means and confidence intervals for volume per time.

4.5 Test of Mastication and Swallowing of Solids (TOMASS)

Three variables were evaluated in this test: time per swallow, masticatory cycles (MC) per swallow and swallows per bite. The individual scores for each parameter are represented in a line graph and attached as Appendix H.

4.5.1 Time per swallow

There was no significant main effect of time [F (3, 27) = 0.398, p = .647] as shown in Figure 4-4. Therefore, post-hoc pair wise comparisons were not conducted.

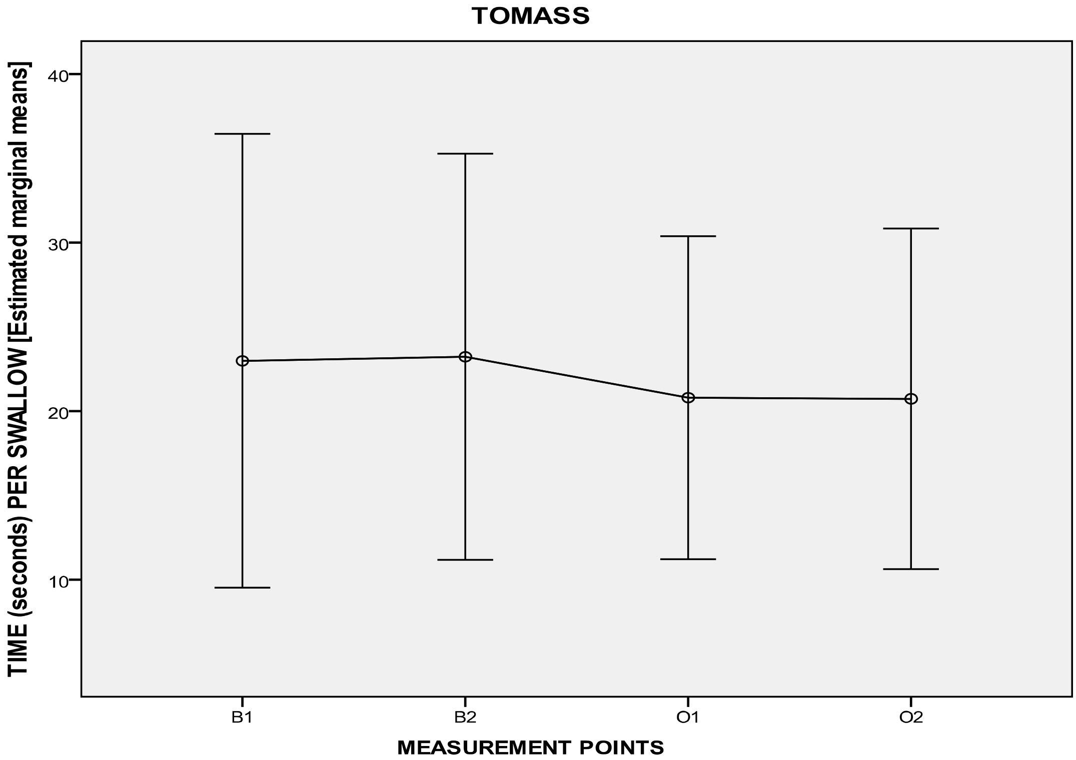

Figure 4-4. Means and confidence intervals for time per swallow.

4.5.2 Masticatory cycles per swallow

Two methods were used to document masticatory cycles (MC): visual observation and surface EMG. Pearson's product correlation co-efficient for masticatory cycles on observation and surface EMG suggested a strong correlation between the two measures (Table 4-2). Therefore, all subsequent analyses of mastication were carried out on data gathered through sEMG measures as it was considered objective when compared to subjective observational MC measurements.

Table 4-2. Pearson's product moment correlation coefficients.

Correlation between MC on observation and sEMG	Pearson's correlation	P
Baseline 1	.900	<.05
Baseline 2	.932	<.05
Outcome 1	.953	<.05

Outcome 2	.947	<.05

There was no significant main effect of time [F (3, 27) = 0.111, p = .887] as shown in Figure 4-5. Therefore, post-hoc pair wise comparisons were not conducted.

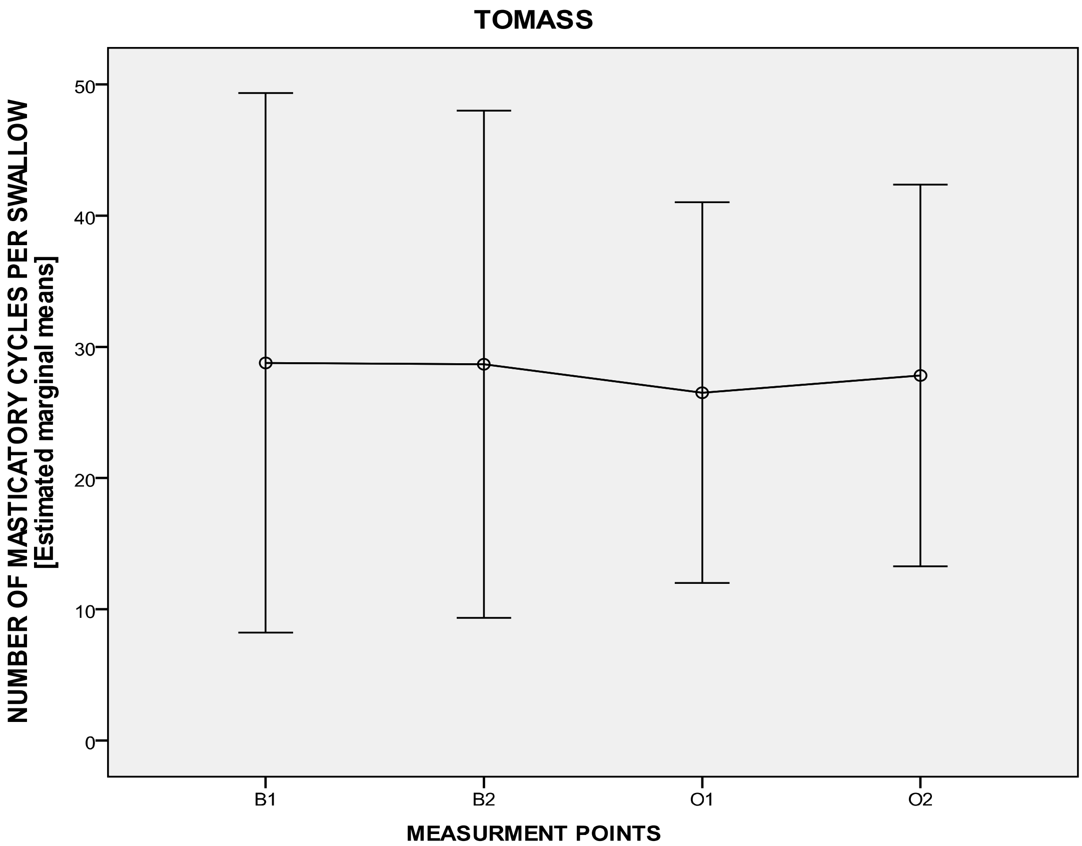

Figure 4-5. Means and confidence intervals for masticatory cycles per swallow.

4.5.3 Swallows per bite

There was no significant main effect of time [F (3, 27) = 0.1899, p = .154] (Figure 4-6). Therefore, post-hoc comparisons were not conducted.

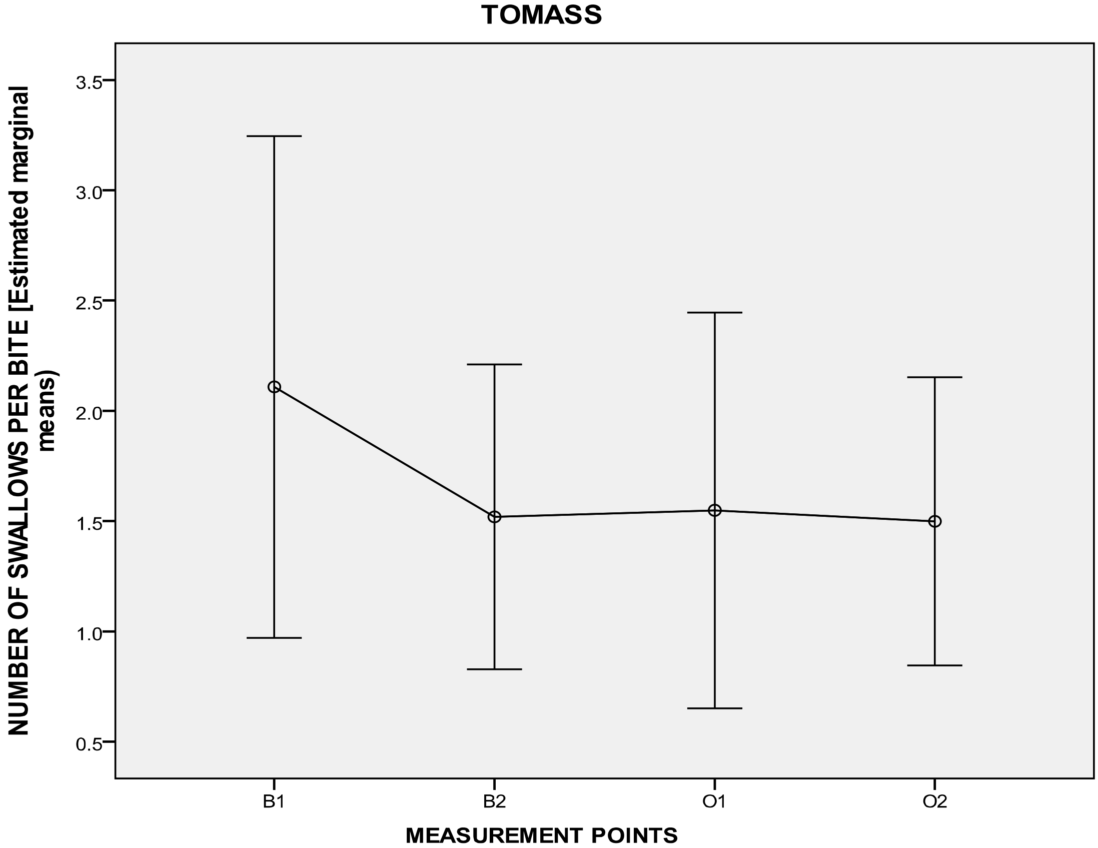

Figure 4-6. Means and confidence intervals for masticatory cycles per bite.

4.6 Surface EMG

There were two task conditions (dry and water swallow) with each having three sub-parameters (PMT, PST and duration of submental muscle contraction). The individual scores for each parameter are given in Appendix I.

4.6.1 Dry swallow PMT

There was a significant main effect of time [$F\,(3, 27) = 8.864$, $p = .000$]. Therefore, post-hoc pair-wise comparisons were conducted. As shown in Figure 4-7, there was a significant improvement in PMT from pre-treatment to post-treatment, B2 and O1 ($p = .003$, $d = 1.14$, $\Delta = 44\%$).

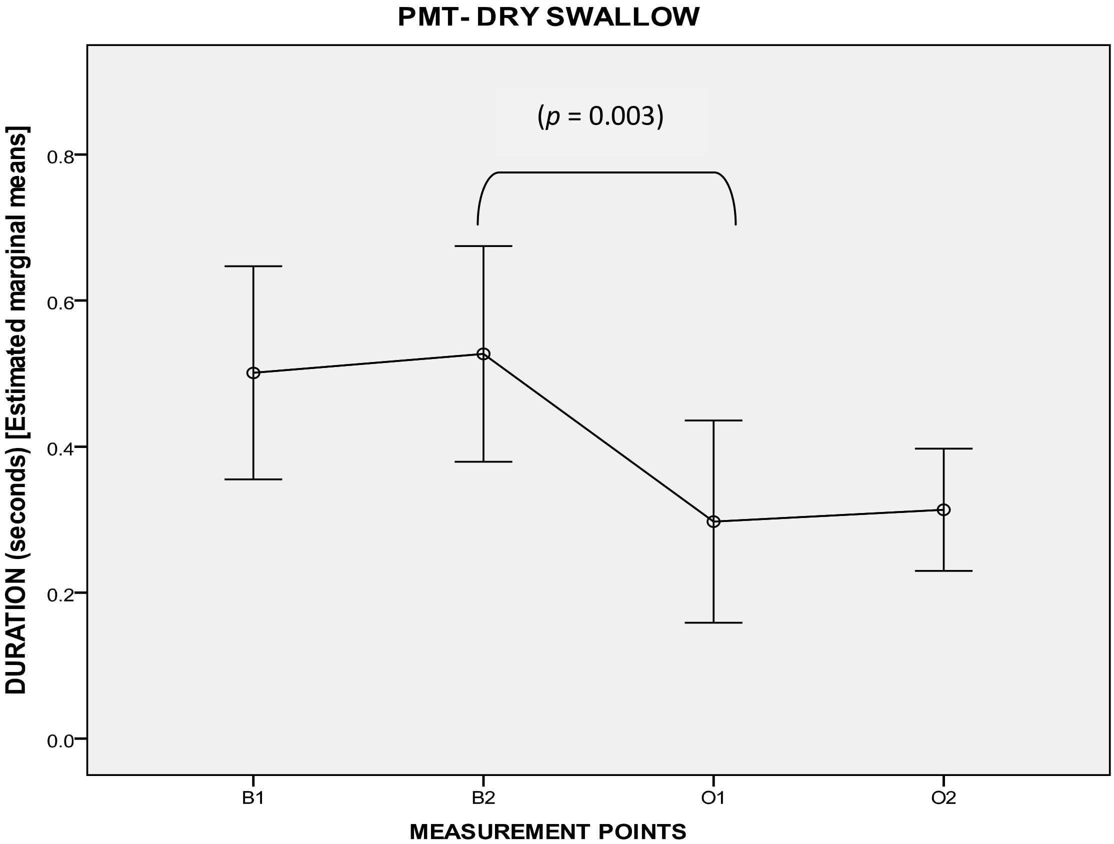

Figure 4-7. Means and confidence intervals for dry swallow PMT.

4.6.2 Dry swallow PST

There was a significant main effect of time [$F\,(3, 27) = 14.432$, $p < .001$]. Therefore, post-hoc pair-wise comparisons were conducted. As shown in Figure 4-8, there was a significant improvement in PST from pre-treatment to post-treatment, B2 and O1 ($p < .001$, $d = 1.62$, $\Delta = 43\%$).

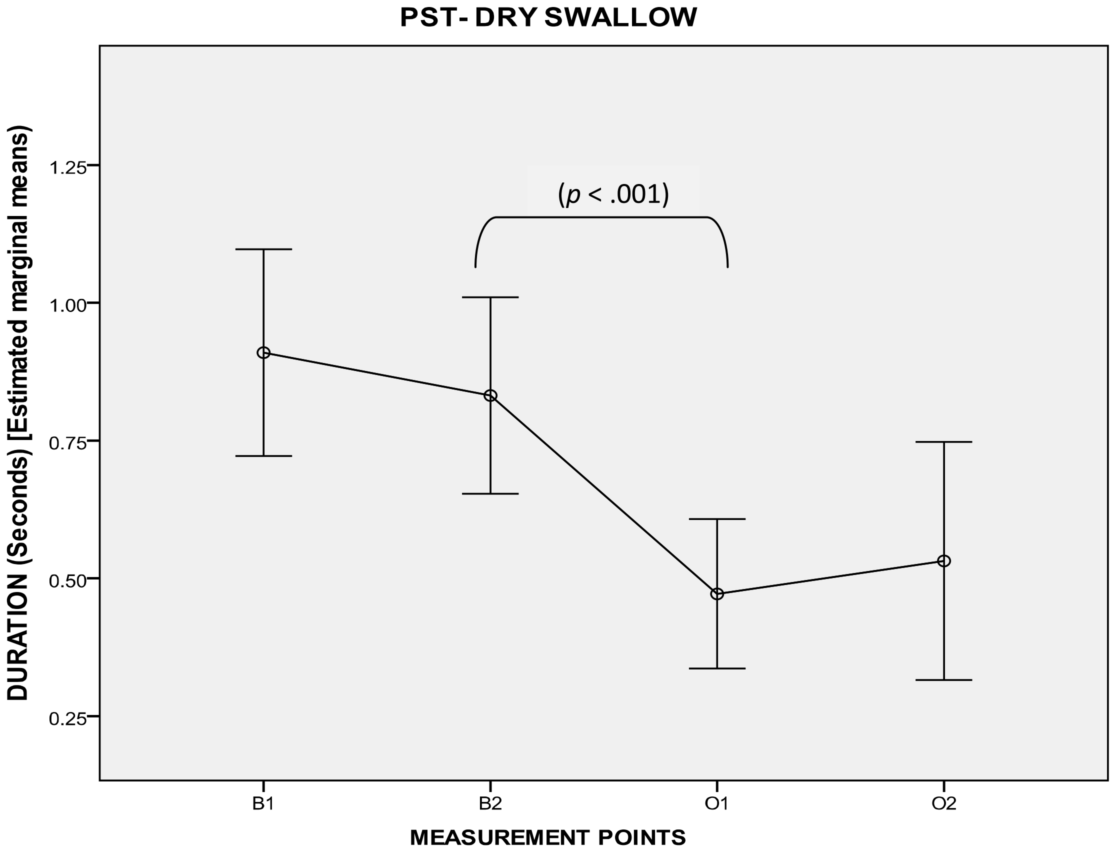

Figure 4-8. Means and confidence intervals for dry swallow PST.

4.6.3 Dry swallow duration of submental muscle contraction

There was a significant main effect of time [F (3, 27) = 4.500, p = .011]. Therefore, post-hoc pair-wise comparisons were conducted. As shown in Figure 4-9, there was a significant improvement in duration of submental muscle contraction from pre-treatment to post-treatment, B2 and O1 (p = .012, d = 1.27, Δ = 26%).

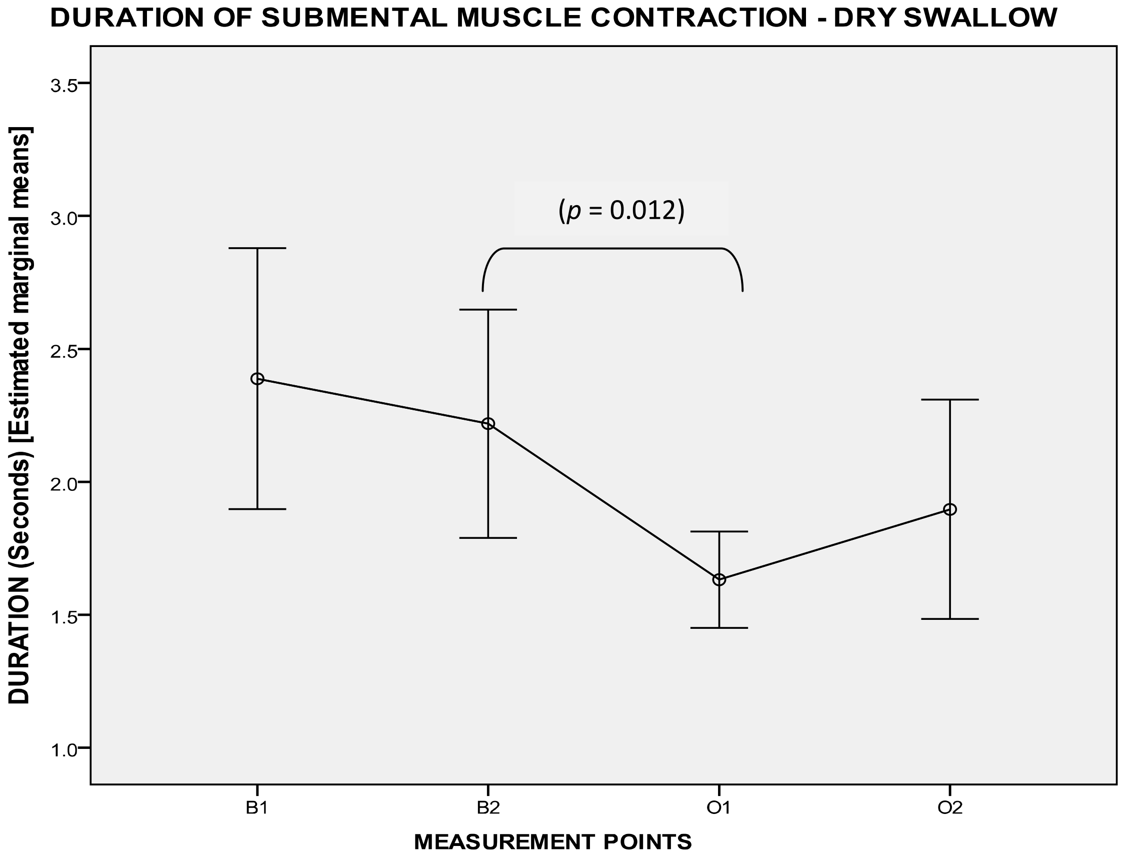

Figure 4-9. Means and confidence intervals for dry swallow duration of submental muscle contraction.

4.6.4 Water swallow PMT

There was a significant main effect of time [$F\,(3, 27) = 4.528$, $p = .044$]. Therefore, post-hoc pair-wise comparisons were conducted. As shown in Figure 4-10, there was a significant improvement in PMT from pre-treatment to post-treatment, B2 and O1 ($p = .009$, $d = 1.20$, $\Delta = 23\%$).

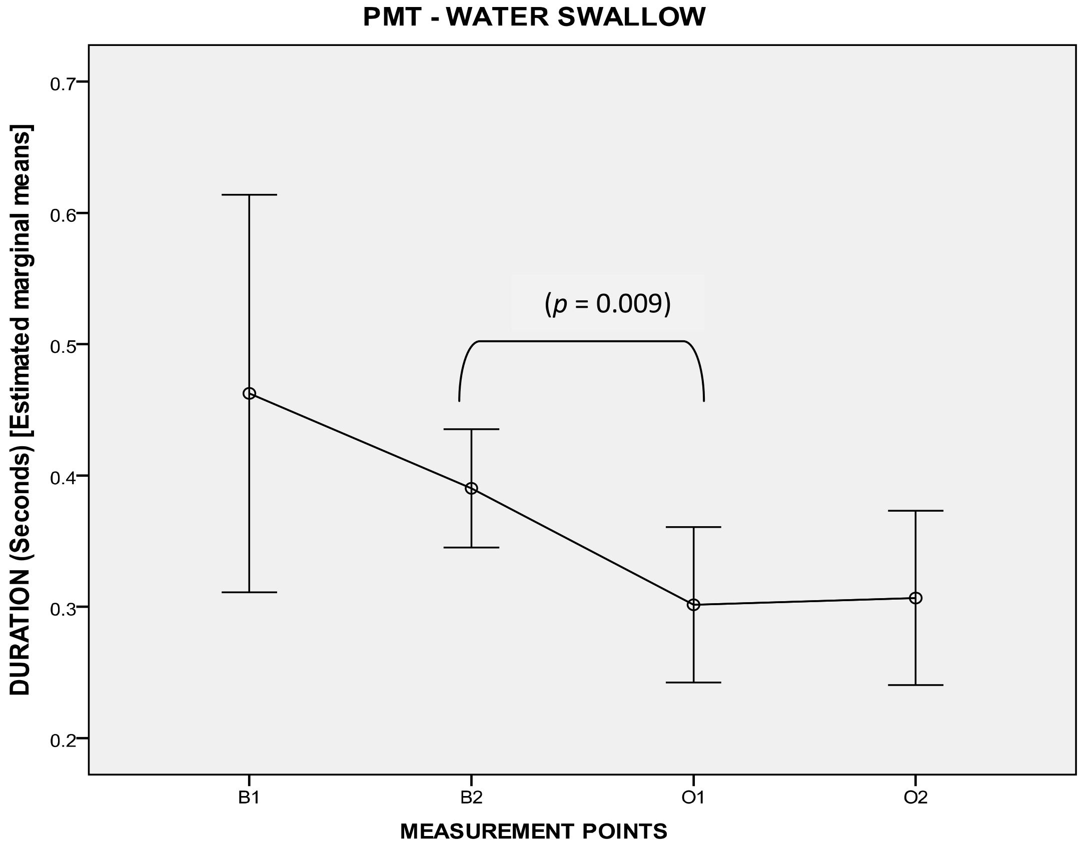

Figure 4-10. Means and confidence intervals for water swallow PMT.

4.6.5 Water swallow PST

There was a significant main effect of time [F (3, 27) = 8.604, p = .007]. Therefore, post-hoc pair-wise comparisons were conducted. As shown in Figure 4-11, there was a significant improvement in PST from pre-treatment to post-treatment, B2 and O1 (p = .034, d = 1.10, Δ = 45%).

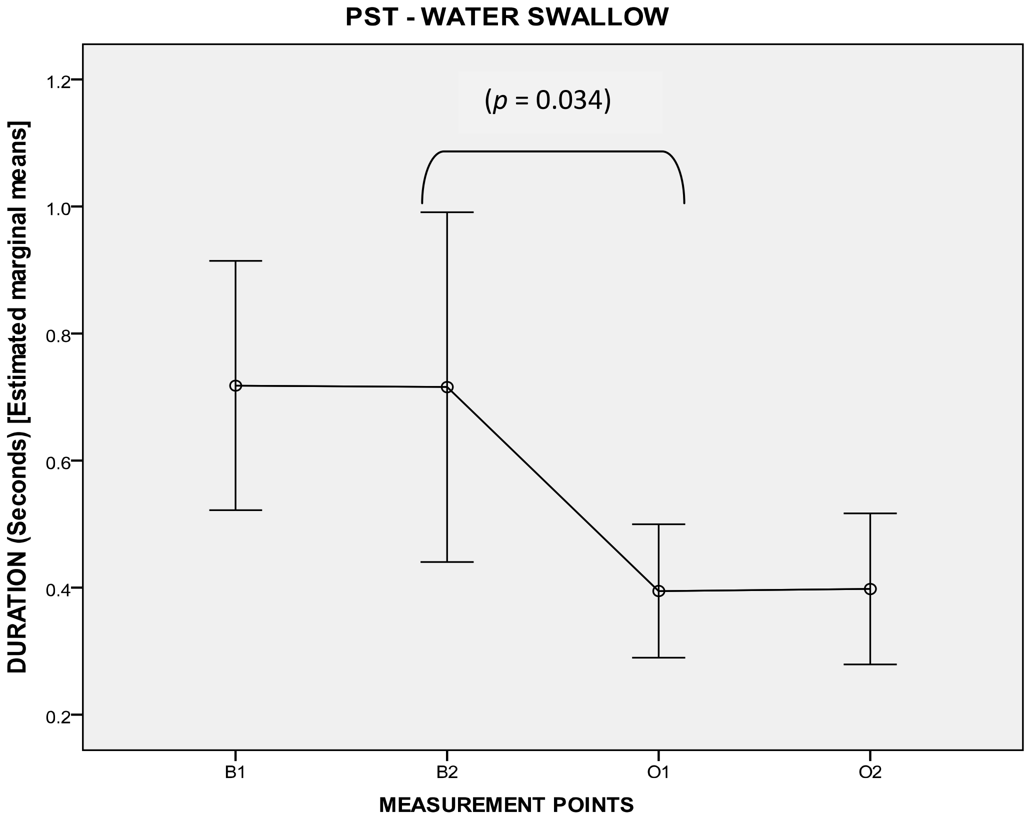

Figure 4-11. Means and confidence intervals for water swallow PST.

4.6.6. Water swallow duration of submental muscle contraction

There was no significant effect of time [F (3, 27) = 1.747, p = .181] (Figure 4-12). Therefore, post-hoc pair wise comparisons were not conducted.

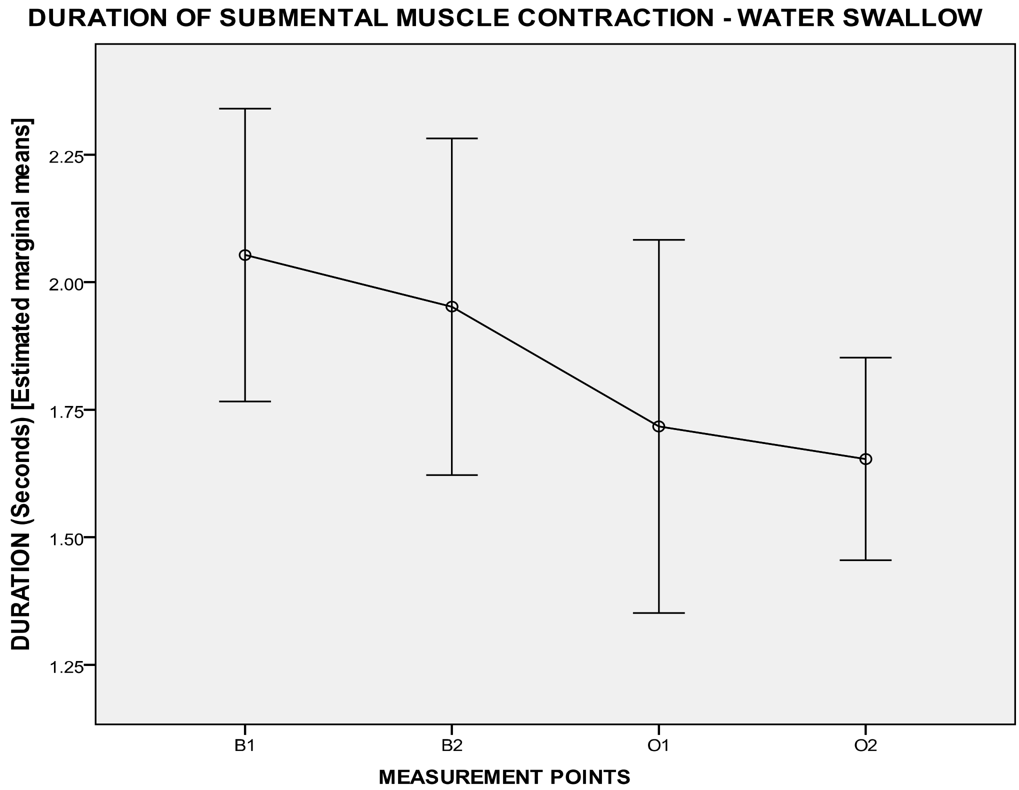

Figure 4-1. Means and confidence intervals for water swallow duration of submental muscle contraction.

4.7 Ultrasound

Three variables were examined: cross sectional area (CSA) of anterior bellies of digastric, geniohyoid, and percentage of displacement of hyoid bone. The individual scores for each parameter are attached as Appendix J.

4.7.1 CSA of anterior bellies of digastric muscle

There was no significant main effect of time [F (3, 27) = 0.470, p = .706] (Figure 4-13). Therefore, post-hoc pair wise comparisons were not conducted.

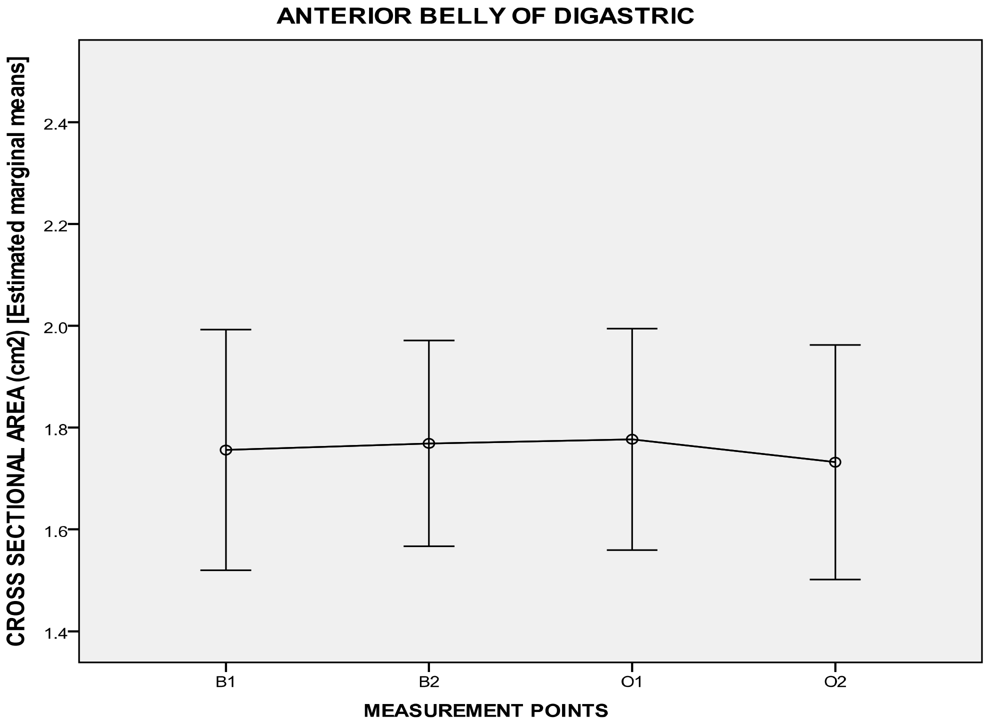

Figure 4-13. Means and confidence intervals for cross-sectional area of anterior bellies of digastric muscle.

4.7.2 CSA of geniohyoid muscle

There was no significant main effect [F (3, 27) = 0.382, p = .767] (Figure 4-14). Therefore, post-hoc pair wise comparisons were not conducted.

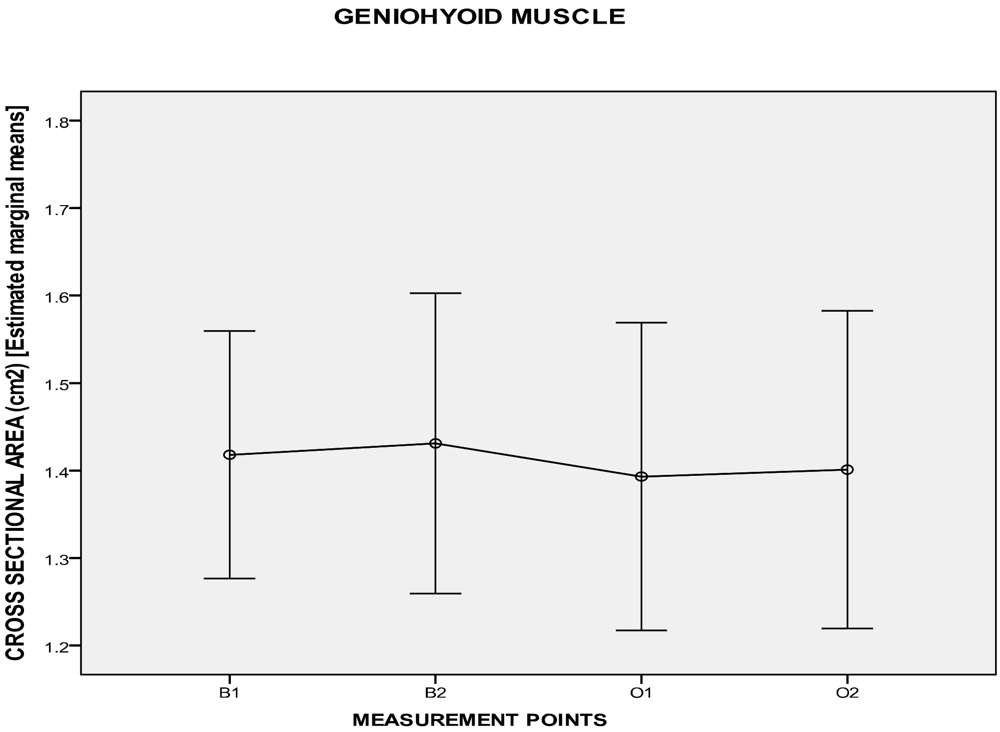

Figure 4-14. Means and confidence intervals for cross-sectional area of geniohyoid muscle.

4.7.3 Percentage of displacement of hyoid bone

There was no significant effect of time [F (3, 27) = 0.724, p = .546] (Figure 4-15). Therefore, post-hoc pair wise comparisons were not conducted.

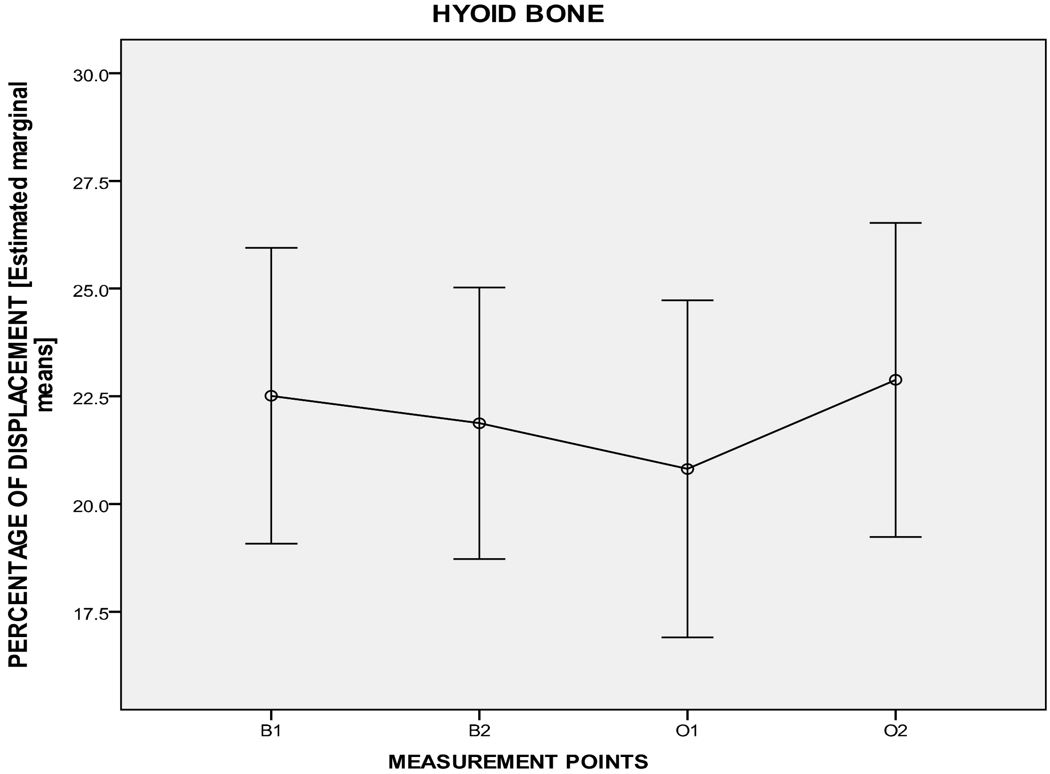

Figure 4-15. Means and confidence intervals for percentage of hyoid displacement.

4.8 SWAL-QOL

Individual values for the percentage scores in SWAL-QOL are given in Appendix K. There was a significant main effect of time [F (3, 27) = 8.163, p = .009]. Therefore, post-hoc pair-wise comparisons were conducted. As indicated in Figure 4-16, there was a significant improvement in swallowing quality of life from pre-treatment to post-treatment, B2 and O1 (p = .018, d = 0 .46, Δ = 8%). Additionally, as mentioned before in section 4.3 there was also an improvement (approaching significance) during the non-treatment phase, B1 and B2 (p = .052, d = 0.27, Δ = 6%).

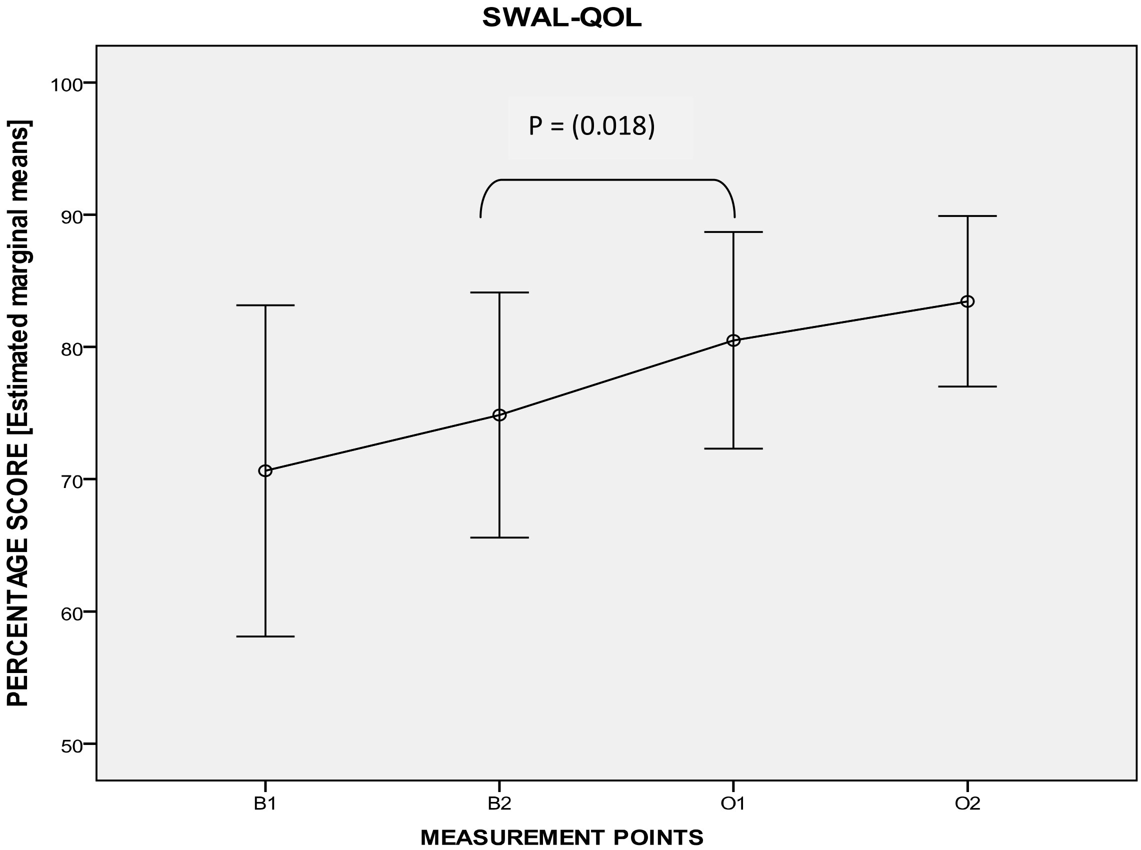

Figure 4-16. Means and confidence intervals for swallowing quality of life

Chapter 5. Discussion

This is the first study to evaluate the concept of skill training as a rehabilitation approach for dysphagia in a patient population, specifically patients with Parkinson's disease. This pilot study evaluated several outcome measures to assess the efficacy of skill training. These outcome measures can be broadly categorised as measures which evaluated functional swallowing (e.g., timed water swallow test, TOMASS), swallowing biomechanics (e.g., hyoid measurements), muscular changes (e.g., cross-sectional area of submental muscles) and swallowing-related quality of life (e.g., SWAL-QOL).

Overall, there were significant effects of treatment in many of the outcome measures. These improvements were congruent with informal reports from patient, family members, and friends on functional swallowing improvement following treatment. The results will be discussed with reference to three measurement periods, namely a non-treatment baseline phase (B1 - B2), a treatment phase (B2 - O1), and a skill retention phase (O1 – O2).

5.1 Non-Treatment baseline phase

As anticipated, all parameters on all of the outcome measures, apart from SWAL-QOL, remained essentially unchanged during this period. This indicates that the group as a whole were physiologically stable and exhibited consistent behaviour before treatment and with no order effects of practice confounding any effects of treatment. Additionally, the stable baseline suggests high measurement reliability with the instrumentation used. The exception was SWAL-QOL which revealed that patients perceived improvements in their swallowing even prior to treatment initiation. Interestingly, SWAL-QOL was not significantly different during the non-treatment phase but was just was approaching significance. However, this suggests a possible placebo effect associated with engagement with the clinician that was measured with this qualitative outcome measure. A comparison of the significance values between non-treatment phase and treatment phase revealed a greater significance for treatment phase, suggesting the possibility of a positive effect of treatment on patients swallowing related quality of life. However, the placebo effect cannot be discounted.

5.2 Treatment phase

The volume consumed per swallow (V/S) and swallowing capacity (V/T) did not reveal any significant improvements on the timed water swallow test post-treatment. On the other hand, as hypothesised, the time taken per swallow (T/S) reduced significantly over the treatment phase. Similarly, as anticipated, there were significant reductions in the timing parameters (PMT, PST and duration of sub-metal muscle contraction) for both conditions (dry swallows and water swallows) on sEMG, with the exception of duration of submental muscle contraction for water swallow. Additionally, significant improvements were seen in swallowing-related quality of life during this period.

Improvements in timing (T/S, PMT, PST and duration of submental muscle contraction) may be attributed to several factors. Explanations for these improvements can be inferred from limb studies on gait rehabilitation in PD, which suggest improved neuromuscular co-ordination, timing, speed of reaction, planning of movement and range of movements following skill training (Cakit et al., 2007; Fisher et al., 2008; Herman et al., 2007; Miyani et al., 2002; Petzinger et al., 2010). Therefore, following skill training the timing of swallowing and speed of reaction of swallowing may have improved. The skill training treatment task involved swallowing saliva; hence, the reduction in time taken to consume the water (T/S) suggests that there was also a carry-over of improvements to functional swallowing tasks.

However, swallowing capacity (V/T) did not change post-treatment or during the retention period unlike V/S which improved during the retention period despite no significant improvements immediately following treatment. The absence of no improvement in V/T may be attributed to the dose of the treatment. It can be assumed that the dose provided in this study was insufficient to produce a significant change/increase in the swallowing capacity. Unfortunately, the current dysphagia literature does not indicate an optimal dose for treatment. Hence, until further research is conducted in this area it is difficult to distinguish whether the changes in swallowing capacity were not noticed immediately post-treatment due to insufficient dose or due to the treatment being ineffective for this parameter.

Increased cortical awareness may have contributed to reducing the durational parameters (i.e., PMT, PST, duration of submental muscle contraction). Evidence from Brodsky et al. (2011) on the role of attention in swallowing in PD revealed an increase in reaction time for the dual-task condition during the anticipatory phase of swallowing rather than the oropharyngeal phase. This suggests greater demand of attention for planning and organising movements rather than executing oral movements (Brodsky et al., 2011). Biofeedback allows an individual to actively participate in the therapy by identifying the correct movement patterns, modifying the movement patterns to meet the target and maintaining focus of goals (Basjamin, 1989; Wolf, 1994). Therefore, it can be considered that this treatment approach increased the individual's awareness regarding movement sequences involved in executing the target swallow. Allowing the patients to gain conscious control over the timing and strength of their swallowing resulted in initiating and executing the swallow in a timely efficient manner. This was further supported by patients, family members, and friends' reports of the patient paying more attention to how they swallow while eating, than before. Secondly, reduced co-activation of antagonistic muscles may have resulted in better range of movement and better co-ordination of oro-lingual muscles, thus, facilitating the pharyngeal swallow. This is indicated by the significant reductions in PST for both task conditions. Improved precision and motor control of swallowing may have also resulted in reducing the unwanted lingual movements thereby reducing PST.

Additionally, it can be speculated that external feedback provided by the sEMG device may have at least partially bypassed the defective basal ganglia and activated the cortical and parieto-premotor pathways, providing access to the cortical motor programmes involved with swallowing and facilitating conscious control of swallowing movements. Although at present there is no published study to support this speculation in the realm of swallowing rehabilitation, inferences can be drawn from neuroscience imaging studies (Cunnington, Iansek, Bradshaw & Philips, 1995; Debaere, Wenderoth, Sunaert, Hecke, Swinnen, 2003). Activation of different neural pathways in the presence and absence of external visual feedback in humans has been documented during a bimanual hand movement coordination task (Dabaere et al., 2003). This group of researchers found that the premotor cortex, superior parietal, and thalamus were activated when external visual feedback was provided. However, the basal ganglia, supplementary motor area, cingulate motor cortex, inferior parietal cortex and frontal operculum were involved for internally-generated movement. Hence, Dabaere et al. (2003) suggested that, for motor disorders such as PD, providing external feedback may activate the parietal-premotor network by bypassing the basal ganglia and facilitating movement control. Similarly, when external cues such as visual and auditory were provided, there were significant functional improvements in gait speed and step length in patients with

PD (Morris, Iansek, Matyas & Summers, 1996; Rochester et al., 2005). It is suggested that these changes occurred as a result of bypassing the defective basal ganglia and using frontal cortex to consciously control movement (Morris, Martin, Schenkman, 2010). However, this speculation warrants investigation in the area of dysphagia management.

Finally, the task specificity nature of the treatment may have increased neural activation pattern and synchronisation of motor units. This might have resulted in developing an efficient motor programme for swallowing. Evidence for this can be inferred from neuroscience literature, which suggests that tasks which replicate the desired task results in cortical reorganisations (Karni et al., 1995; Plautz et al., 2000). Therefore, when carrying out specific tasks, cortico-motor neurons arrange together (Hubbard, Parsons, Neilson & Carey, 2009) and activate in a synchronous manner.

Even though the duration of submental muscle contraction for dry swallowing reduced, it did not for water swallows, it can be assumed that, although transference to functional swallowing took place, the prescribed dose of the treatment may have been insufficient to produce a significant change for this parameter. Unfortunately, current dysphagia literature does not indicate an optimal dose for treatment. Hence, until further research is conducted in this area it is difficult to distinguish whether the submental muscle contraction for water swallowing did not reduce significantly as a result of insufficient dose or due to ineffectiveness of the treatment for this parameter.

Additionally, patients perceived that their swallowing related quality of life improved following treatment. As there was transference of skills to functional swallowing (improvements in timed water swallow test), it is not surprising that patients perceived their swallowing to have improved. Additionally, most of the patient’s spouses and/or care takers reported that they spent less time preparing meals, had frequent outings to restaurants, and took part in family gatherings. Patients also reported that they had less fear of choking and felt confident to try different/normal food textures. These factors are likely to have substantially contributed to improved quality of life following treatment.

On the other hand, patients did not show any improvements post-treatment in any of the parameters on the TOMASS (time per swallow, masticatory cycles per swallow and swallows per bite). Several reasons might be attributed to this finding. Firstly, seven out of the 10 patients in this study had mild or moderate dysphagia as identified on clinical swallowing examination. Of these seven patients, four had mild while the remaining three were identified as having a moderate degree of dysphagia. The longest duration taken to consume the biscuit by a patient in this study was approximately two min. When compared to age-and-gender matched normative data, this is only twice as long (about one min. more). Hence, it can be postulated that since the majority of patients in this study were not severely or profoundly dysphagic, their swallowing efficiency for solids pre-treatment was not severely affected. Therefore, changes in parameters measured by TOMASS would be unlikely. Secondly, patients with PD generally have more difficulties with liquids than solids (Eadie & Tyrer; 1965; Stroudley & Walsh, 1991). Patients with PD are able to manage their swallowing using self-learnt compensatory techniques such as, taking smaller bites, chewing for longer, cutting food into smaller pieces and avoidance (Miller et al., 2006). Similarly, seven patients in the current study complained that they were mainly having difficulties swallowing liquids "(able to 'manage' food better than liquid)," while only three complained that they had greater difficulties for solids than liquids. Therefore, it can be postulated that the use of self-learnt compensatory behaviour lessened the symptoms for solids in this patient group. Thus, TOMASS test may not have been sensitive for identifying the proportion of people who actually exhibited problems with solid food.

As hypothised, the cross-sectional area of the submental muscles did not change following skill training. Strength training results in peripheral myogenic changes such as fibre type shifts and hypertrophy (Moritani, 1993). Hypertrophy, or enlargement of the muscle fibres, can result in an increase in the CSA of the muscles undergoing strength training, as evidenced in Narici et al.'s (1989) study in quadriceps muscles. Similar findings were seen in Robbins et al.'s (2005) study on tongue muscles following strength training. However, skill training results in cortical changes, such as increased synaptogenesis, cortical reorganisations, dendritic arborisation, and intracortical connections (Adkins et al., 2006; Bury & Jones, 2002; Karni et al., 1995; Kleim et al., 2005). Hence, skill training had no effect on the CSA of the geniohyoid and of the anterior bellies of digastric muscles.

It was hypothesised that the displacement of the hyoid bone would increase post-treatment but this was not supported by the data. Surprisingly, despite the functional improvements (as discussed above), no biomechanical changes were revealed. Even though this study focused on skill training and not on strength training, similar findings were reported in a strength training approach by Logemann et al. (2009). These researchers documented absence of physiological changes (no changes in hyoid displacement) in the presence of functional improvements (reduced post-swallow aspiration) following head-lift exercise. However, the researchers did not provide any explanation for this result.

Several reasons may explain the reasons for the lack of change in hyoid displacement in this study. Firstly, the ultrasound instrument used in this study (Siemens, Premium edition) may not have had adequate resolution to detect subtle changes in movement. Evidence from a recent replicated study (Davis, personal communications) conducted in the same lab using the same ultrasound machine revealed no significant change in hyoid movement following a floor-of- mouth strengthening exercise. However, an initial study (Bauer, 2010) conducted in the same lab using a different ultrasound machine identified an increase in the hyoid displacement. Similarly, in the current study inter-rater reliability was relatively low for ultrasound measures when compared to other outcome measures. Therefore, difficulties in identifying the exact reference point and hyoid point might have affected the measurements, masking any true changes.

Secondly, it can be postulated that displacement of the hyoid bone is not a sensitive outcome measure of change following treatment. Even though no studies have directly evaluated hyoid bone movement in PD using ultrasound, Wintzen, Badrising, Ross, Vielvoye and Liauw (1994) revealed that patients with PD did not have any effects on the rest position of the hyoid bone or the maximum displacement to different bolus volumes as compared to healthy controls on the lateral view of videofluoroscopy. However, the number of swallows with hesitancy was higher in their PD group. Similarly, Sonies, Wang and Sapper (1996) documented that the hyoid movement pattern was different in three dysphagic patients (aetiologies not mentioned) when compared to healthy controls as measured using B-mode ultrasound imaging. These researchers identified multiple swallows and hesitancy swallows (hyoid pausing in mid-sequence) in the patients. Likewise, multiple extra-lingual gestures and prolonged duration of hyoid displacement were seen with advancing age in healthy individuals on ultrasound imaging (Sonies, Parent, Morish & Baum, 1988). Therefore, it can be postulated that the patients in this study may have had fewer hesitancy swallows following treatment, due to improved precision and coordination of muscles. However, this outcome measure was not evaluated. Similarly, instead of displacement of the hyoid bone, the speed of the hyoid bone might have improved following skill training, due to improved timing and faster recruitment of muscle fibres. Unfortunately, again, this parameter was not measured. Additionally, it can be speculated that since there was no change in the size of the submental muscles, the force of contraction of these muscles did not increase. Thus, hyoid displacement, which is achieved by the contraction of the submental muscles and strap muscles (Cook et al., 1989; Vaiman et al., 2004), did not change following treatment.

5.3 Skill retention phase

As hypothesised, during the skill retention period there was no deterioration in any of the outcome measures. This is consistent with the finding that cortical reorganisation during skill training remains, even in the absence of practice (Kleim et al., 2000; Plautz et al., 1999). Therefore, the biomechanical/functional changes following skill training did not undergo any detraining after the treatment was terminated. Inferences from limb literature indicate similar maintenance of improvements in gait even after four weeks following termination of treadmill training in PD (Herman et al., 2007).

In contrast there was no significant increase in the volume per swallow on the timed water swallow test immediately following treatment, it significantly increased during the skill retention period. This may suggest that it took longer than hypothesed for the treatment to become effective and for it to be carried over into functional swallowing. As a result immediate post-treatment improvements may not have been sufficient to reach statistical significance. However, following skill training the neuromuscular system may have been primed for functional change, which was detected during the skill retention period.

5.4 Limitations of the study

1. Small sample size — since this was a feasibility study conducted to evaluate the effects of a novel treatment approach, a small sample was selected. Hence, the findings from this study cannot be generalised to the broader population based on this study alone.

2. Broad inclusionary criteria — since this was a pilot study, the primary goal was to assess whether this novel treatment approach would result in any changes. Hence, the patient inclusionary criteria were kept wide. That is the heterogeneous dysphagic patient sample in this study did not attempt to take into account possible confounding

factors such as age, gender, disease severity, type of dysphagia and severity of dysphagia. Notwithstanding the repeated measures within subject design of the study was strong enough to reveal changes over time, even in a small heterogeneous sample.

3. Confounding variable of depression — there is evidence to suggest a significant relationship between swallowing specific QOL and depression (Plowman-Prine et al., 2009). Three patients in the study were diagnosed with depression and were all on medication for the same. Therefore, it was an assumed that these subjects had depression symptoms adequately controlled by medication. However, no steps were taken to identify and exclude patients with undiagnosed and subclinical depression, which may have had an influence on the results.

4. Maturation effect — as with any long-term treatment research, changes within participants during the 6-week period were not controlled by the experimenter. Three patients underwent a medication change due to changes in PD symptoms. Hence, interaction between maturational factors might have an effect on the internal validity of the study.

5. All testing, treatment and analysing was done during the 'on' phase of medication and, therefore, results cannot be generalised to when 'off' medication.

5.5 Future directions

The preliminary findings from this study indicate substantial promise for this novel approach but further investigation is required. Future studies should be directed toward accounting for the aforementioned limitations. Ideally, a larger sample recruited to a randomised control trial with a cross over design is needed. Unfortunately, there was no blinding of the participants and experimenter in this study. Hence, future replications should include double- blinding.

Additionally conducting a videofluoroscopy on the patients, pre- and post-treatment would strengthen the research. VFSS was not conducted in this study hence; patient selection was based on the subjective clinical swallowing evaluation only. VFSS evaluation would provide a comprehensive evaluation of the oral, pharyngeal and esophageal phases assess bolus flow parameters, thus not only providing diagnostic precision but also assessment of the efficacy of the treatment. Furthermore, the speed of hyoid displacement and number of hesitancy swallows before the onset of swallow on ultrasound imaging may provide valuable information regarding the changes in the efficiency of swallowing. In this pilot study several outcome measures were conducted on a small sample size, as the aim was to investigate the treatment' s feasibility. However, future replicated studies can choose the salient measures (e.g., timed water swallow test, durational measurements in sEMG, SWAL-QOL) to assess its efficacy.

Similarly, the dose of the treatment requires investigation. In order to produce a change in the neuromuscular system, the exercise needs to be conducted beyond the usual threshold (Burkhead et al., 2007). Findings on the timed water swallow test indicate that the current dose (two weeks) is insufficient. Unfortunately, there is no agreement regarding an optimal dose in dysphagia rehabilitation literature, varying from four weeks (Pitts et al., 2009) to eight weeks (Robbins et al., 2007). For practical purposes, eight weeks of continuous one hourly treatment for a neurodegenerative patient population can be both physiologically and cognitively challenging. However, three or four weeks might seem less fatiguing and psychologically achievable to the patient. Finally, since skill training has been shown to produces cortical changes (Adkins et al., 2006; Karni et al., 1995; Kleim et al., 2002; Monfills et al., 2005), it is recommended to investigate neural changes following skill training in swallowing. This may be evaluated by conducting and comparing the amplitude and durational parameters on motor evoked potentials, pre and post-treatment.

5.6 Conclusion

This study has shown that a skill-training approach provided functional, biomechanical and swallowing related quality of life improvements in patients with PD and documented the initial viability of this novel approach for dysphagia rehabilitation, albeit in a small sample. Findings suggest that skill training may have increased the neuromuscular co-ordination, timing, speed of reaction and planning of movement of oro-lingual structures in this sample. Additionally, heightened cortical awareness may have contributed to better movement planning and sequencing, resulting in efficient and safe swallowing in this group. However, future replications with a larger population controlling for the above discussed limitations are needed before the findings can be generalised to the broader population.

References

Aarsland, D., Tandberg, E., Larsen, J. P., & Cummings, J. L. (1996). Frequency of dementia in Parkinson disease. *Archives of Neurology, 53*(6), 538-542.

Adkins, D. L., Boychuk, J., Remple, M. S., & Kleim, J. A. (2006). Motor training induces experience-specific patterns of plasticity across motor cortex and spinal cord. *Journal of Applied Physiology, 101*(6), 1776-1782.

Adler, C. H. (2005). Nonmotor complications in Parkinson's disease. *Movement Disorders: official journal of the Movement Disorder Society, 20 Suppl 11*, S23-29.

Ali, G. N., Wallace, K. L., Schwartz, R., DeCarle, D. J., Zagami, A. S., & Cook, I. J. (1996). Mechanisms of oral-pharyngeal dysphagia in patients with Parkinson's disease. *Gastroenterology, 110*(2), 383-392.

Aydogdu, I., Tanriverdi, Z., & Ertekin, C. (2011). Dysfunction of bulbar central pattern generator in ALS patients with dysphagia during sequential deglutition. *Clinical Neurophysiology, 122*(6), 1219-1228.

Baijens, L. W., & Speyer, R. (2009). Effects of therapy for dysphagia in Parkinson's disease: systematic review. *Dysphagia, 24*(1), 91-102.

Baker, S., Davenport, P., & Sapienza, C. (2005). Examination of strength training and detraining effects in expiratory muscles. *Journal of Speech, Language, and Hearing Research, 48*(6), 1325-1333.

Barofsky, I. (1995). Surface electromyographic biofeedback and the patient with dysphagia: clinical opportunities and research questions. *Dysphagia, 10*(1), 19-21.

Basmajian, J. V. (1989). *Biofeedback: principles and practice for clinicians*. Baltimore, MD: Williams & Wilkins.

Bass, N., & Morrell, R. (1992). The Neurology of Swallowing. In M.Groher (Ed.), *Dysphagia: Diagnosis and Management* (2 ed., pp. 2). Massachusetts: Butterworth-Heinimann.

Bauer, S., (2010). *An ultrasound-based comparison of exercises concerning suprahyoidal muscles and hyoid movement - A controlled trial with healthy adults* (Master's Thesis). University of Canterbury, Christchurch, New Zealand.

Bayona, N. A., Bitensky, J., Salter, K., & Teasell, R. (2005). The role of task-specific training in rehabilitation therapies. *Topics in Stroke Rehabilitation, 12*(3), 58-65.

Belafsky, P. C., Mouadeb, D. A., Rees, C. J., Pryor, J. C., Postma, G. N., Allen, J., et al. (2008). Validity and reliability of the Eating Assessment Tool (EAT-10). *Annals of Otolology, Rhinology, and Laryngology, 117*(12), 919-924.

Bird, M. R., Woodward, M. C., Gibson, E. M., Phyland, D. J., & Fonda, D. (1994). Asymptomatic swallowing disorders in elderly patients with Parkinson's disease: a description of findings on clinical examination and videofluoroscopy in sixteen patients. *Age and Ageing, 23*(3), 251-254.

Bland, J. M., & Altman, D. G. (1995). Multiple significance tests: the Bonferroni method. *British Medical Journal, 310*(6973), 170.

Bodén, K., Hallgren, A., & Witt Hedström, H. (2006). Effects of three different swallow maneuvers analyzed by videomanometry. *Acta Radiologica, 47*(7), 628-633.

Brodsky, M. B., Abbott, K. V., McNeil, M. R., Palmer, C. V., Grayhack, J. P., & Martin-Harris, B. (2011). Effects of Divided Attention on Swallowing in Persons with Idiopathic Parkinson's Disease. *Dysphagia*. DOI: 10.1007/s00455-011-9381-x

Bryant, M. (1991). Biofeedback in the treatment of a selected dysphagic patient. *Dysphagia, 6*(3), 140-144.

Buchholz, D. (1987). Neurologic causes of dysphagia. *Dysphagia*(3), 152-156.

Bülow, M., Olsson, R., & Ekberg, O. (2001). Videomanometric analysis of supraglottic swallow, effortful swallow, and chin tuck in patients with pharyngeal dysfunction. *Dysphagia, 16*(3), 190-195.

Buonomano, D. V., & Merzenich, M. M. (1998). Cortical plasticity: from synapses to maps. *Annual Review of Neuroscience, 21*, 149-186.

Burgio, K. L., Locher, J. L., Goode, P. S., Hardin, J. M., McDowell, B. J., Dombrowski, M., et al. (1998). Behavioural vs drug treatment for urge urinary incontinence in older women: a randomized controlled trial. *Journal of the American Medical Association, 280*(23), 1995-2000.

Burkhead, L. M., Sapienza, C. M., & Rosenbek, J. C. (2007). Strength-training exercise in dysphagia rehabilitation: principles, procedures, and directions for future research. *Dysphagia, 22*(3), 251-265.

Bury, S. D., & Jones, T. A. (2002). Unilateral sensorimotor cortex lesions in adult rats facilitate motor skill learning with the "unaffected" forelimb and training-induced dendritic structural plasticity in the motor cortex. *Journal of Neuroscience, 22*(19), 8597-8606.

Bushmann, M., Dobmeyer, S. M., Leeker, L., & Perlmutter, J. S. (1989). Swallowing abnormalities and their response to treatment in Parkinson's disease. *Neurology, 39*(10), 1309-1314.

Cakit, B. D., Saracoglu, M., Genc, H., Erdem, H. R., & Inan, L. (2007). The effects of incremental speed-dependent treadmill training on postural instability and fear of falling in Parkinson's disease. *Clinical Rehabilitation, 21*(8), 698-705.

Carroll, T. J., Riek, S., & Carson, R. G. (2002). The sites of neural adaptation induced by resistance training in humans. *The Journal of Physiology, 544*(Pt 2), 641-652.

Clark, H. M. (2003). Neuromuscular treatments for speech and swallowing: a tutorial. *American Journal of Speech-Language Pathology, 12*(4), 400-415.

Clark, H. M., Henson, P. A., Barber, W. D., Stierwalt, J. A., & Sherrill, M. (2003). Relationships among subjective and objective measures of tongue strength and oral phase swallowing impairments. *American Journal of Speech-Language Pathology, 12*(1), 40-50.

Clark, H. M., O'Brien, K., Calleja, A., & Corrie, S. N. (2009). Effects of directional exercise on lingual strength. *Journal of Speech, Language, and Hearing Research, 52*(4), 1034-1047.

Coates, C., & Bakheit, A. M. (1997). Dysphagia in Parkinson's disease. *European Neurology, 38*(1), 49-52.

Cook, I. J., Dodds, W. J., Dantas, R. O., Kern, M. K., Massey, B. T., Shaker, R., et al. (1989). Timing of videofluoroscopic, manometric events, and bolus transit during the oral and pharyngeal phases of swallowing. *Dysphagia, 4*(1), 8-15.

Craig, A. R., & Cleary, P. J. (1982). Reduction of stuttering by young male stutterers using EMG feedback. *Biofeedback and Self-Regulation, 7*(3), 241-255.

Crary, M. A. (1995). A direct intervention program for chronic neurogenic dysphagia secondary to brainstem stroke. *Dysphagia, 10*(1), 6-18.

Crary, M. A., Carnaby, G. D., Groher, M. E., & Helseth, E. (2004). Functional benefits of dysphagia therapy using adjunctive sEMG biofeedback. *Dysphagia, 19*(3), 160-164.

Crary, M.A., & Groher, M.E., (2000). Basic concepts of surface electromyographic biofeedback in the treatment of dysphagia: A tutorial. *American Journal of Speech-Language Pathology, 9*(2), 116.

Cunnington, R., Iansek, R., Bradshaw, J. L., & Phillips, J. G. (1995). Movement-related potentials in Parkinson's disease. Presence and predictability of temporal and spatial cues. *Brain, 118 (Pt 4)*, 935-950.

Daniels, S. K. (2000). Swallowing apraxia: a disorder of the Praxis system? *Dysphagia, 15*(3), 159-166.

Daniels, S. K., & Huckabee, M. L. (2008). *Dysphagia following stroke*. San Diego, CA: Plural publishing.

Debaere, F., Wenderoth, N., Sunaert, S., Van Hecke, P., & Swinnen, S. P. (2003). Internal versus external generation of movements: differential neural pathways involved in bimanual coordination performed in the presence or absence of augmented visual feedback. *Neuroimage, 19*(3), 764-776.

Dodds, W. J., Stewart, E. T., & Logemann, J. A. (1990). Physiology and radiology of the normal oral and pharyngeal phases of swallowing. *American Journal of Roentgenology, 154*(5), 953-963.

Doeltgen, S. H., Witte, U., Gumbley, F., & Huckabee, M. L. (2009). Evaluation of manometric measures during tongue-hold swallows. *American Journal of Speech-Language Pathology, 18* (1), 65-73

Donner, M. W., Bosma, J. F., & Robertson, D. L. (1985). Anatomy and physiology of the pharynx. *Gastrointestinal Radiology, 10*(3), 196-212.

Duffau, H. (2006). Brain plasticity: from pathophysiological mechanisms to therapeutic applications. *Journal of Clinical Neuroscience, 13*(9), 885-897.

Duffy, J. R. (1995). *Motor Speech Disorders: substrates, differential diagnosis, and management* (1st ed.). St. Louis, MO: Don Ladig.

Dworkin, J. P., & Hartman, D. E. (1979). Progressive speech deterioration and dysphagia in amyotrophic lateral sclerosis: case report. *Archives of Physical Medicine Rehabilitation, 60*(9), 423-425.

Eadie, M. J., & Tyrer, J. H. (1965). Alimentary disorder in Parkinsonism. *Australasian Annals of Medicine, 14*, 13-22.

Easterling, C., Grande, B., Kern, M., Sears, K., & Shaker, R. (2005). Attaining and maintaining isometric and isokinetic goals of the Shaker exercise. *Dysphagia, 20*(2), 133-138.

Ebihara S., Saito H., Kanda A., Nakajoh M., & et al. (2003). Impaired efficacy of cough in patients with Parkinson disease. *Chest*, *124*(3), 1009-15.

Ekberg, O. (1986). The normal movements of the hyoid bone during swallow. *Investigative Radiology, 21*(5), 408-410.

El Sharkawi, A., Ramig, L., Logemann, J. A., Pauloski, B. R., Rademaker, A. W., Smith, C. H., et al. (2002). Swallowing and voice effects of Lee Silverman Voice Treatment (LSVT): a pilot study. *Journal of Neurology, Neurosurgery, and Psychiatry, 72*(1), 31-36.

Fall, P. A., Saleh, A., Fredrickson, M., Olsson, J. E., & Granerus, A. K. (2003). Survival time, mortality, and cause of death in elderly patients with Parkinson's disease: a 9-year follow-up. *Movement Disorders, 18*(11), 1312-1316.

Felix, V. N., Corrêa, S. M., & Soares, R. J. (2008). A therapeutic maneuver for oropharyngeal dysphagia in patients with Parkinson's disease. *Clinics (Sao Paulo, Brazil), 63*(5), 661-666.

Fisher, B. E., Wu, A. D., Salem, G. J., Song, J., Lin, C. H., Yip, J., et al. (2008). The effect of exercise training in improving motor performance and corticomotor excitability in people with early Parkinson's disease. *Archives of Physical Medicine and Rehabilitation, 89*(7), 1221-1229.

Fitzgerald, S., Huckabee, M. L., Lin, E., Coombes, T., & Bryant, M. (2004). Perception of muscle strength with and without biofeedback during swallowing and fist-clenching tasks. *Contemporary Issues in Communication Science and Disorders, 31*, 225–235.

Folland, J. P., & Williams, A. G. (2007). The adaptations to strength training: morphological and neurological contributions to increased strength. *Sports Medicine, 37*(2), 145-168.

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

Fujiu, M., Logemann, J. A., & Pauloski, B. R. (1995). Increased postoperative posterior phrayngeal wall movement in patients with anterior oral cancer:preliminary findings and possible implications for treatment. *American Journal of Speech-Language Pathology, 4*(2), 24-30.

Garcia, J. M., Hakel, M., & Lazarus, C. (2004). Unexpected consequence of effortful swallowing: case study report. *Journal of Medical Speech-Language Pathology*, *12*(2), 59-66.

Goetz, C. G., Tilley, B. C., Shaftman, S. R., Stebbins, G. T., Fahn, S., Martinez-Martin, P., et al. (2008). Movement Disorder Society-sponsored revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS): scale presentation and clinimetric testing results. *Movement Disorders, 23*(15), 2129-2170.

Guttman, M., Kish, S. J., & Furukawa, Y. (2003). Current concepts in the diagnosis and management of Parkinson's disease. *Canadian Medical Association Journal, 168*(3), 293-301.

Guyatt, G. H., Feeny, D. H., & Patrick, D. L. (1993). Measuring health--related quality of life. *Annals of Internal Medicine, 118*(8), 622.

Hamdy, S., Aziz, Q., Rothwell, J. C., Singh, K. D., Barlow, J., Hughes, D. G., et al. (1996). The cortical topography of human swallowing musculature in health and disease. *Nature Medicine, 2*(11), 1217-1224.

Hamdy, S., Rothwell, J. C., Aziz, Q., & Thompson, D. G. (2000). Organization and reorganization of human swallowing motor cortex: implications for recovery after stroke. *Clinical Science, 99*(2), 151-157.

Han, B. U. (2009). Specification for sEMG biofeedback software. Retrieved from Department of Electrical Engineering, University of Canterbury. Christchurch: New Zealand.

Hely, M. A., Morris, J. G., Reid, W. G., & Trafficante, R. (2005). Sydney Multicenter Study of Parkinson's disease: non-L-dopa-responsive problems dominate at 15 years. *Movement Disorders, 20*(2), 190-199.

Herman, T., Giladi, N., & Hausdorff, J. M. (2009). Treadmill training for the treatment of gait disturbances in people with Parkinson's disease: a mini-review. *Journal of Neural Transmission, 116*(3), 307-318.

Herman, T., Giladi, N., Gruendlinger, L., & Hausdorff, J. M. (2007). Six weeks of intensive treadmill training improves gait and quality of life in patients with Parkinson's disease: a pilot study. *Archives of Physical Medicine and Rehabilitation, 88*(9), 1154-1158.

Hind, J. A., Nicosia, M. A., Roecker, E. B., Carnes, M. L., & Robbins, J. (2001). Comparison of effortful and noneffortful swallows in healthy middle-aged and older adults. *Archives of Physical Medicine and Rehabilitation, 82*(12), 1661-1665.

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

Hubbard, I. J., Parsons, M. W., Neilson, C., & Carey, L. M. (2009). Task-specific training: evidence for and translation to clinical practice. *Occupational Therapy International, 16*(3-4), 175-189.

Huckabee, M. L. & Kelly, B.N. (2005). Rehabilitation models in dysphagia management: A case for swallowing apraxia and spastic dysphagia. In S. Stanschus (Ed.), *Methoden in der Klinischen Dysphagiologie*. Schulz-Kirchner Verlag, Idstein

Huckabee, M. L., & Cannito, M. P. (1999). Outcomes of swallowing rehabilitation in chronic brainstem dysphagia: A retrospective evaluation. *Dysphagia, 14*(2), 93-109.

Huckabee, M. L., & Pelletier, C. A. (1998). *Management of Adult Neurogenic Dysphagia*. San Diego, CA: Singular Publishing Group.

Huckabee, M. L., Butler, S. G., Barclay, M., & Jit, S. (2005). Submental Surface Electromyographic Measurement and Pharyngeal Pressures During Normal and effortful Swallowing. *Archives of Physical Medicine and Rehabilitation, 86*(11), 2144–2149.

Hughes, T. A., & Wiles, C. M. (1996). Clinical measurement of swallowing in health and in neurogenic dysphagia. *QJM: monthly journal of the Association of Physicians, 89*(2), 109-116.

Ishida, R., Palmer, J. B., & Hiiemae, K. M. (2002). Hyoid motion during swallowing: factors affecting forward and upward displacement. *Dysphagia, 17*(4), 262-272.

Jankovic, J. (2008). Parkinson's disease: clinical features and diagnosis. *Journal of Neurology, Neurosurgery, and Psychiatry, 79*(4), 368-376.

Jensen, J. L., Marstrand, P. C., & Nielsen, J. B. (2005). Motor skill training and strength training are associated with different plastic changes in the central nervous system. *Journal of Applied Physiology, 99*(4), 1558-1568.

Johnston, B. T., Li, Q., Castell, J. A., & Castell, D. O. (1995). Swallowing and esophageal function in Parkinson's disease. *American Journal of Gastroenterology, 90*(10), 1741-1746.

Kahrilas, P. J., Lin, S., Chen, J., & Logemann, J. A. (1996). Oropharyngeal accommodation to swallow volume. *Gastroenterology, 111*(2), 297-306.

Kahrilas, P. J., Lin, S., Logemann, J. A., Ergun, G. A., & Facchini, F. (1993). Deglutitive tongue action: volume accommodation and bolus propulsion. *Gastroenterology, 104*(1), 152-162.

Kahrilas, P. J., Logemann, J. A., Krugler, C., & Flanagan, E. (1991). Volitional augmentation of upper esophageal sphincter opening during swallowing. *American Journal of Physiology, 260*(3 Pt 1), G450-456.

Kahrilas, P. J., Logemann, J. A., Lin, S., & Ergun, G. A. (1992). Pharyngeal clearance during swallowing: a combined manometric and videofluoroscopic study. *Gastroenterology, 103*(1), 128-136.

Karni, A., Meyer, G., Jezzard, P., Adams, M. M., Turner, R., & Ungerleider, L. G. (1995). Functional MRI evidence for adult motor cortex plasticity during motor skill learning. *Nature, 377*(6545), 155-158.

Kim, J., & Sapienza, C. M. (2005). Implications of expiratory muscle strength training for rehabilitation of the elderly: Tutorial. *Journal of Rehabilitation Research & Development, 42*(2), 211-224.

Kim, J., Davenport, P., & Sapienza, C. (2009). Effect of expiratory muscle strength training on elderly cough function. *Archives of Gerontology Geriatrics, 48*(3), 361-366.

Kleim, J. A., Barbay, S., & Nudo, R. J. (1998). Functional reorganization of the rat motor cortex following motor skill learning. *Journal of Neurophysiology, 80*(6), 3321-3325.

Kleim, J. A., Barbay, S., Cooper, N. R., Hogg, T. M., Reidel, C. N., Remple, M. S., et al. (2002). Motor learning-dependent synaptogenesis is localized to functionally reorganized motor cortex. *Neurobiology of Learning and Memory, 77*(1), 63-77.

Kleim, J. A., Hogg, T., Whishaw, I., Reidel, C., Cooper, N., & VandenBerg, P. (2000). Time course and persistence of motor learning dependent changes in the functional organization of the motor cortex. *Society for Neuroscience, Abstract*, 26: 475

Kleim, J. A., Monfils, M.-H., & Plautz, E. J. In search of the motor engram: motor map plasticity as a mechanism for encoding motor experience. *The Neuroscientist, 11*(5), 471-483.

Krakauer, J. W. (2006). Motor learning: its relevance to stroke recovery and neurorehabilitation. *Current Opinion in Neurology, 19*(1), 84-90.

Lam, K., Lam, F. K., Lau, K. K., Chan, Y. K., Kan, E. Y., Woo, J., et al. (2007). Simple clinical tests may predict severe oropharyngeal dysphagia in Parkinson's disease. *Movement Disorders, 22*(5), 640-644.

Landis, J.R., Koch, G.G. (1977). The measurement of observer agreement for categorical data. *Biometrics, 33* (1), 159-74.

Langmore, S. E. (2001). Normal swallowing: The endoscopic perspective. In S. E. Langmore (Eds.). *Endoscopic Evaluation and Treatment of Swallowing Disorders* (pp. 37-60). New York: Thieme.

Langmore, S. E., Terpenning, M. S., Schork, A., Chen, Y., Murray, J. T., Lopatin, D., et al. (1998). Predictors of aspiration pneumonia: how important is dysphagia? *Dysphagia, 13*(2), 69-81.

Lazarus, C. (2006). Tongue strength and exercise in healthy individuals and in head and neck cancer patients. *Seminars in Speech and Language, 27*(4), 260-267.

Lazarus, C., Logemann, J. A., Huang, C. F., & Rademaker, A. W. (2003). Effects of two types of tongue strengthening exercises in young normals. *Folia Phoniatrica et Logopaedica,, 55*(4), 199-205.

Lazarus, C., Logemann, J. A., Song, C. W., Rademaker, A. W., & Kahrilas, P. J. (2002). Effects of voluntary maneuvers on tongue base function for swallowing. *Folia Phoniatrica et Logopaedica, 54*(4), 171-176.

Leopold, N. A., & Kagel, M. C. (1996). Prepharyngeal dysphagia in Parkinson's disease. *Dysphagia, 11*(1), 14-22.

Leopold, N. A., & Kagel, M. C. (1997). Dysphagia—ingestion or deglutition?: A proposed Paradigm. *Dysphagia*(4), 202-206.

Leopold, N. A., & Kagel, M. C. (1997). Pharyngo-esophageal dysphagia in Parkinson's disease. *Dysphagia, 12*(1), 11-18; discussion 19-20.

Leow, L. P., Huckabee, M. L., Anderson, T., & Beckert, L. (2010). The impact of dysphagia on quality of life in ageing and Parkinson's disease as measured by the swallowing quality of life (SWAL-QOL) questionnaire. *Dysphagia, 25*(3), 216-220.

Liepert, J., Bauder, H., Wolfgang, H. R., Miltner, W. H., Taub, E., & Weiller, C. (2000). Treatment-induced cortical reorganization after stroke in humans. *Stroke, 31*(6), 1210-1216.

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology, 140*, 5-55.

Logemann, J. A. (1983). *Evaluation and Treatment of Swallowing Disorders*. Austin, Texas: Pro-ed.

Logemann, J. A. (1988). Swallowing physiology and pathophysiology. *Otolaryngology Clinics of North America, 21*(4), 613-623.

Logemann, J. A. (1990). Effects of aging on the swallowing mechanism. *Otolaryngologic Clinics of North America, 23*(6), 1045-1056.

Logemann, J. A., & Kahrilas, P. J. (1990). Relearning to swallow after stroke--application of maneuvers and indirect biofeedback: a case study. *Neurology, 40*(7), 1136-1138.

Logemann, J. A., Fisher, H. B., Boshes, B., & Blonsky, E. R. (1978). Frequency and cooccurrence of vocal tract dysfunctions in the speech of a large sample of Parkinson patients. *Journal of Speech and Hearing Disorders, 43*(1), 47-57.

Logemann, J. A., Rademaker, A., Pauloski, B. R., Kelly, A., Stangl-McBreen, C., Antinoja, J., et al. (2009). A randomized study comparing the Shaker exercise with traditional therapy: a preliminary study. *Dysphagia, 24*(4), 403-411.

Love, R. J., & Webb, W. G. (1996). *Neurology for the Speech-Language Pathologist* (3rd ed.). Newton: MA: Butterworth-Heinemann.

Ludlow, C. L., Hoit, J., Kent, R., Ramig, L. O., Shrivastav, R., Strand, E., et al. (2008). Translating principles of neural plasticity into research on speech motor control recovery and rehabilitation. *Journal of Speech Language and Hearing Research, 51*(1), S240-258.

Macrae, P. R., Doeltgen, S. H., Jones, R. D., & Huckabee, M. L. (2012). Intra- and inter-rater reliability for analysis of hyoid displacement measured with sonography. *Journal of Clinical Ultrasound, 40*(2), 74-78.

Mark, V. W., & Taub, E. (2004). Constraint-induced movement therapy for chronic stroke hemiparesis and other disabilities. *Restorative Neurology and Neuroscience, 22*(3-5), 317-336.

Marks, L., & Rainbow, D. (2001). *Working with Dysphagia*. Oxon, UK: Speechmark.

Martin, W. R. W., & Wieler, M. (2003). Treatment of Parkinson's Disease. *The Canadian Journal of Neurological Sciences, 30*(0), 27-33.

McConnel, F. M., Cerenko, D., Jackson, R. T., & Guffin, T. N., Jr. (1988). Timing of major events of pharyngeal swallowing. *Archives of Otolaryngology Head Neck Surgery, 114*(12), 1413-1418.

McFarland, D. H., & Tremblay, P. (2006). Clinical implications of cross-system interactions. *Seminars in Speech and Language, 27*(4), 300-309.

McHorney, C. A., Bricker, D. E., Kramer, A. E., Rosenbek, J. C., Robbins, J., Chignell, K. A., et al. (2000a). The SWAL-QOL outcomes tool for oropharyngeal dysphagia in adults: I. Conceptual foundation and item development. *Dysphagia, 15*(3), 115-121.

McHorney, C. A., Bricker, D. E., Robbins, J., Kramer, A. E., Rosenbek, J. C., & Chignell, K. A. (2000b). The SWAL-QOL outcomes tool for oropharyngeal dysphagia in adults: II. Item reduction and preliminary scaling. *Dysphagia, 15*(3), 122-133.

McHorney, C. A., Martin-Harris, B., Robbins, J., & Rosenbek, J. (2006). Clinical validity of the SWAL-QOL and SWAL-CARE outcome tools with respect to bolus flow measures. *Dysphagia, 21*(3), 141-148.

McHorney, C. A., Robbins, J., Lomax, K., Rosenbek, J. C., Chignell, K., Kramer, A. E., et al. (2002). The SWAL-QOL and SWAL-CARE outcomes tool for oropharyngeal dysphagia in adults: III. Documentation of reliability and validity. *Dysphagia, 17*(2), 97-114.

Miller, A. J. (1982). Deglutition. *Physiological Reviews, 62*(1), 129-184.

Miller, A. J. (2008). The neurobiology of swallowing and dysphagia. *Development Disabilities Research Reviews, 14*(2), 77-86.

Miller, N., Allcock, L., Hildreth, A. J., Jones, D., Noble, E., & Burn, D. J. (2009). Swallowing problems in Parkinson disease: frequency and clinical correlates. *Journal of Neurology, Neurosurgery and Psychiatry, 80*(9), 1047-1049.

Miller, N., Noble, E., Jones, D., & Burn, D. (2006). Hard to swallow: dysphagia in Parkinson's disease. *Age and Ageing, 35*(6), 614-618.

Miyai, I., Fujimoto, Y., Ueda, Y., Yamamoto, H., Nozaki, S., Saito, T., et al. (2000). Treadmill training with body weight support: its effect on Parkinson's disease. *Archives of Physical Medicine and Rehabilitation, 81*(7), 849-852.

Moldover, J.R., & Borg-Stein, J. (1994). Exercise and Fatigue. In J. A. Downey, S. J. Myers, E. G. Gonzalez & J. S. Liberman (Eds.), *The Physiological Basis of Rehabilitation Medicine* (pp. 393-411). Stoneham, MA: Butterworth-Heinemann.

Moore, N. C. (2000). A review of EEG biofeedback treatment of anxiety disorders. *Clinical Electroencephalography, 31*(1), 1-6.

Morgan, A. T., & Ward, E. C. (2001). Swallowing disorders following traumatic brain injury. In B. E. Murdoch & D. G. Theodoros (Eds.), *Traumatic brain injury associated with speech, language and swallowing disorders* (pp. 312-341). San Diego: Singular Thompson Learning.

Moritani, T. (1993). Neuromuscular adaptations during the acquisition of muscle strength, power and motor tasks. *Journal of Biomechanics, 26 Suppl 1*, 95-107.

Morris, M. E., Iansek, R., Matyas, T. A., & Summers, J. J. (1996). Stride length regulation in Parkinson's disease. Normalization strategies and underlying mechanisms. *Brain, 119 (Pt 2)*, 551-568.

Morris, M. E., Martin, C. L., & Schenkman, M. L. (2010). Striding out with Parkinson disease: evidence-based physical therapy for gait disorders. *Physical Therapy, 90*(2), 280-288.

Mulder, T., & Hulstyn, W. (1984). Sensory feedback therapy and theoretical knowledge of motor control and learning. *American Journal of Physical Medicine, 63*(5), 226-244.

Munchau, A., & Bhatia, K. P. (2000). Pharmacological treatment of Parkinson's disease. *Postgraduate Medical Journal, 76*(900), 602-610.

Mutch, W. J., Strudwick, A., Roy, S. K., & Downie, A. W. (1986). Parkinson's disease: disability, review, and management. *British Medical Journal (Clinical Research Ed), 293*(6548), 675-677.

Nagaya, M., Kachi, T., & Yamada, T. (2000). Effect of swallowing training on swallowing disorders in Parkinson's disease. *Scandinavian Journal of Rehabilitation Medicine, 32*(1), 11-15.

Nagaya, M., Kachi, T., Yamada, T., & Igata, A. (1998). Videofluorographic study of swallowing in Parkinson's disease. *Dysphagia, 13*(2), 95-100.

Narici, M. V., Roi, G. S., Landoni, L., Minetti, A. E., & Cerretelli, P. (1989). Changes in force, cross-sectional area and neural activation during strength training and detraining of the human quadriceps. *European Journal of Applied Physiology Occupational Physiology, 59*(4), 310-319.

Nathadwarawala, K. M., McGroary, A., & Wiles, C. M. (1994). Swallowing in neurological outpatients: use of a timed test. *Dysphagia, 9*(2), 120-129.

Nelson, L. A. (2007). The role of biofeedback in stroke rehabilitation: past and future directions. *Topics in Stroke Rehabilitation, 14*(4), 59-66.

Nicholson, G., Pereira, A. C., & Hall, G. M. (2002). Parkinson's disease and anaesthesia. *British Journal of Anaesthesia, 89*(6), 904-916.

Nilsson, H., Ekberg, O., Olsson, R., & Hindfelt, B. (1996). Quantitative assessment of oral and pharyngeal function in Parkinson's disease. *Dysphagia, 11*(2), 144-150.

Nudo, R. J. (2003). Adaptive plasticity in motor cortex: implications for rehabilitation after brain injury. *Journal of Rehabilitation Medicine* (41 Suppl), 7-10.

Nudo, R. J. (2007). The role of skill versus use in the recovery of motor function after stroke. *Occupation, Participation and Health, 27*, 24S-32S.

Nudo, R. J., Plautz, E. J., & Frost, S. B. (2001). Role of adaptive plasticity in recovery of function after damage to motor cortex. *Muscle & Nerve, 24*(8), 1000-1019.

Olson, R. P. (1995). Definitions of biofeedback and applied psychophysiology. In M. Schwartz (Ed.), *Biofeedback: A practitioner's guide* (2 ed., pp. 27-31). New York: the Guilford Press.

Palmer, J. B., Drennan, J. C., & Baba, M. (2000). Evaluation and treatment of swallowing impairments. *American Family Physician, 61*(8), 2453-2462.

Perez, M. A., Lungholt, B. K., Nyborg, K., & Nielsen, J. B. (2004). Motor skill training induces changes in the excitability of the leg cortical area in healthy humans. *Experimental Brain Research, 159*(2), 197-205.

Perlman, A. L., & Christensen, J. (1997). Topography and functional anatomy of swallowing structures. In A. L. Perlman & K. Schulze-Delrieu (Eds.), *Deglutition and its disorders. Anatomy, Physiology, Clinical diagnosis and Management* (pp. 15-42). Clifton Park, NY: Thomson Delmar Learning.

Perlman, A. L., VanDaele, D. J., & Otterbacher, M. S. (1995). Quantitative assessment of hyoid bone displacement from video images during swallowing. *Journal of Speech and Hearing Research, 38*(3), 579-585.

Perneger, T. V. (1998). What's wrong with Bonferroni adjustments. *British Medical Journal, 316*(7139), 1236-1238.

Petzinger, G. M., Fisher, B. E., Van Leeuwen, J. E., Vukovic, M., Akopian, G., Meshul, C. K., et al. (2010). Enhancing neuroplasticity in the basal ganglia: the role of exercise in Parkinson's disease. *Movement Disorders, 25 Suppl 1*, S141-145.

Pitts, T., Bolser, D., Rosenbek, J., Troche, M., Okun, M. S., & Sapienza, C. (2009). Impact of expiratory muscle strength training on voluntary cough and swallow function in Parkinson disease. *Chest, 135*(5), 1301-1308.

Plautz EJ, Nudo RJ, Barbay S, Friel KM, Kleim JA, Frost SB. (1999). Persistence of neurophysiological changes associated with motor skill acquisition. *Society of Neuroscience Abstract,* **25**: 1409

Plautz, E. J., Milliken, G. W., & Nudo, R. J. (2000). Effects of repetitive motor training on movement representations in adult squirrel monkeys: role of use versus learning. *Neurobiology of Learning and Memory, 74*(1), 27-55.

Plowman-Prine, E. K., Sapienza, C. M., Okun, M. S., Pollock, S. L., Jacobson, C., Wu, S. S., et al. (2009). The relationship between quality of life and swallowing in Parkinson's disease. *Movement Disorders: official journal of the Movement Disorder Society, 24*(9), 1352-1358.

Portney LG & Watkins MP (2000) *Foundations of clinical research Applications to practice* (pp. 560- 567). New Jersey: Prentice Hall Inc.

Potulska, A., Friedman, A., Krolicki, L., & Spychala, A. (2003). Swallowing disorders in Parkinson's disease. *Parkinsonism & Relatated Disorders, 9*(6), 349-353.

Pullman, S. L., Watts, R. L., Juncos, J. L., Chase, T. N., & Sanes, J. N. (1988). Dopaminergic effects on simple and choice reaction time performance in Parkinson's disease. *Neurology, 38*(2), 249-254.

Ramig, L. O., Countryman, S., Thompson, L. L., & Horii, Y. (1995). Comparison of two forms of intensive speech treatment for Parkinson disease. *Journal of Speech and Hearing Research, 38*(6), 1232-1251.

Reddy, N. P., Simcox, D. L., Gupta, V., Motta, G. E., Coppenger, J., Das, A., et al. (2000). Biofeedback therapy using accelerometry for treating dysphagic patients with poor laryngeal elevation: case studies. *Journal of Rehabilitation Research and Development, 37*(3), 361-372.

Remple, M. S., Bruneau, R. M., VandenBerg, P. M., Goertzen, C., & Kleim, J. A. (2001). Sensitivity of cortical movement representations to motor experience: evidence that skill learning but not strength training induces cortical reorganization. *Behavioural Brain Research, 123*(2), 133-141.

Robbins J.A., Gangnon, R. E., Theis, S. M., Kays, S. A., Hewitt, A. L., & Hind, J. A. (2005). The effects of lingual exercise on swallowing in older adults. *Journal of the American Geriatrics society, 53,* 1483–1489.

Robbins, J. A., Logemann, J. A., & Kirshner, H. S. (1986). Swallowing and speech production in Parkinson's disease. *Annals of Neurology, 19*(3), 283-287.

Robbins, J., Butler, S. G., Daniels, S. K., Diez Gross, R., Langmore, S., Lazarus, C. L., et al. (2008). Swallowing and dysphagia rehabilitation: translating principles of neural plasticity into clinically oriented evidence. *Journal of Speech, Language, and Hearing Research, 51*(1), S276-300.

Robbins, J., Kays, S. A., Gangnon, R. E., Hind, J. A., Hewitt, A. L., Gentry, L. R., et al. (2007). The effects of lingual exercise in stroke patients with dysphagia. *Archives of Physical Medicine and Rehabilitation, 88*(2), 150-158.

Rochester, L., Hetherington, V., Jones, D., Nieuwboer, A., Willems, A. M., Kwakkel, G., et al. (2005). The effect of external rhythmic cues (auditory and visual) on walking during a functional task in homes of people with Parkinson's disease. *Archives of Physical Medicine and Rehabilitation, 86*(5), 999-1006.

Rose, D. J. (1997). *A multilevel approach to the study of motor control and learning*. Needham Heights, MA: Allyn & Bacon.

Rubow, R., & Swift, E. (1985). A microcomputer-based wearable biofeedback device to improve transfer of treatment in parkinsonian dysarthria. *Journal of Speech and Hearing Disorders, 50*(2), 178-185.

Sapienza, C. M., & Wheeler, K. (2006). Respiratory muscle strength training: functional outcomes versus plasticity. *Seminars in Speech and Language, 27*(4), 236-244.

Sapir S, Ramig L, Fox C. Voice, speech and swallowing disorders (2008). In: S. Factor & W. Weiner, (Eds.), *Parkinson disease: diagnosis and clinical management (*pp. 77–97). New York City: Demos Medical Publishing.

Schapira, A. H., Bezard, E., Brotchie, J., Calon, F., Collingridge, G. L., Ferger, B., et al. (2006). Novel pharmacological targets for the treatment of Parkinson's disease. *Nature Reviews Drug Discovery, 5*(10), 845-854.

Shaker, R., Easterling, C., Kern, M., Nitschke, T., Massey, B., Daniels, S., et al. (2002). Rehabilitation of swallowing by exercise in tube-fed patients with pharyngeal dysphagia secondary to abnormal UES opening. *Gastroenterology, 122*(5), 1314-1321.

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

Shaker, R., Ren, J., Bardan, E., Easterling, C., Dua, K., Xie, P., et al. (2003). Pharyngoglottal closure reflex: characterization in healthy young, elderly and dysphagic patients with predeglutitive aspiration. *Gerontology, 49*(1), 12-20.

Sheridan, M. R., Flowers, K. A., & Hurrell, J. (1987). Programming and execution of movement in Parkinson's disease. *Brain, 110 (Pt 5)*, 1247-1271.

Shumway-Cook, A., & Woollacott, M. H. (2001) *Motor control theory and practical applications.* (second ed.). Baltimore, MD: Lippincott Williams & Wilkins.

Sonies, B. C., Parent, L. J., Morrish, K., & Baum, B. J. (1988). Durational aspects of the oral-pharyngeal phase of swallow in normal adults. *Dysphagia, 3*(1), 1-10.

Sonies, B. C., Parent, L. J., Morrish, K., & Baum, B. J. (1988). Durational aspects of the oral-pharyngeal phase of swallow in normal adults. *Dysphagia, 3*(1), 1-10.

Sonies, B. C., Wang, C., & Sapper, D. J. (1996). Evaluation of normal and abnormal hyoid bone movement during swallowing by use of ultrasound duplex-Doppler imaging.*Ultrasound in Medicine & Biology, 22*(9), 1169-1175.

Steele, C. M., Bailey, G. L., Monlfenter, S. M., & Yeates, E. M. (2009). Rationale for strength and skill goals in tongue resistance training: a review. *American Speech-Language-Hearing Association, 18*(2), 49-54.

Stroudley, J., & Walsh, M. (1991). Radiological assessment of dysphagia in Parkinson's disease. *The British Journal of Radiology, 64*(766), 890-893.

Sundgren, P., Maly, P., & Gullberg, B. (1993). Elevation of the larynx on normal and abnormal cineradiogram. *British journal of Radiology, 66*(789), 768-772.

The Parkinsonism society of New Zealand. (n.d) Retrieved from http://www.parkinsons.org.nz/what-parkinsons

Thought Technology Ltd. (n.d.) *Basics of surface electromyography applied to psychophysiology.* Retrieved October, 2008, from http://www.thoughttechnology.com/bioinfdoc.htm

Tracy, J., Logemann, J., Kahrilas, P., Jacob, P., Kobara, M., & Krugler, C. (1989). Preliminary observations on the effects of age on oropharyngeal deglutition. *Dysphagia*(2), 90-94.

Tse, D. W., & Spaulding, S. J. (1998). Review of motor control and motor learning:implications for occupational therapy with individuals with Parkinson's Disease. *Physical & Occupational Therapy in Geriatrics, 15*(3), 19-38.

Vaiman, M., Eviatar, E., & Segal, S. (2004a). Surface electromyographic studies of swallowing in normal subjects: a review of 440 adults. Report 1. Quantitative data: timing measures. *Otolaryngology Head Neck Surgery, 131*(4), 548-555.

Vaiman, M., Eviatar, E., & Segal, S. (2004b). Surface electromyographic studies of swallowing in normal subjects: a review of 440 adults. Report 2. Quantitative data: amplitude measures. *Otolaryngology Head Neck Surgery, 131*(5), 773-780.

Vaiman, M., Eviatar, E., & Segal, S. (2004c). Surface electromyographic studies of swallowing in normal subjects: a review of 440 adults. Report 3. Qualitative data. *Otolaryngology Head Neck Surgery, 131*(6), 977-985.

Van Daele, D. J., McCulloch, T. M., Palmer, P. M., & Langmore, S. E. (2005). Timing of glottic closure during swallowing: a combined electromyographic and endoscopic analysis. *Annals of Otology, Rhinology and Laryngology, 114*(6), 478-487.

Van Lieshout, P. H., Steele, C. M., & Lang, A. E. (2011). Tongue control for swallowing in Parkinson's disease: effects of age, rate, and stimulus consistency. *Movement Disorders, 26*(9), 1725-1729.

Vandaele, D. J., Perlman, A. L., & Cassell, M. D. (1995). Intrinsic fibre architecture and attachments of the human epiglottis and their contributions to the mechanism of deglutition. *Journal of Anatomy, 186 (Pt 1)*, 1-15.

Ward, E. C., Theodoros, D. G., Murdoch, B. E., & Silburn, P. (2000). Changes in maximum capacity tongue function following the Lee Silverman Voice Treatment Program. *Journal of Medical Speech-Language Pathology*, *8* (4), 331–335.

Weijnen, F. G., Kuks, J. B., van der Bilt, A., van der Glas, H. W., Wassenberg, M. W., & Bosman, F. (2000). Tongue force in patients with myasthenia gravis. *Acta Neurologica Scandinavica, 102*(5), 303-308.

Wheeler, K. M., Chiara, T., & Sapienza, C. M. (2007). Surface electromyographic activity of the submental muscles during swallow and expiratory pressure threshold training tasks. *Dysphagia, 22*(2), 108-116.

Wheeler-Hegland, K. M., Rosenbek, J. C., & Sapienza, C. M. (2008). Submental sEMG and hyoid movement during Mendelsohn maneuver, effortful swallow, and expiratory muscle strength training. *Journal of Speech, Language and Hearing Research, 51*(5), 1072-1087.

White, K. T., Easterling, C., Roberts, N., Wertsch, J., & Shaker, R. (2008). Fatigue analysis before and after shaker exercise: physiologic tool for exercise design. *Dysphagia, 23*(4), 385-391.

Winkelman, C. (2011). *Variability in ultrasound measurement of hyoid displacement and submental muscle size within and across sessions using two methods of data acquisition in healthy participants.* (Master's thesis), University of Canterbury, Christchurch.

Wintzen, A. R., Badrising, U. A., Roos, R. A., Vielvoye, J., & Liauw, L. (1994). Influence of bolus volume on hyoid movements in normal individuals and patients with Parkinson's disease. *The Canadian Journal of Neurological Sciences, 21*(1), 57-59.

Wirdefeldt, K., Adami, H. O., Cole, P., Trichopoulos, D., & Mandel, J. (2011). Epidemiology and etiology of Parkinson's disease: a review of the evidence. *European Journal of Epidemiology, 26 Suppl 1*, S1-58.

Wolf, S. L. (1994). Biofeedback. In J. A. Downey, S. J. Myers, E. G. Gonzalez & J. S. Liberman (Eds.), *The physiological basis of rehabilitation medicine* (pp. 563-572). Stoneham, MA: Butterworth-Heinemann.

Wolf, S., & Binder-Macleod. (1989). Neurophysiological factors in electromyographic feedback for neuromotor disturbances. In J. V. Basmajian (Ed.), *Biofeedback and principles and practice for clinicians* (3 ed., pp. 17-36). Baltimore, MD: Williams & Wilkins.

Yabunaka, K., Sanada, H., Sanada, S., Konishi, H., Hashimoto, T., Yatake, H., et al. (2011). Sonographic assessment of hyoid bone movement during swallowing: a study of normal adults with advancing age. *Radiological Physics and Technology, 4*(1), 73-77.

Appendix A: Advertisement

Swallowing treatment for Parkinson's disease

Approximately 90% of individuals with Parkinson's disease develop swallowing difficulties (dysphagia) at some stage in their disease. If untreated, dysphagia can lead to chest infection, or cause embarrassment, anxiety and hinder the ability to enjoy eating in a social setting.

How do you know if you have a swallowing problem?

My swallowing problem has caused me to lose weight

Swallowing liquid/ solids/ pills takes extra effort

When I swallow food sticks in my throat

I cough/choke when I eat food or drink liquid

I avoid eating certain types of food and/or liquid

It takes me a longer time to eat food

I notice changes in my voice quality after eating or drinking

I have trouble keeping food and/or liquid in my mouth

Swallowing is painful and/or stressful

My swallowing problem interferes with my ability to go out for meals

If 'yes' is the answer to many of these questions, you may benefit from the swallowing treatment study, which is being conducted through the Swallowing Rehabilitation Research Lab at the Van der Veer Institute.

Contact Ruvini Athukorala on 3786098/ 0226359170 or e-mail: ruvini.athukorala@pg.canterbury.ac.nz for more information or if interested in taking part.

Appendix B: Swallowing screening sheet

The University of Canterbury Department of Communication Disorders
Swallowing Rehabilitation Research Laboratory and Clinics
At the Van der Veer Institute

Some patients with movement disorders have difficulty with chewing and swallowing their food. This self-assessment tool might help you identify if you are experiencing any difficulties in these areas. Please complete the short questionnaire below and return it to the front desk.

Eating Assessment Tool (EAT-10)
(Belafsky, et al., 2008)

Circle the appropriate response.

To what extent are the following scenarios problematic for you?	0=no problem			4=severe problem	
My swallowing problem has caused me to lose weight.	0	1	2	3	4
My swallowing problem interferes with my ability to go out for meals.	0	1	2	3	4
Swallowing liquids takes extra effort.	0	1	2	3	4
Swallowing solids takes extra effort.	0	1	2	3	4
Swallowing pills takes extra effort.	0	1	2	3	4
Swallowing is painful.	0	1	2	3	4

The pleasure of eating is affected by my swallowing.	0	1	2	3	4
When I swallow food sticks in my throat.	0	1	2	3	4
I cough when I eat.	0	1	2	3	4
Swallowing is stressful.	0	1	2	3	4

Would you like to be contacted by clinicians at the Swallowing Rehabilitation Clinics for an assessment? Please leave your name and telephone number below.

Name: ____ Phone: ________________________________

Appendix C: Exclusionary questionnaire

Identifying number: ____________________ Age/ D.O.B:___________

Which ethnic group(s) do you belong to?

New Zealand European □ New Zealand Maori

Samoan □ Cook Island Maori

Tongan □ Niuean

Chinese □ Indian

Other __________________________

Please complete the following questionnaire by ticking the box that is most applicable to you.

Do you suffer from the effects of any of the following medical problems?

Stroke

Dementia

Head and/or neck injury

Head and/or neck surgery

Neurological disorders other that Parkinson`s disease

Gastroesophageal Reflux Disease

Muscular disease (e.g., Muscular atrophy)

Do you have any other medical problems which you feel may impact on your ability to participate?

Yes / No (Please circle one)

If **yes**, please describe:

____

____

Are you currently taking any medications that may affect your swallowing?

Yes / No (Please circle one)

If **yes**, please describe

____

____

Appendix D: Information sheet

Research Title:

Swallowing Skill Therapy in Parkinson`s Disease

Primary Researcher:

Oshrat Sella , BA

PhD candidate, Department of Communication Disorders

University of Canterbury

Van der Veer Institute for Parkinson's and Brain Research

66 Stewart St., Christchurch NZ

(03) 3786 069

Principal Investigator:

Maggie-Lee Huckabee, PhD

Senior lecturer, Department of Communication Disorders

University of Canterbury

Van der Veer Institute for Parkinson's and Brain Research

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(03) 378 6070

Co-Investigators:

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Biomedical Engineer & Neuroscientist,

Department of Medical Physics and Bioengineering, Canterbury District Health Board.

Van der Veer Institute for Parkinson's and Brain Research

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Tim Anderson, BSc(Hons), MBChB, MD, FRACP

Acting Director, Van der Veer Institute,

Professor, Department of Medicine, University of Otago, Christchurch,

Neurologist, Department of Neurology,

Canterbury District Health Board

Van der Veer Institute for Parkinson's and Brain Research

66 Stewart St., Christchurch NZ

(03) 378 6079

Ruvini Athukorala, BSc

MSc candidate, Department of communication Disorders

University of Canterbury

Van der Veer Institute for Parkinson's and Brain Research

66 Stewart St., Christchurch NZ

(03) 378 6070

Interpreter:

If you need an interpreter, this can be provided

Introduction and aims of the project:

You are invited to participate in a research project that will explore how swallowing skill therapy influences your swallowing ability and your swallowing muscles. This research is a part of a PhD qualification for the lead investigator. Interest in participating should be expressed within 1 week of the information being provided. You have the right not to participate in the study or subsequently withdraw from this study at any time.

The aim of this project is to provide important information about the influence of a skill training technique on swallowing function using different measurements. Understanding how this technique influence swallowing function and swallowing muscles can improve treatment approaches for swallowing impairment in Parkinson`s disease.

Participant selection:

You have been identified as a potential participant for this study based on your recent evaluation of swallowing at the Swallowing Rehabilitation Research Laboratory. After reading this information sheet, you are free to consent to participate in our research project, or you may receive swallowing rehabilitation services through the laboratory that are not a part of the study. Declining to participate in the study will in no way compromise your current or potential future treatment at the Swallowing Rehabilitation Research Laboratory. If you consent to participate in this study, you will be asked to fill in a consent form prior to initiating the treatment.

Inclusion criteria:

You are eligible to participate in this study if you have the following conditions:

Parkinson`s disease as diagnosed by a neurologist

Self reported swallowing difficulties that last for at least 2 months

Exclusion criteria:

You may not be eligible to participate in this study if you have the following conditions:

Parkinsonism that is not caused by Parkinson`s disease, for example: Multiple System Atrophy (MSA), Progressive Supranuclear Palsy (PSP), side effects of medications, such as some antipsychotics.

Dementia

Stroke

Head and/or neck injury

Head/ and/or neck surgery

Muscular disease (e.g., Muscular atrophy)

The research procedure:

The study involves assessment and therapy sessions at the Van der Veer Institute for Parkinson's and Brain Research. If you agree to participate in the study, the following steps will occur:

You will be given an appointment and asked to come to the Swallowing Rehabilitation Research Laboratory at the Van der Veer Institute, 66 Stewart St, Christchurch, New Zealand.

A researcher will meet with you at the Van der Veer Institute and you will have an opportunity to have any questions answered. After completing a questionnaire to ensure inclusion criteria are met, you will be asked to sign the consent form. If you agree to participate in the study, you will also be providing consent to use information collecting during your first swallowing assessment in the research. You will then be seated in a comfortable chair and be ready to begin the first assessment session.

ASSESSMENT SESSION (BASELINE)

Clinical Swallowing Assessment

You will undergo a clinical assessment of your swallowing function. This assessment is a standard evaluation procedure performed in our clinic to evaluate the presence of swallowing difficulties in all patients that are referred to our swallowing clinic. This standard evaluation includes the following:

The nerves that are involved in swallowing are assessed by asking you to make certain movements in the muscles around your mouth, tongue and face.

The clinician will ask you to eat and drink small amounts of food and water. The clinician will document their observation of your eating behaviour; for example, how well you have chewed your food and whether you cough during eating or drinking. If you have any dietary restriction, those will be taken into consideration.

You will be asked to inhale some citric acid using a face mask, and your reaction will be documented. This test will help in understanding how strong your cough is, and how fast you cough.

You will be given a cup filled with 150 ml of tap water and the clinician will measure the time it takes you to drink the water and how many times you swallowed during that time. This test will help in understanding how efficient your swallowing is.

Electromyography (EMG) Measurements

Electromyography (EMG) measures will be taken. EMG is used to measure your muscle activity during swallowing. The researcher will attach 3 small discs to the skin underneath your chin. These discs are used to record electrical activity only and do not put any electricity into the muscles.

You will be given a demonstration and directions about how to perform an effortful swallow, which requires you to swallow hard using all the muscles in your mouth and throat.

Once the electrodes are in place, you will be asked to complete 5 repetitions of 4 different types of swallows: saliva swallows, 10-ml water swallows, effortful saliva swallows and effortful 10-ml water swallows. This is so the strength of your swallowing can be determined.

Ultrasound Measurements

Ultrasound measurements will be taken. Ultrasound is non-invasive procedure that allows us to measure the size of your swallowing muscles and to visualize how they work during swallowing.

You will be seated in a comfortable chair. A head stabilizing unit with two arms will be placed in front of you. One arm will stabilize the imaging tool and one arm will stabilize your head. This stabilizing unit will ensure the measurements are more accurate.

You will be asked to bite soft putty in order to have an impression of your teeth so the exact same head position will be maintained during the assessment. The putty will be shaped in a U curve. It will be placed on a U shape plastic mould that will be inserted into the arm on the head stabilizing unit. You will be asked to bite into the putty during the ultrasound procedure in order to remain still.

Jelly will be put on the skin under your chin to allow imaging of the muscles. The ultrasound`s imaging tool will be lightly placed under your chin by adjusting the stabilizing unit (described above).

You will be asked to remain still during the first part of the ultrasound imaging procedure while 5 images of the muscles under your chin will be taken. For the second part you will be asked to complete 5 repetitions of saliva swallows. During these procedures, you will not feel anything unusual or experience any discomfort.

Quality of Life in Swallowing Disorders Questionnaire (SWAL-QOL)

You will be asked to fill in a questionnaire. This questionnaire is designed to find out how your swallowing problem has been affecting your day-to-day quality of life.

THERAPY SESSIONS

Swallowing Skill Therapy

Once your first (baseline) assessment session is completed, you will be scheduled for 10 training sessions starting on a Monday. The training sessions will be held every weekday (Monday-Friday) for two weeks. Each session will last for one hour.

You will have two electrodes (small metal discs) placed under your chin and one over your jaw bone. These electrodes will record the activity of your muscles under the chin and present that information to you in the form of a moving line on the computer. You will be seated in front of a computer screen. The electrodes will give you feedback about the precision of your swallowing movements. You will need to swallow accurately enough so that the waveform created by your swallowing is able to "hit" a target on the screen. You will receive visual feedback about how precise you were. When you swallow with great precision, the target becomes smaller so you have to be even more precise. If you miss the target, it will become bigger. Each session will be divided to 5 sections, each 10 minutes long, with a 2.5 minutes break between each section. If you will need a longer break you will receive it.

OUTCOME SESSIONS

Outcome measurements

1.Two outcome assessment sessions will be performed: the first one will be held on the Monday following completion of your 2-week training programme (3 days after your last training session), and the second one will be held 2 weeks following the completion of your training, on a Monday as well. Both outcome sessions will be carried out at the Van der Veer Institute.

During the first outcome session and the second outcome session, the researcher will repeat the same assessment done on the first (baseline) session: clinical swallowing assessment (described in step 3), EMG (described in steps 4-6), ultrasound (described in steps 7-11) and filling in SWAL-QOL questionnaire (described in paragraph IV)

The whole research project should take approximately 13 lab sessions over a period of four weeks plus two days. 16 hours in total.

Below is a table summarising training and assessments time:

Base-line Assessment	Therapy sessions: 1st-10th	First Outcome Session	Second Outcome Session
Thursday / Friday	Week 1: Monday-Friday Week 2: Monday-Friday	Monday	Monday
Clinical swallowing assessment EMG Ultrasound SWAL-QOL	Skill training	Clinical swallowing assessment EMG Ultrasound SWAL-QOL	Clinical swallowing assessment EMG Ultrasound SWAL-QOL
2 hours	10 hours (10 sessions*1 hr each)	2 hours	2 hours

Risks and Benefits:

You will be part of a study that contributes important information on how swallowing training influences swallowing function. This information will assist with the development of improved treatment techniques for swallowing disorders. It is anticipated that some participants will experience an improvement in swallowing function after the therapy, although this cannot be promised.

Though not expected, you will be monitored very carefully by the researchers for any negative outcomes arising from your participation in this study. The Van der Veer Institute has equipment for dealing with medical emergencies.

Participation:

If you agree to take part in this study, you are free to withdraw at any time, without having to give a reason.

Confidentiality:

Research findings will be presented at international research meetings and submitted for publication in peer reviewed journals. Additionally, research findings will be made available to the local Canterbury medical community through research presentations and regional forums. However, no material which could personally identify you will be used in any reports on this study. Consent forms will be kept in a locked filing cabinet in the locked Swallowing Research Laboratory or will be stored on password-protected laboratory computers. Research data will be stored for a period of ten years after data collection is complete, at which time they will be destroyed. With your permission, data from this study may be used in future related studies, which have been given ethical approval from a Health & Disability Ethics Committee.

Atypical findings:

You will be notified about any atypical findings that might be revealed during the assessments, and upon your consent we will this information to your GP.

Results:

If requested, you will be offered copies of the publications that arise from this research. However, you should be aware that a significant delay may occur between completion of data collection and completion of the final report. Alternatively, or in addition, you can choose to have the results of the study discussed with you personally by the lead investigator.

Questions:

You may have a friend, family, or whanau support to help you understand the risks and/or benefits of this study and any other explanation you may require.

Please contact the Ruvini Athukorala if you require any further information about the study. Ruvini can be contacted during work hours at 03-3786098 or after hours at 022 6359170 Email: ruvini.athukorala@pg.canterbury.ac.nz

If you have any queries or concerns about your rights as a participant in this study, you may wish to contact a Health and Disability Advocate, telephone: South Island 0800 377 766 or 03-3777501 in Christchurch. Free Fax (NZ wide): 0800 2787 7678 (08002SUPPORT) Email (NZ wide): advocacy@hdc.org.nz

This study has received ethical approval from the Upper South B Regional Ethics Committee.

Appendix E: Consent form

CONSENT FORM
Swallowing Skill Therapy in Parkinson`s Disease

English	I wish to have an interpreter.	Yes	No
Maori	E hiahia ana ahau ki tetahi kaiwhakamaori/kaiwhaka pakeha korero.	Ae	Kao
Samoa n	Oute mana'o ia iai se fa'amatala upu.	Ioe	Leai
Tongan	Oku ou fiema'u ha fakatonulea.	Io	Ikai
Cook Island	Ka inangaro au i tetai tangata uri reo.	Ae	Kare
Niuean	Fia manako au ke fakaaoga e taha tagata fakahokohoko kupu.	E	Nakai

I, ____, have read and I understand the Information Sheet dated *11/11/10* for volunteers taking part in the study designed to explore the effects of swallowing skill therapy among people with Parkinson`s disease. I have had the opportunity to discuss this study. I am satisfied with the answers I have been given.

I have had this project explained to me by: RUVINI ATHUKORALA

I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time and this will in no way affect my current, continuing or future health care. I understand that if I choose to withdraw from the study, I may also withdraw all information that I have provided.

I understand that the information obtained from this research may be published. However, I understand that my participation in this study is confidential and that no material which could identify me will be used in any reports on this study.

CONSENT FORM
Swallowing Skill Therapy in Parkinson`s Disease

I understand that the investigation will be stopped if it should appear harmful to me and I know who to contact if I have any side effects to the study or have any questions about the study.

I understand the potential risks of participation in the study as explained to me by the researcher.

I understand the compensation provisions for this study.

I have had time to consider whether to take part.

I wish to receive a copy of the results: YES / NO

I wish to be notified of any atypical findings that might be revealed during the assessments: YES / NO

After being advised of such, I wish to have any atypical findings reported to my GP: YES / NO

I, _________________________________ hereby consent to take part in this study.

Date____________________________________

Signature _______________________________

Signature of researcher____________________ Name of researcher____________________

Name of primary researcher and contact phone numbers:

Name: Ruvini Athukorala

Work: 03-3786098

Home: 022-6359170

Appendix F: SWAL-QOL

The SWAL-QOL SURVEY

Understanding
Quality of Life
in Swallowing Disorders

Instructions for Completing the SWAL-QOL Survey

This questionnaire is designed to find out how your swallowing problem has been affecting your day-to-day quality of life.

Please take the time to carefully read and answer each question. Some questions may look like others, but each one is different.

Here's an <u>example</u> of how the questions in the survey will look.

1. In the last month how often have you experiences each of the symptoms below.

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
Feel weak	1	2	3	4	5

Thank you for your help in taking part in this survey!

IMPORTANT NOTE: We understand that you may have a number of physical problems. Sometimes it is hard to separate these from swallowing difficulties, but we hope that you can do your best to concentrate ***only*** on your ***swallowing problem.*** Thank you for your efforts in completing this questionnaire.

1. Below are some general statements that people with ***swallowing problems*** might mention. In the last month, **how true** have the following statements been for you.

(circle one number on each line)

	Very much true	**Quite a bit true**	**Somewhat true**	**A little true**	**Not at all true**
Dealing with my swallowing problem is very difficult.	1	2	3	4	5
My swallowing problem is a major distraction in my life.	1	2	3	4	5

2. Below are aspects of day-to-day eating that people with ***swallowing problems*** sometimes talk about. In the last month, **how true** have the following statements been for you?

(circle one number on each line)

	Very much true	**Quite a bit true**	**Somewhat true**	**A little true**	**Not at all true**
Most days, I don't care if I eat or not.	1	2	3	4	5
It takes me longer to eat than other people.	1	2	3	4	5
I'm rarely hungry anymore.	1	2	3	4	5
It takes me forever to eat a meal.	1	2	3	4	5
I don't enjoy eating anymore.	1	2	3	4	5

3. Below are some physical problems that people with ***swallowing problems*** sometimes experience. In the last month, **how often** you have experienced each problem as a result of your swallowing problem?

(circle one number on each line)

	Almost always	Often	Sometimes	Hardly ever	Never
Coughing	1	2	3	4	5
Choking when you eat food	1	2	3	4	5
Choking when you take liquids	1	2	3	4	5
Having thick saliva or phlegm	1	2	3	4	5
Gagging	1	2	3	4	5
Drooling	1	2	3	4	5
Problems chewing	1	2	3	4	5
Having excess saliva or phlegm	1	2	3	4	5
Having to clear your throat	1	2	3	4	5
Food sticking in your throat	1	2	3	4	5
Food sticking in your mouth	1	2	3	4	5
Food or liquid dribbling out of your mouth	1	2	3	4	5
Food or liquid coming out your nose	1	2	3	4	5
Coughing food or liquid out of your mouth when it gets stuck	1	2	3	4	5

4. Next, please answer a few questions about how your ***swallowing problem*** has affected your diet and eating in the last month.

(circle one number on each line)

	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
Figuring out what I can and can't eat is a problem for me.	1	2	3	4	5
It is difficult to find foods that I both like and can eat.	1	2	3	4	5

5. In the last month, **how often** have the following statements about communication applied to you because of your ***swallowing problem***?

(circle one number on each line)

	All of the time	**Most of the time**	**Some of the time**	**A little of the time**	**None of the time**
People have a hard time understanding me.	1	2	3	4	5
It's been difficult for me to speak clearly.	1	2	3	4	5

6. Below are some concerns that people with ***swallowing problems*** sometimes mention. In the last month, **how often** have you experienced each feeling?

(circle one number on each line)

	Almost always	**Often**	**Sometimes**	**Hardly ever**	**Never**
I fear I may start choking when I eat food.	1	2	3	4	5
I worry about getting pneumonia.	1	2	3	4	5
I am afraid of choking when I drink liquids.	1	2	3	4	5
I never know when I am going to choke.	1	2	3	4	5

7. In the last month, how often have the following statements **been true** for you because of your ***swallowing problem***?

(circle one number on each line)

	Always true	**Often true**	**Sometimes true**	**Hardly ever true**	**Never true**
My swallowing problem depresses me.	1	2	3	4	5
Having to be so careful when I eat or drink annoys me.	1	2	3	4	5
I've been discouraged by my swallowing problem.	1	2	3	4	5
My swallowing problem frustrates me.	1	2	3	4	5
I get impatient dealing with my swallowing problem.	1	2	3	4	5

8. Think about your social life in the last month. How strongly would you agree or disagree with the following statements?

(circle one number on each line)

	Strongly agree	**Agree**	**Uncertain**	**Disagree**	**Strongly disagree**
I do not go out to eat because of my swallowing problem.	1	2	3	4	5
My swallowing problem makes it hard to have a social life.	1	2	3	4	5
My usual work or leisure activities have changed because of my swallowing problem.	1	2	3	4	5
Social gatherings (like holidays or get-togethers) are not enjoyable because of my swallowing problem.	1	2	3	4	5
My role with family and friends has changed because of my swallowing problem.	1	2	3	4	5

9. In the last month, **how often** have you experienced each of the following physical symptoms?

(circle one number on each line)

	All of the time	**Most of the time**	**Some of the time**	**A little of the time**	**None of the time**
Feel weak?	1	2	3	4	5
Have trouble falling asleep?	1	2	3	4	5
Feel tired?	1	2	3	4	5
Have trouble staying asleep?	1	2	3	4	5
Feel exhausted?	1	2	3	4	5

10. Do you now take any food or liquid through a feeding tube?

(circle one)

No 1

Yes.. 2

11. Please circle the letter of the one description below that best describes the consistency or texture of the food you have been eating most often in the last week.

Circle one:

A. Circle this one if you are eating a full normal diet, which would include a wide variety of foods, including hard to chew items like steak, carrots, bread, salad, and popcorn.

B. Circle this one if you are eating soft, easy to chew foods like casseroles, canned fruits, soft cooked vegetables, ground meat, or cream soups.

C. Circle this one if you are eating food that is put through a blender or food processor or anything that is like pudding or pureed foods.

D. Circle this one if you take most of your nutrition by tube, but sometimes eat ice cream, pudding, apple sauce, or other pleasure foods.

E. Circle this one if you take all of your nourishment through a tube.

12. **Please circle the letter** of the one description below that best describes the consistency of liquids you have been drinking most often in the last week.

Circle one:

A. Circle this if you drink liquids such as water, milk, tea, fruit juice, and coffee.

B. Circle this if the majority of liquids you drink are thick, like tomato juice or apricot nectar. Such thick liquids drip off your spoon in a slow steady stream when you turn it upside down.

C. Circle this if your liquids are moderately thick, like a thick milkshake or smoothie. Such moderately thick liquids are difficult to suck through a straw, like a very thick milkshake, or drip off your spoon slowly drop by drop when you turn it upside down, such as honey.

D. Circle this if your liquids are very thick, like pudding. Such very thick liquids will stick to a spoon when you turn it upside down, such as pudding.

E. Circle this if you did not take any liquids by mouth or if you have been limited to ice chips.

13. In general, would you say your health is:

(circle one)

Poor 1

Fair.. 2

Good 3

Very Good.. 4

Excellent 5

General Questions About You

What is the date of your birth?

Please write in your date of birth here: ______/______/______ (month / day / year)

What is your age today? _______

Are you –

(circle one)

Male 1

Female 2

What is your <u>main</u> racial or ethnic group?

(circle one)

White or Caucasian, but not Hispanic or Latino 1

Black or African-American, but not Hispanic or Latino 2

Hispanic or Latino 3

Asian 4

Other 5

What is the highest year of school or college you have ever completed?

(circle one number)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	16+
Grade School								High School				College				Post Graduate

What is your current marital status?

(circle one)

Never married 1

Married... 2

Divorced... 3

Separated 4

Widowed.. 5

Did anybody help you complete this questionnaire?

(circle one)

No, I did it myself 1

Yes, someone helped me fill it out... 2

IF SOMEONE HELPED YOU FILL OUT THIS QUESTIONNAIRE, how did that person help you?

(circle one)

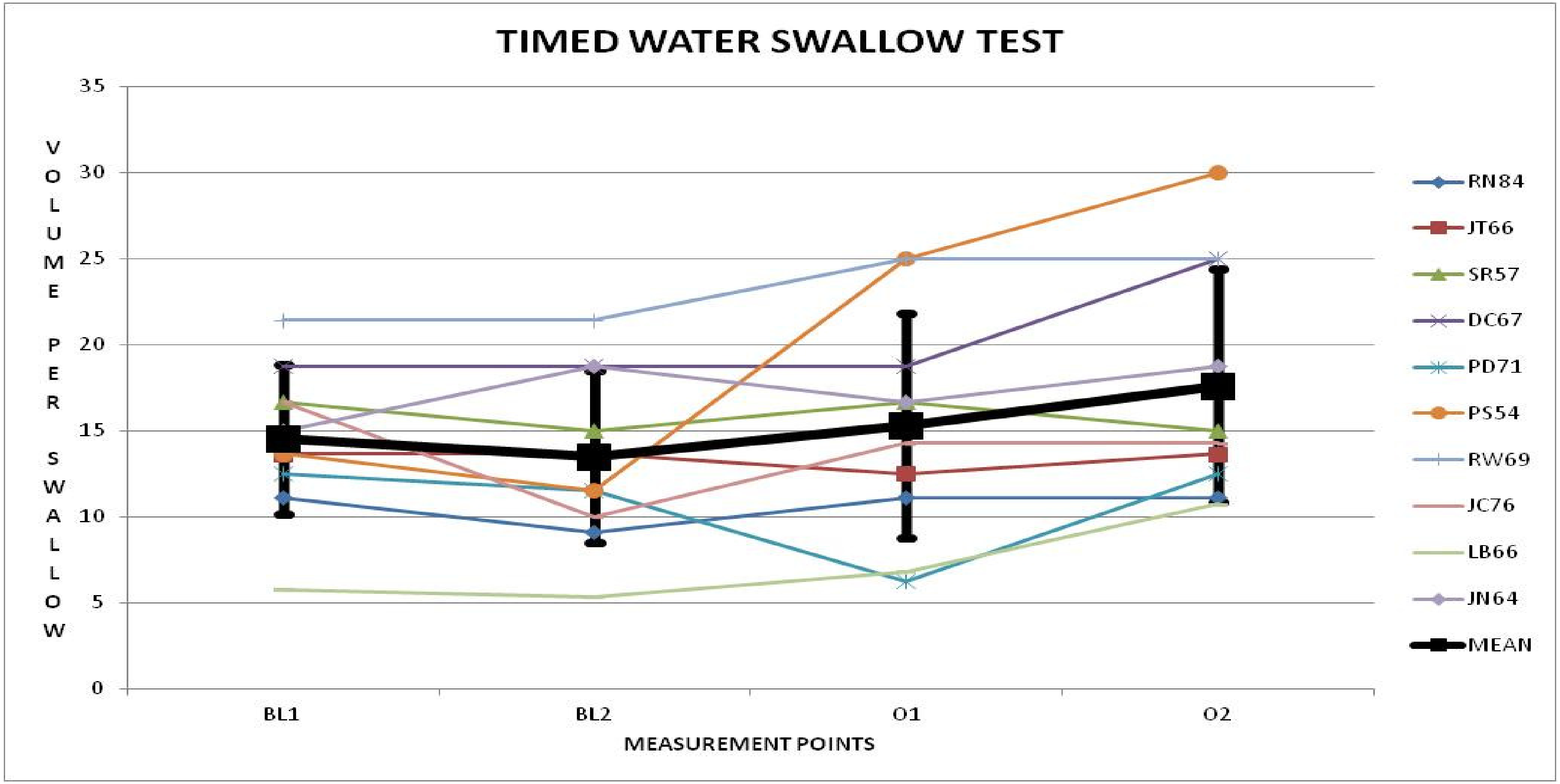
Read you the questions and/or wrote down the answers you gave........... 1

Answered the questions for you 2

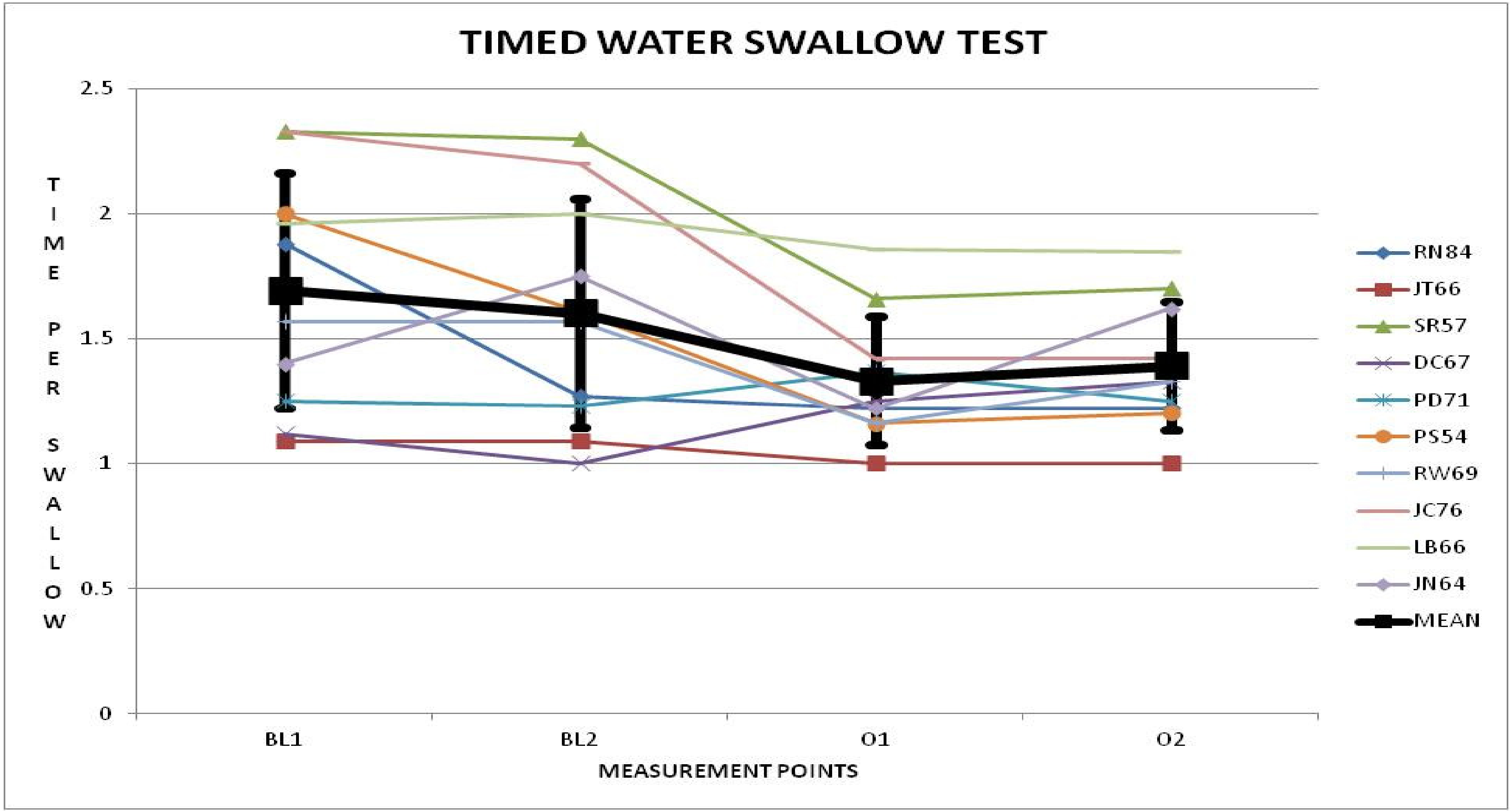
Helped in some other way 3

Please write today's date here: ______/______/______
month day year

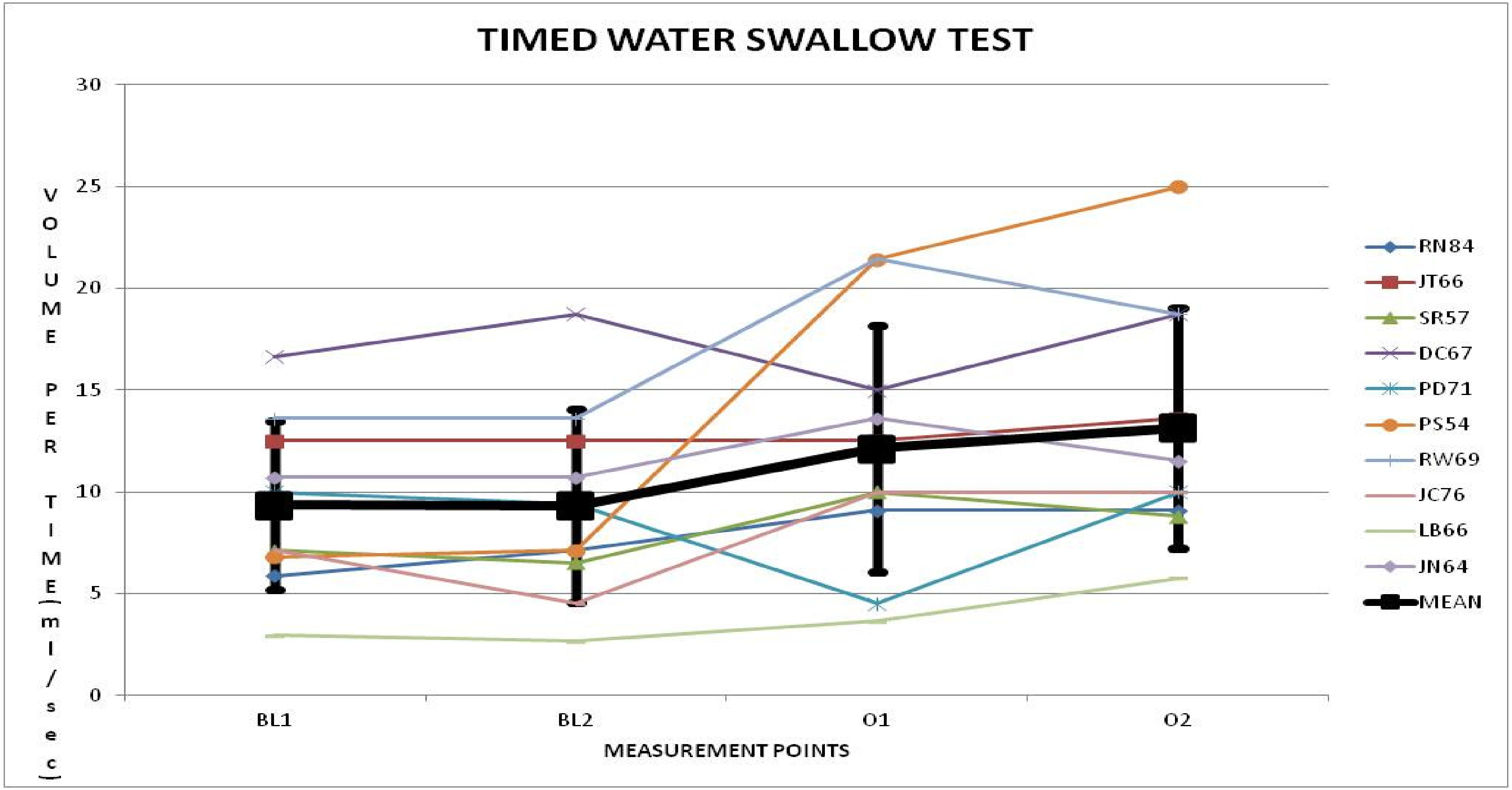
Appendix G-1: Individual scores for Volume per swallow in timed water swallow test (mean and standard deviation in black)



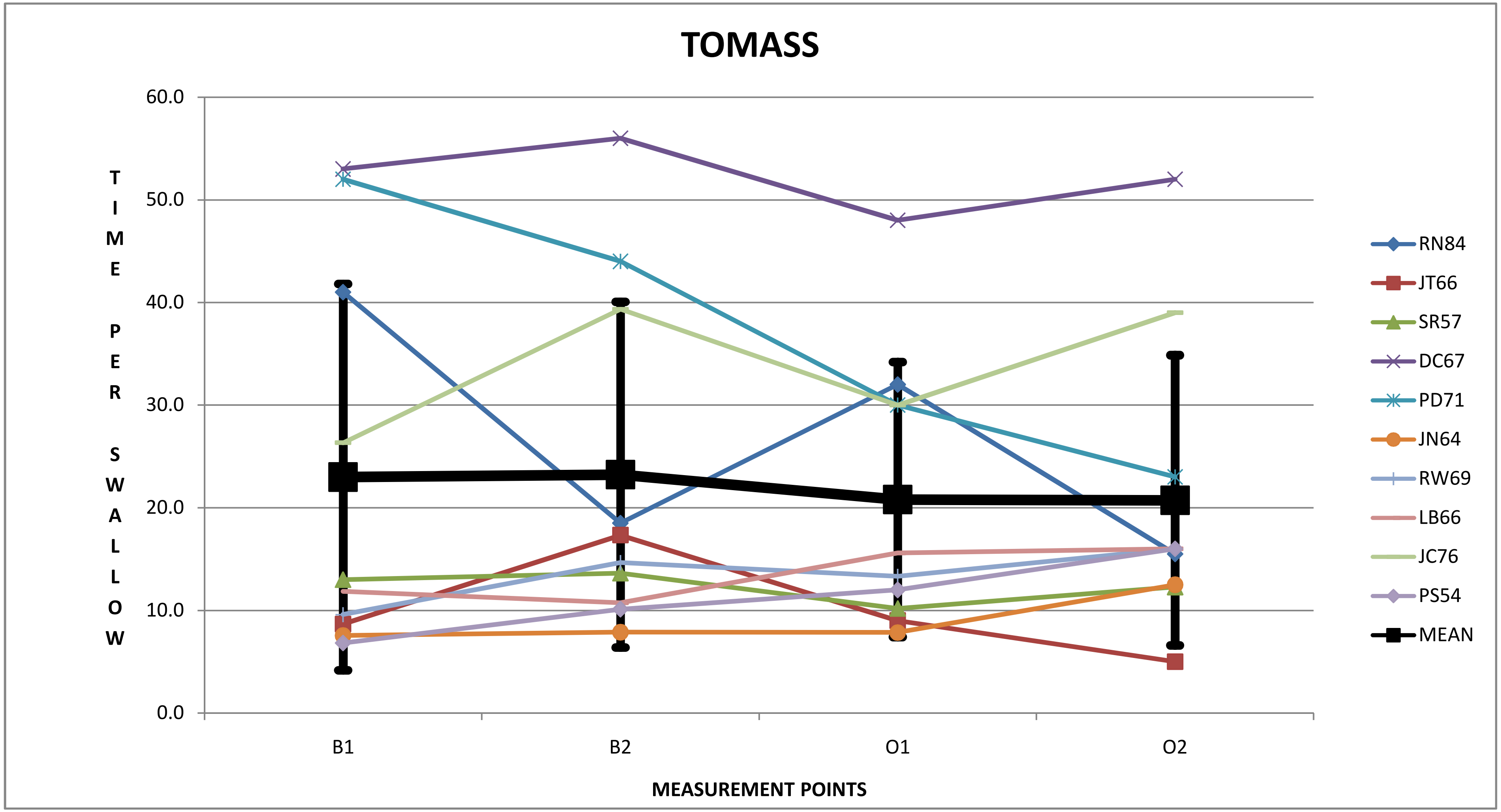
Appendix G-2: Individual scores for Time per swallow in timed water swallow test (mean and standard deviation in black)



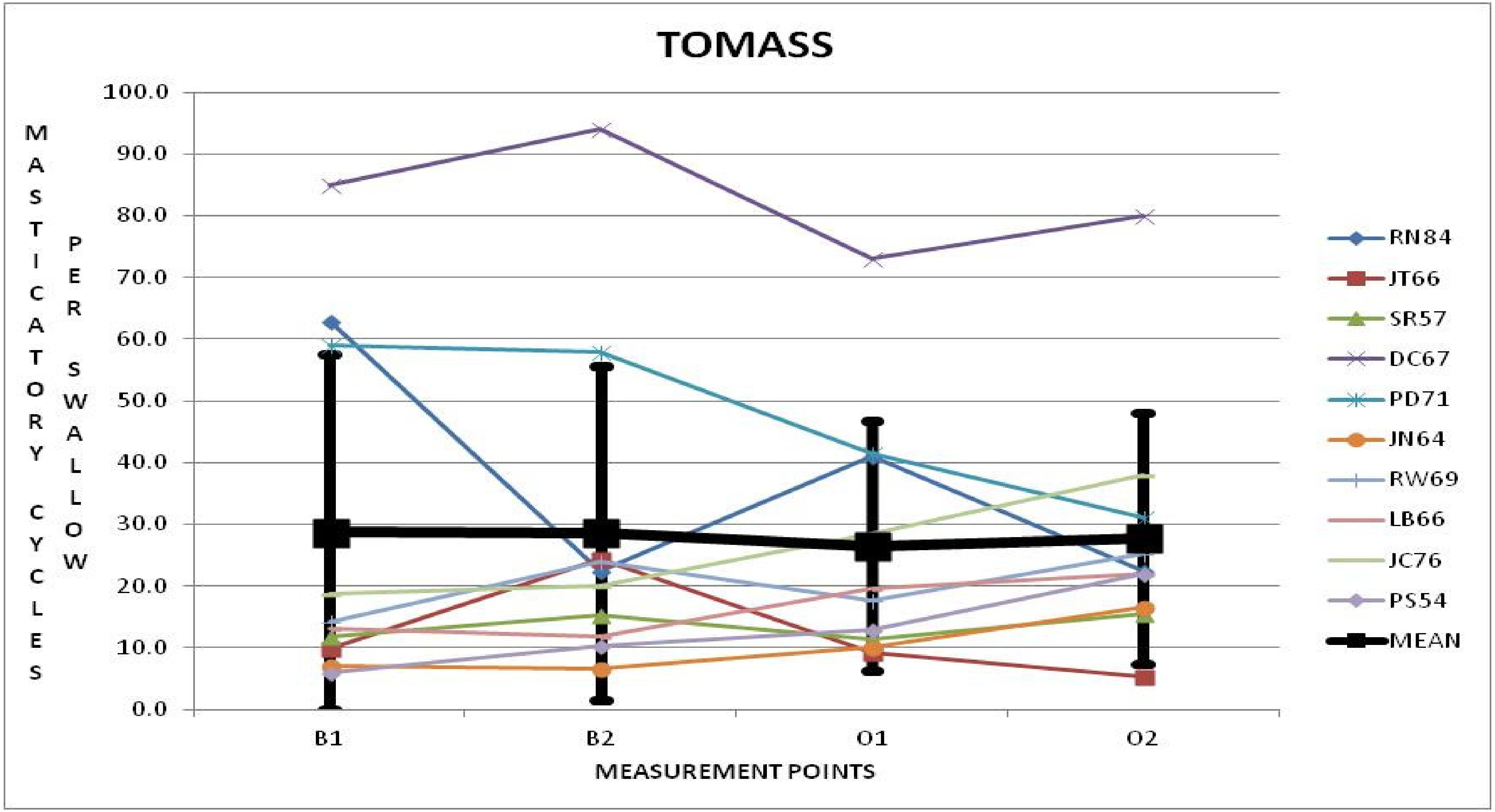
Appendix G-3: Individual scores for volume per time in timed water swallow test (mean and standard deviation in black)



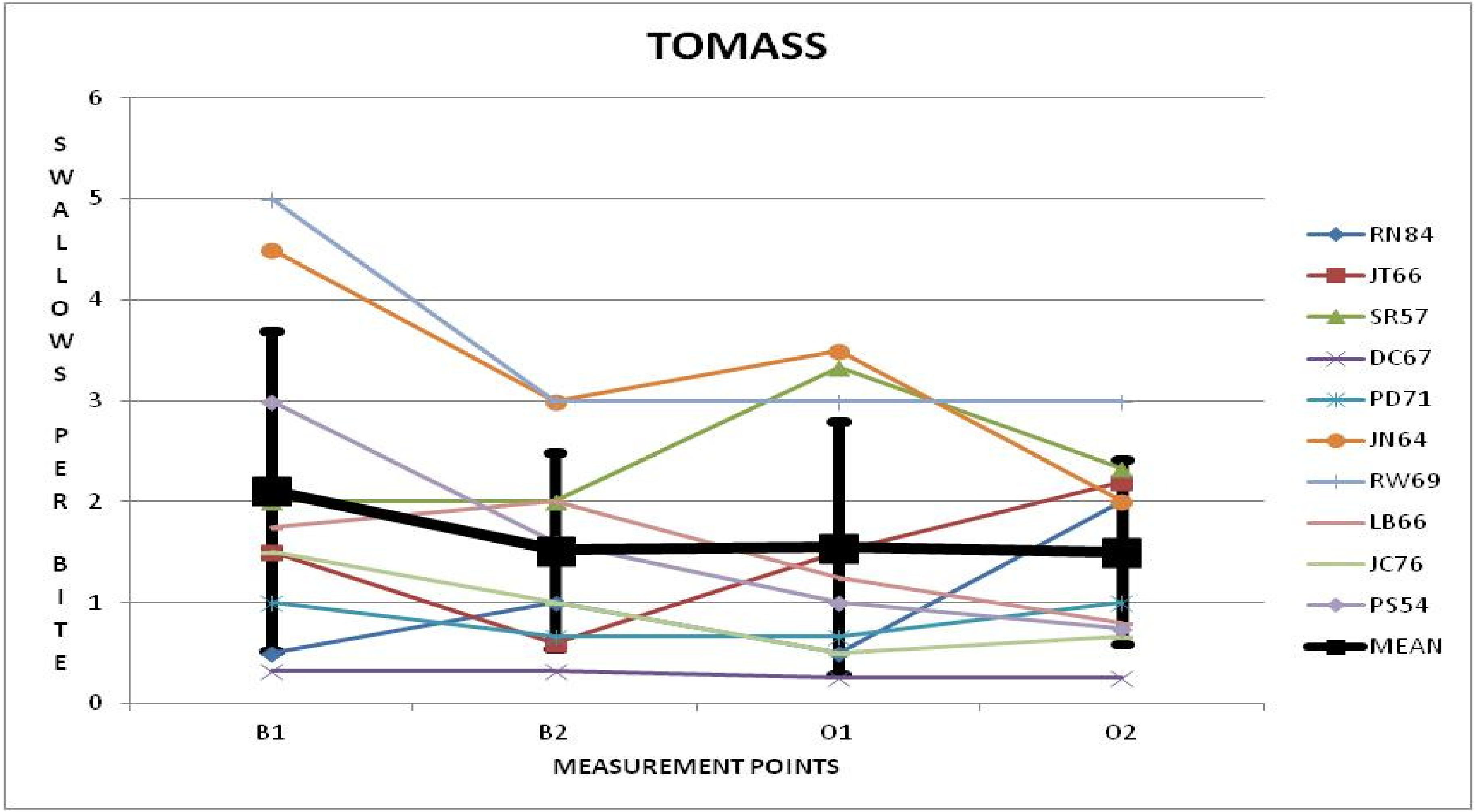
Appendix H-1: Individual scores for time per swallow in TOMASS (mean and standard deviation in black)



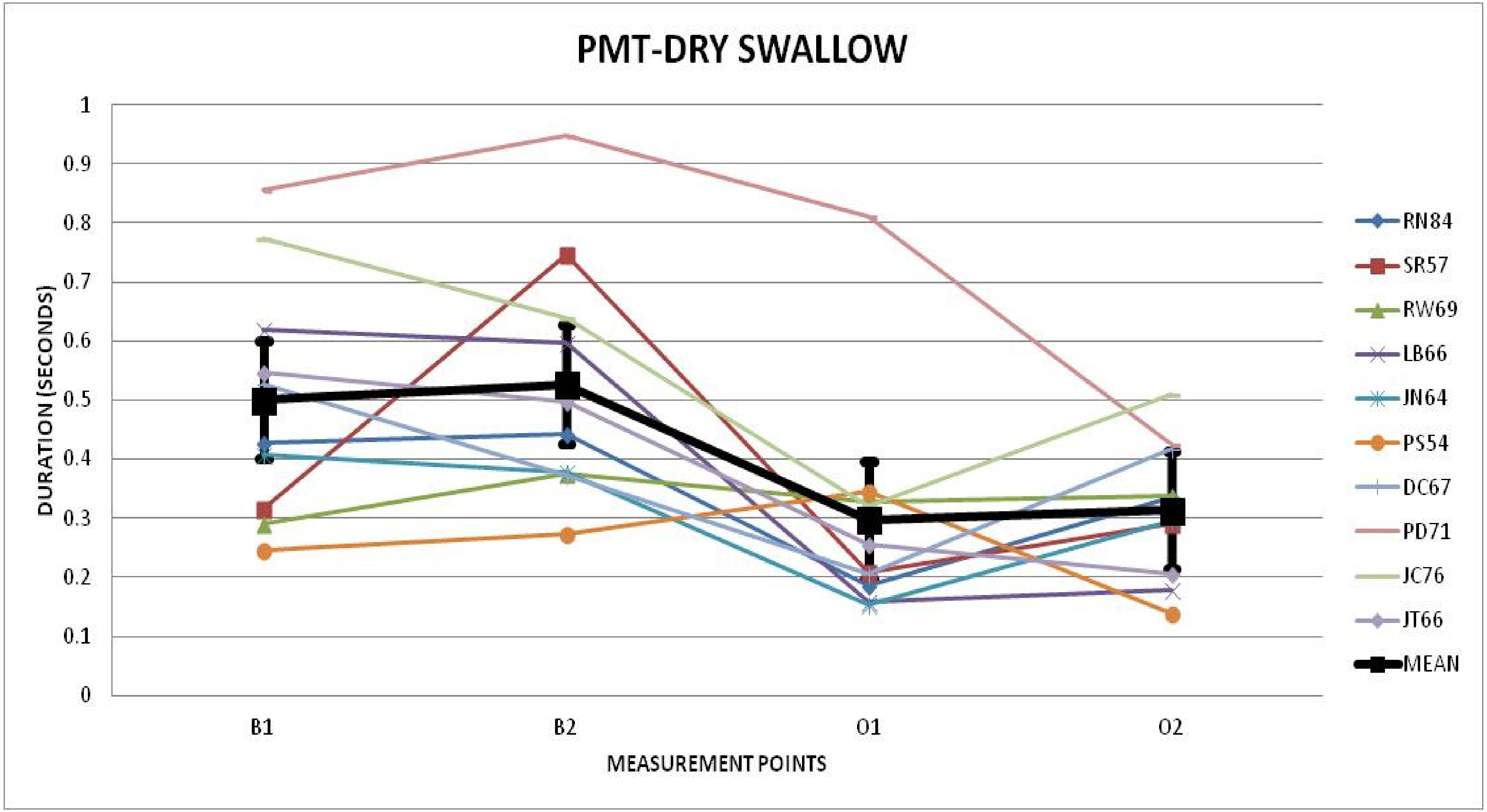
Appendix H-2: Individual scores for masticatory cycles per swallow in TOMASS (mean and standard deviation in black)



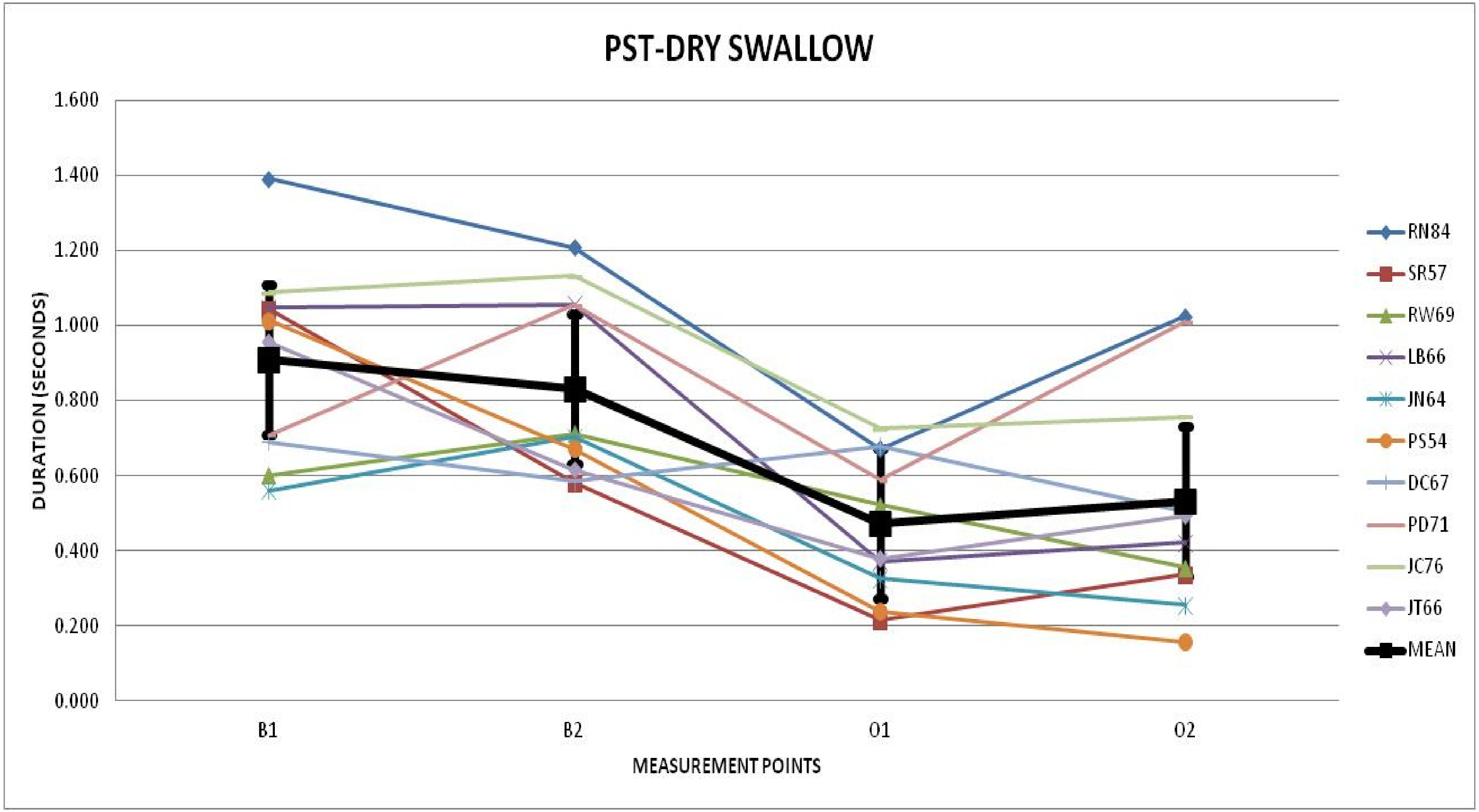
Appendix H-3: Individual scores for swallows per bite in TOMASS (mean and standard deviation in black)



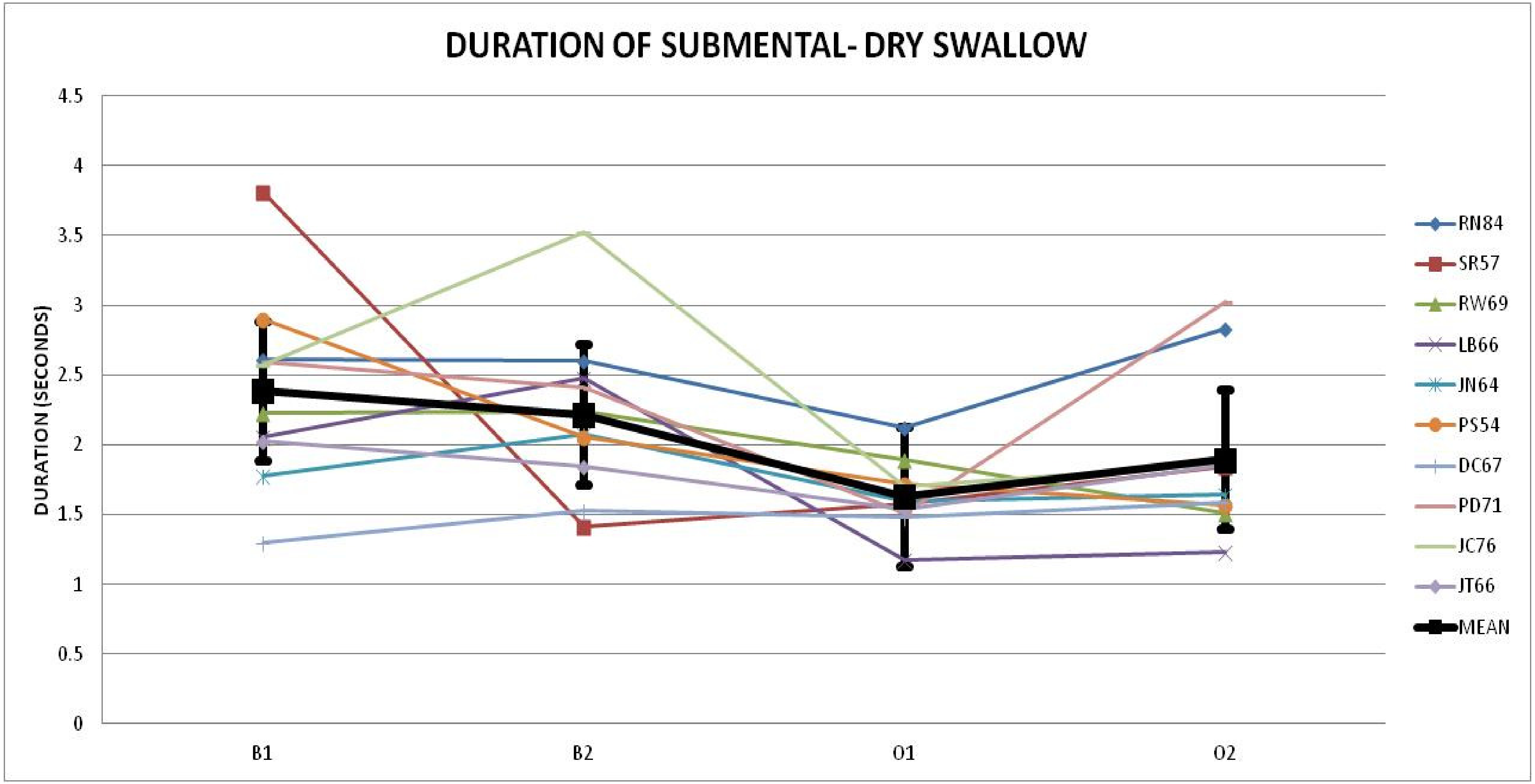
Appendix I-1: Individual scores for dry swallow PMT (mean and standard deviation in black)



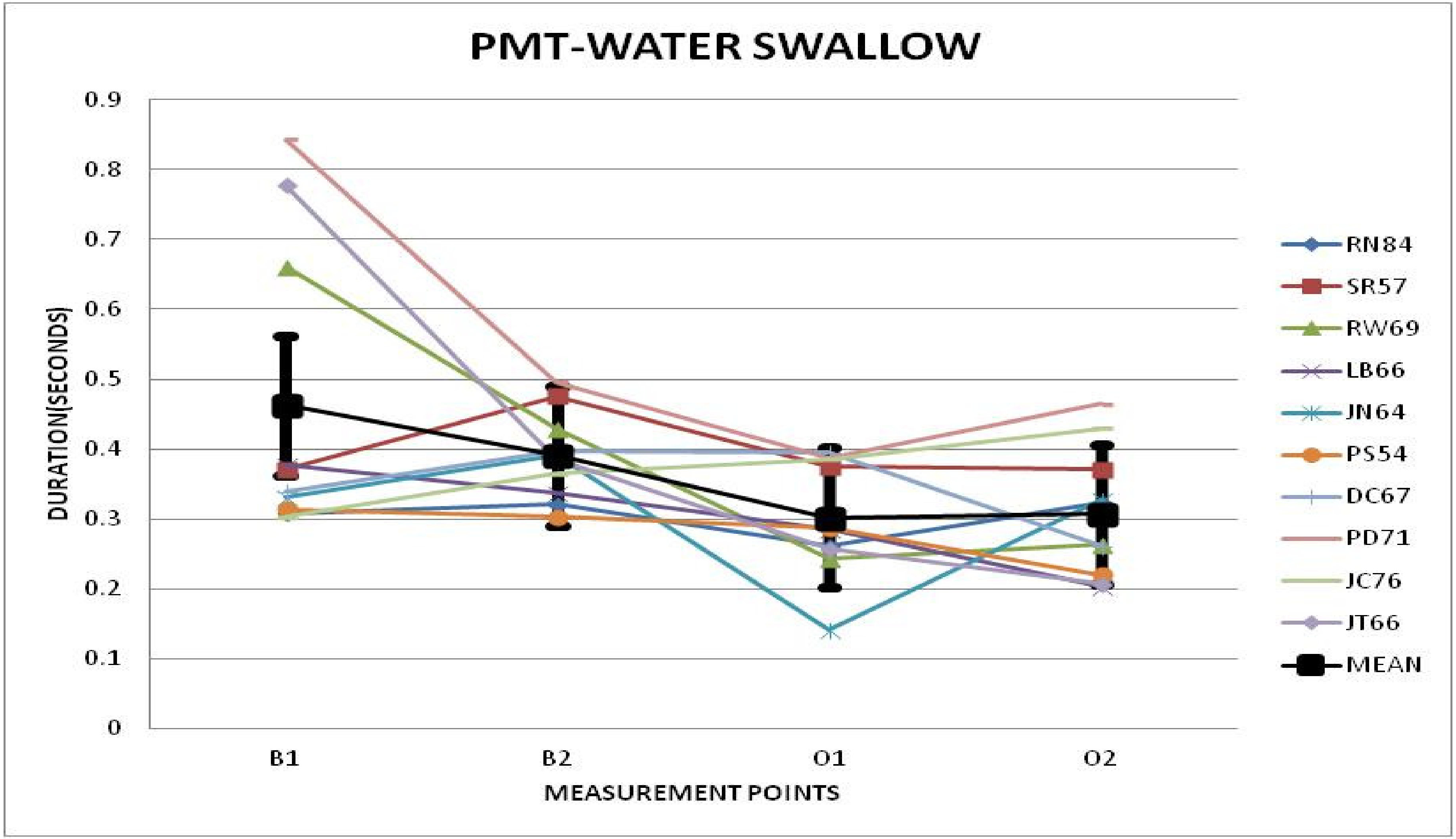
Appendix I-2: Individual scores for dry swallow PST (mean and standard deviation in black)



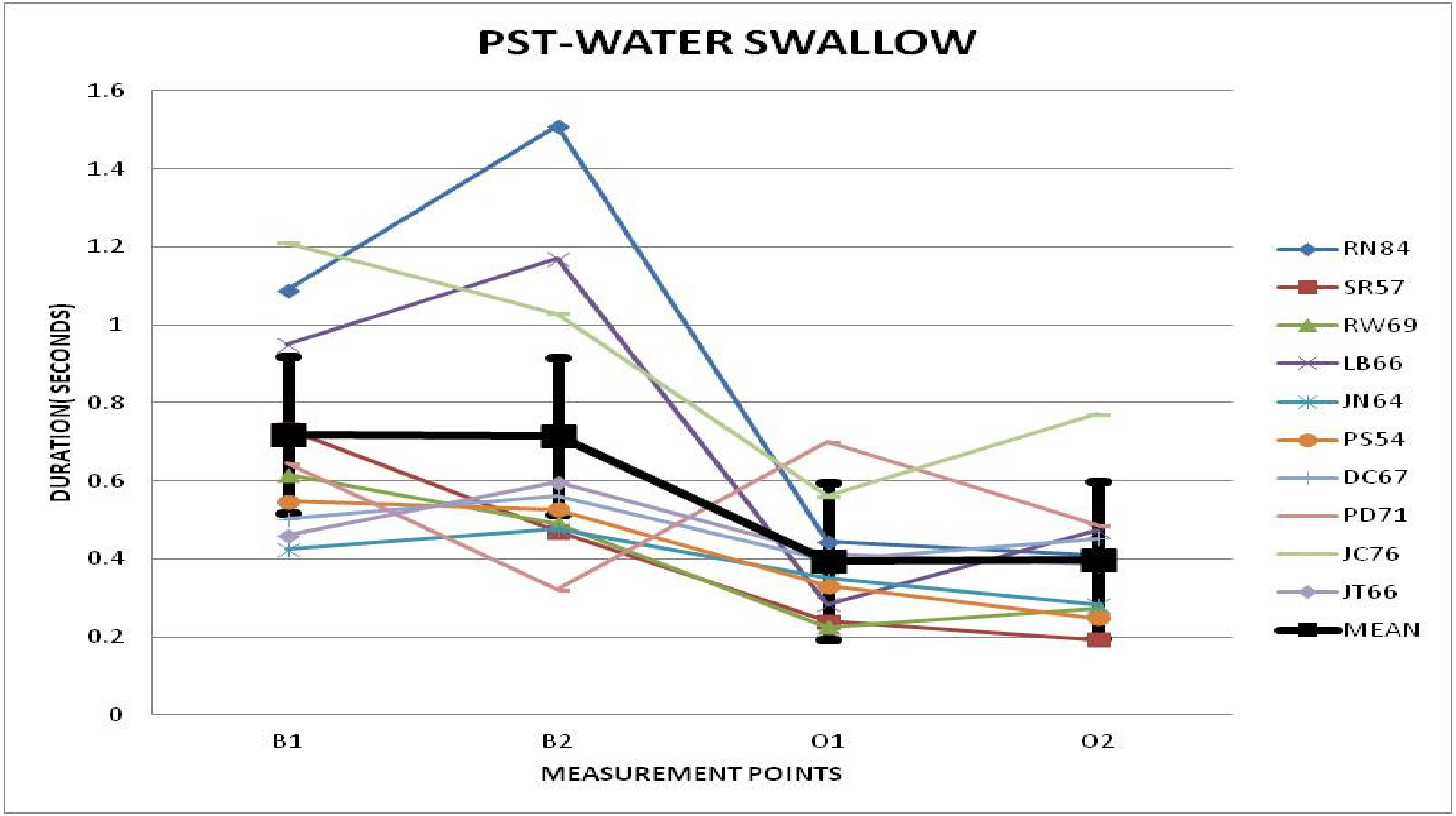
Appendix I-3: Individual scores for dry swallow duration of submental muscle contraction (mean and standard deviation in black)



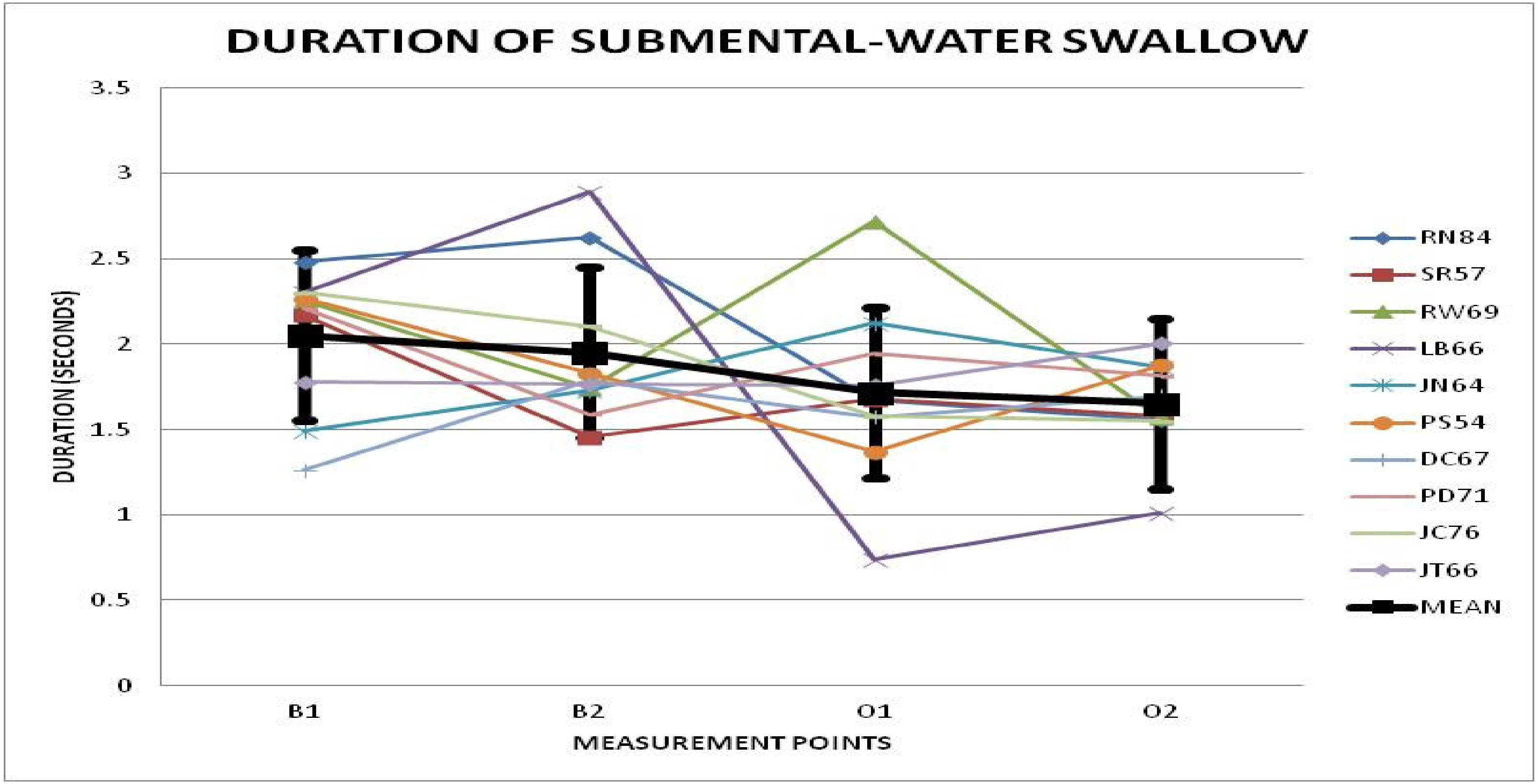
Appendix I-4: Individual scores for water swallow PMT **(mean and standard deviation in black)**



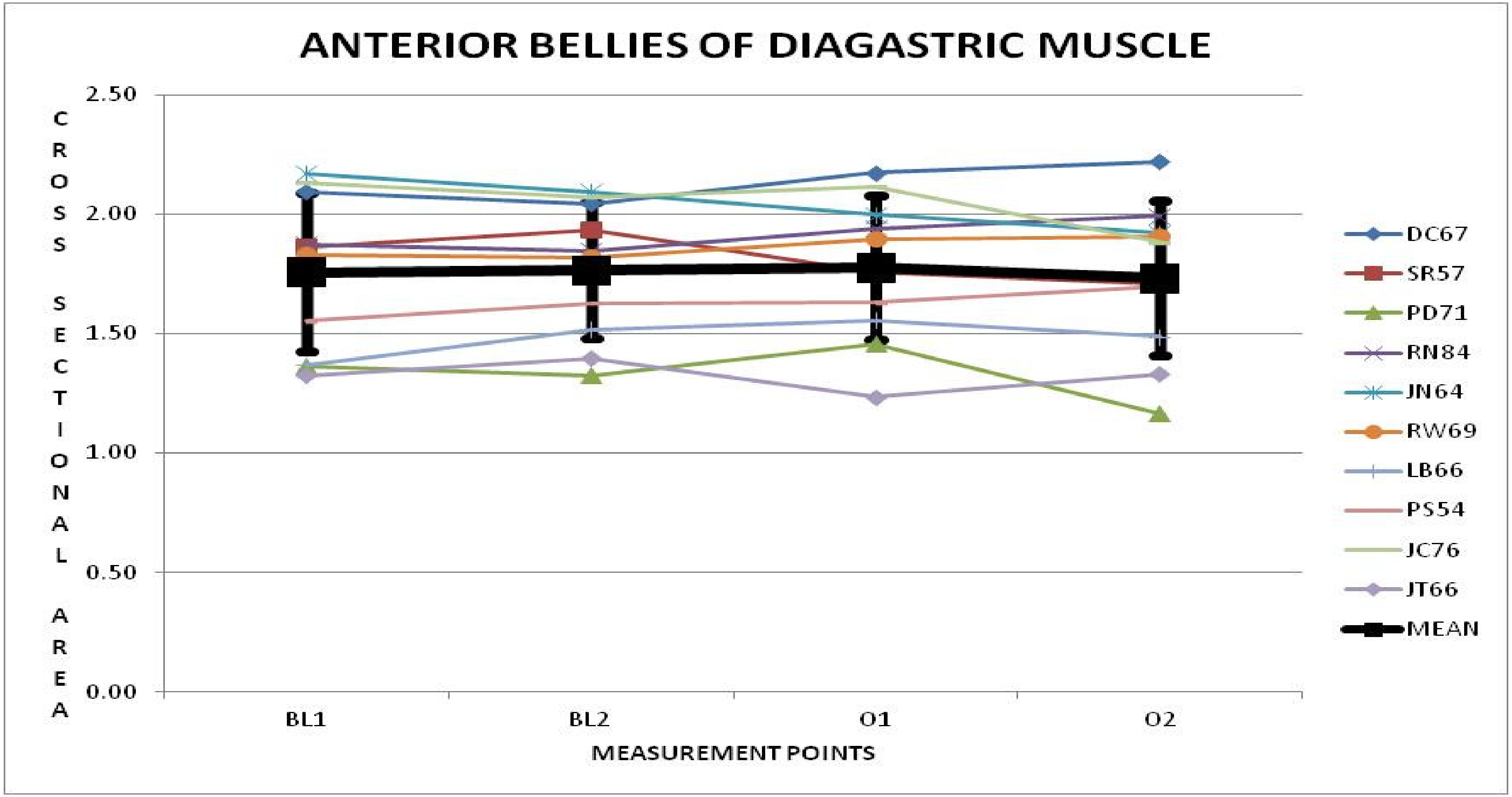
Appendix I-5: Individual scores for water swallow PST (mean and standard deviation in black)



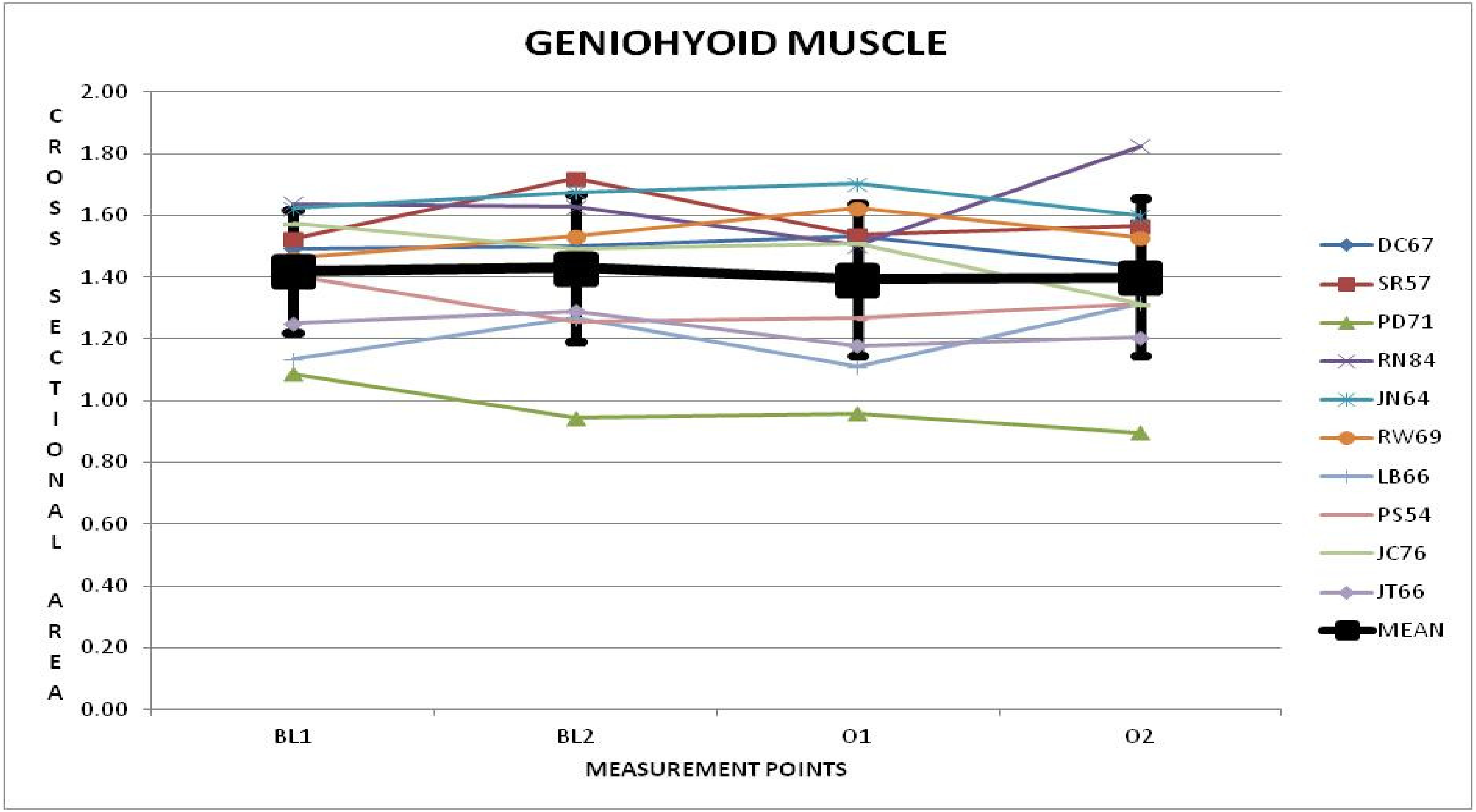
Appendix I-6: Individual scores for water swallow duration of submental muscle contraction (mean and standard deviation in black)



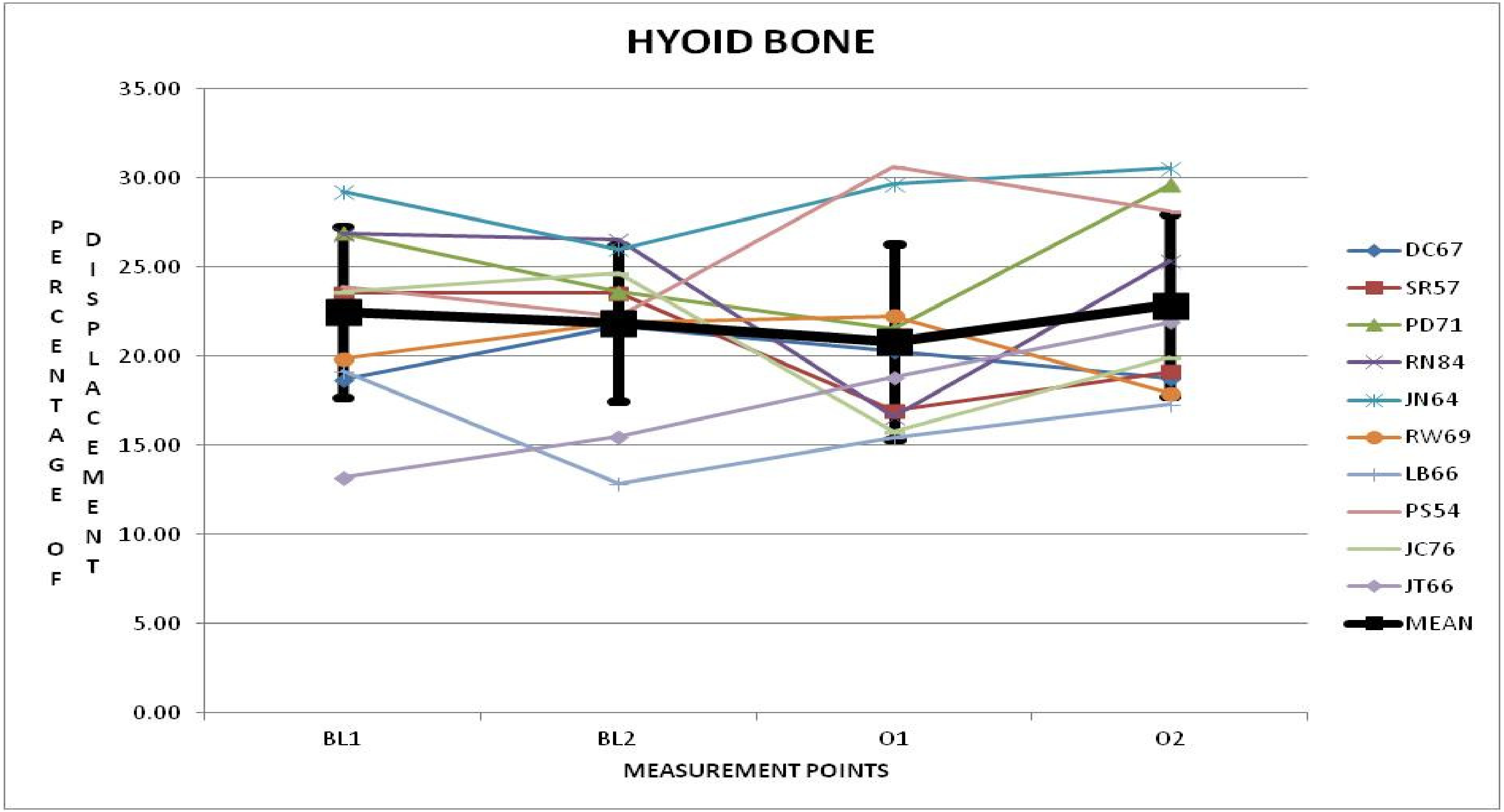
Appendix J-1: Individual scores for CSA of anterior bellies of digastric muscle (mean and standard deviation in black)



Appendix J-2: Individual scores for CSA of geniohyoid muscle (mean and standard deviation in black)



Appendix J-3: Individual scores for percentage of displacement of hyoid bone (mean and standard deviation in black)



Appendix K: Individual scores for percentage score of SWAL-QOL (mean and standard deviation in black)