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A Comparison of Laryngeal Diadochokinetic Tasks

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A COMPARISON OF LARYNGEAL DIADOCHOKINETIC TASKS

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Laryngeal diadochokinetic (LDDK) tasks require fine motor control of the larynx to produce rapid repetition of the glottal syllables /ʌ/ and /hʌ/. Fine motor control of the larynx is also essential for phonation and swallowing. Therefore, assumptions have been made in the literature that performance on LDDK tasks could possibly predict laryngeal function during speech and swallowing. Before those assumptions can be tested, normative data on LDDK performance must be established. Very few studies have been conducted that identify LDDK values. The studies that do provide data on LDDK performance include inconsistencies among them in the in tasks, population and measurement. The purpose of this study was to compare two stimuli, /ʌ/ and /hʌ/, found in previous studies of LDDK to determine if there are any differences in rate within a group of normal participants who were between the ages of 40-60 years of age. The study also identifies normative values for LDDK production in this population including gender comparisons. Thirty seven adults with no previous medical history significant to laryngeal function participated in the study. SPSS software was utilized to analyze results to calculate normative values. The results revealed that there is no significant difference between the repetitions per second of /ʌ/ and /hʌ/ tasks (Wilks' Lambda = .869, $F(5.00,29.00)= .871$, $p=.512$). There is no significant effect of gender for LDDK tasks ($p=.252$). Normative values for were calculated. Limitations and implications for these results are discussed.

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CHAPTER I

REVIEW OF THE LITERATURE

Diadochokinesis

Merriam-Webster's Medical Desk Dictionary (2005) defines diadochokinesia as "the normal power of alternating diametrically opposite muscular actions." Clinically, in the field of speech-language pathology, oral diadochokinesis has been used frequently to examine motor coordination and control of the major articulators. The rapid repetition of syllables /pʌ/, /tʌ/, /kʌ/ and combinations of those syllables are used as stimuli to measure oral diadochokinetics of the lips, tongue, and velum. Production of these stimuli simulate the fine motor coordination required for speech tasks (Yoss & Darley, 1974). Several authors have collected normative data and conducted studies in disordered populations using oral diadochokinesis (Chuma, Cacace, Rosen, Feustel, & Koltaii, 1999; Fletcher, 1972; Irwin & Becklund, 1953; Ruscello, St Louis, Barry, & Barr, 1982). Studies suggest that oral diadochokinetic rates outside the normative range can facilitate differential diagnosis of developmental delays, progressive neurologic conditions, and neuromuscular impairments of the lips, tongue, and velum (Gadesmann & Miller, 2008).

Laryngeal diadochokinesis (LDDK), on the other hand, uses the glottal production of the syllables /ʌ/ and /hʌ/ to isolate laryngeal function in the absence of oral articulation. Production of these syllables requires rapid opening and closing of the vocal folds during a controlled exhale with a relatively open vocal tract. Laryngeal DDK has received much less attention than oral DDK in research. However, authors have discussed its potential in assessing laryngeal function (Leeper & Jones, 1991; Ptacek, Sander, Maloney, & Jackson, 1966; Stemple, Glaze, & Klaben, 2000; Verdolini & Palmer, 1997).

Anatomy and Innervation

Knowledge of the anatomy and innervation of the larynx is important to understanding the mechanism required to rapidly produce the syllables /ʌ/ and /hʌ/ as stimuli for laryngeal diadochokinesis. Fine motor control of vocal fold movement is essential to successful completion of the phonatory tasks. The vocal folds are located in the larynx, which is a cartilaginous tube located superior to the trachea and anterior to the hypopharynx. Airflow is produced as an exhale from the lungs and its release is controlled by thoracic muscles. The vocal folds open and close to manipulate the airstream during phonation. Adduction, or closing, of the vocal folds builds subglottic pressure necessary to initiate vocal fold vibration. Abduction, or opening, of the vocal folds terminates phonation and allows for continuous flow of air through the vocal tract (Stemple, et al., 2000). Shanks (1966) quoted Ptacek and Maloney from an unpublished National Institutes of Health (NIH) grant report that, “vocal folds themselves act as articulators in initiating and terminating the sound” (p. 9). It is the intrinsic muscles of the larynx that control dynamic changes in mass distribution, length, tension, medial compression, and position of the vocal folds. The cricothyroid, thyroarytenoid, lateral cricoarytenoid, and interarytenoid muscles are all intrinsic muscles of the larynx that work together to adduct the vocal folds; otherwise known as the adductor muscles. Each muscle also contributes to the motoric adjustments necessary for phonation. The cricothyroid anteriorly lengthens and tenses the vocal folds. Laterally, the thyroarytenoid, which includes the thyrovocalis and thyromuscularis, works to tense and relax the vocal folds and control vocal fold body and shape. They also work along with the lateral cricoarytenoids and the interarytenoids by providing medial compression to increase strength of adduction. Abduction is less complex; as it involves one muscle, the posterior cricoarytenoid, and occurs upon contraction of the posterior cricoarytenoid. These fine motor adjustments of alternating between adduction and abduction along with auxiliary muscle adjustments occur rapidly during connected speech. Therefore, the LDDK task of laryngeal function must also demonstrate these rapid alternating and opposing movements.

These muscles that control adduction and abduction are innervated by cranial nerve X, the vagus nerve. The vagus nerve supplies the intrinsic laryngeal muscles with efferent and afferent innervations (Sulica, Blitzer, & Springer, 2006). The recurrent laryngeal branch (RLN) of the vagus nerve innervates all of the intrinsic muscles of the larynx with the exception of the cricothyroid. The RLN further separates into two divisions: the anterior and posterior divisions. These divisions supply innervation to four of the intrinsic muscles (Sulica, et al., 2006). The anterior division supplies three of the adductor muscles including the interarytenoids, lateral cricoarytenoid, and thyroarytenoid. The posterior division supplies the posterior cricoarytenoid, the sole abductor muscle of the vocal folds. The fourth adductor muscle, the cricothyroid, receives innervation via the internal branch of the superior laryngeal nerve (SLN; Sulica, et al., 2006). Sulica (2006) explained that recent research suggests that the SLN may contribute some motor input to the interarytenoids and thyroarytenoid, as well.

In the clinical setting, the most common dynamic laryngeal abnormalities are due to neurologic deficits rather than mechanical deficits; and these neurologic deficits involve innervation via the RLN and SLN (Stemple, et al., 2000). Deficits or damage to the RLN or SLN result in an impaired ability to abduct and adduct the vocal folds (Verdolini & Palmer, 1997). This impairment would thus affect the rate of the rapid, alternating abduction and adduction of the vocal folds required to produce laryngeal diadochokinetic tasks.

Mechanical deficits may not affect the dynamic adjustments to the larynx as frequently as neurologic impairment, but the structure of the vocal folds has a significant impact on the physiologic modifications necessary to achieve phonation. For example, when a lesion exists in the lamina propria, or cover, of the vocal folds, increased medial compression is necessary to compensate for the gaps in glottal closure created around the lesion. Alternatively, if the thyroarytenoid muscle is atrophied, increased medial compression may not even be enough to compensate for the glottal gap making subglottic pressure difficult to achieve. Increased laryngeal effort and glottal incompetence decrease the efficiency of the laryngeal movements necessary for phonation and phonatory tasks, such as the LDDK.

Impact of Aging

According to a World Health Organization document (Bourliere, 1970), linear decrement of all systems of the body can begin as early as age 30. As with other systems of the body, the phonatory system experiences changes due to aging. Starting with the respiratory system that provides the power for phonation, the lungs become less elastic, the thorax stiffens, and respiratory strength is decreased (Linville, 2004; Sauder, Roy, Tanner, Houtz, & Smith, 2010). This decrease in overall respiratory ability makes it more difficult to sustain phonation for long periods of time.

The source of phonation, the larynx, also experiences changes related to age; this process is also known as presbylaryngis. Presbylaryngis occurs at the histological level in the lamina propria of the vocal folds with a reduction of hyaluronic acid in the extracellular matrix (Sauder, et al., 2010). The elastin fiber size and density increase in the superficial layer (resulting in a less flexible structure and atrophy of elastin in the intermediate layer) causes the structure to become loose and thin (Stemple, et al., 2000). These changes in the layers of the vocal folds cause the vocal folds to become 'bowed' in appearance, the hallmark of presbylaryngis (Sauder, et al., 2010; Stemple, et al., 2000). Bowing of the vocal folds and concavity of the medial edges causes changes in glottic closure patterns during abduction and adduction (Sauder, et al., 2010; Stemple, et al., 2000). The greatest effect of presbylaryngis is most commonly recognized between the ages of 60 and 70 years (Ramig & Ringel,1983).

In addition to changes in the histological layers of the vocal folds in the larynx, aging also causes changes in the mechanics of abduction and adduction of the vocal folds. These changes are affected by changes in laryngeal cartilage and muscle, as well as the cricoarytenoid joint. The laryngeal cartilages, which form the structure of the larynx, begin to calcify and ossify. Atrophy and degeneration of the laryngeal muscles create a weakness in abduction and adduction. Deterioration of the cricoarytenoid joint may lessen vocal fold approximation or reduce smoothness in vocal fold adjustments (Linville, 2004). These changes in the mechanism could drastically impair the ability to rapidly produce LDDK abduction and adduction tasks.

Luschei, Ramig, Baker, and Smith (1999) also noted that electromyographic (EMG) studies suggest change in neurologic function as we age. These neurologic changes could impact rate, strength, and consistency of vocal fold adduction and abduction. These changes in neurologic function, histological layers of the vocal folds, and respiratory function suggest that aging should have a significant impact on laryngeal function.

Gender Differences

Although the male and female vocal folds are structurally similar, there are significant differences in overall size, location, vocal fold membranous length, and elastic properties of the tissue. The vocal folds in prepubescent boys and girls appear to be similar until the age of 10 years. At the onset of puberty gradual changes in the overall length of the thyroarytenoid and the ratio of membranous-to-cartilage portions begin and continue until maturation (Stemple, et al., 2000). According to Stemple (2000), a study by Hirano, Kurita, and Nakashima examined size and structure of the vocal folds. Findings of the Hirano, Kurita, and Nakashima study indicated that by adulthood male vocal fold length is 17 to 21mm and female vocal fold length is 11 to 15mm. Gender differences in membranous to cartilage portions is a ratio of 5.3:1 in adult males and 4:1 in adult females. The cricoid sits at the level of cervical vertebrae seven in adult males and cervical vertebrae six in adult females. The thyroid cartilage angle is smaller in males than females at 90 degrees for males and 110 degrees for females. These anatomical differences in male and female larynges may cause differences in laryngeal function.

Laryngeal Diadochokinesis

Laryngeal diadochokinesis has been used very little in research of laryngeal function and pathologies. Although this measure has not been formally evaluated as an indicator for laryngeal deficits, Verdolini and Palmer (1997) indicated that, "LDDK rate, strength, and rhythmia were selected as likely indicators of arytenoid ab/adducation integrity." Laryngeal diadochokinesis requires the rapid, consistent production of glottal syllables, such as /ʌ/ and /hʌ/, for a period of a few seconds (Ptacek, et al., 1966). In order to perform this task consistently, individuals must exhibit controlled abduction and adduction of the vocal folds (Verdolini & Palmer, 1997), making it ideal for identification of pathology. Producing the glottal syllable /ʌ/ is an adductory task that assesses the laryngeal mechanism's ability to execute a rapid vocal fold onset-offset. On the other hand, production of the glottal syllable /hʌ/ is an abductory task that evaluates rapid vocal fold offset-onset (Bassich-Zeren, 2004).

LDDK Tasks

Repetitions of the vowel /ʌ/ and the syllable /hʌ/ are most commonly used to test LDDK. However, studies using LDDK as a measure of laryngeal function are inconsistent. Some studies only used /ʌ/ (Fung et al., 2001; Gartner-Schmidt & Rosen, 2009; Herbert A. Leeper & Jones, 1991; Ptacek, et al., 1966); some studies only used /hʌ/(Canter, 1965; Renout, Leeper, Bandur, & Hudson, 1995; Shanks, 1966). Other studies used both tasks (Bassich-Zeren, 2004; Verdolini & Palmer, 1997). Ptacek (1966) reasoned that producing the glottal vowel /ʌ/ in isolation causes the vocal folds to initiate and terminate the sound by acting as articulators. On the other hand, Canter (1965) argued that the production of the glottal consonant plus the vowel /hʌ/ creates a continuous airstream requiring greater laryngeal function in order to compensate, and thus is a better measure of laryngeal function. Bassich-Zeren's (2004) rationale for using both tasks was that /ʌ/ measured adduction of the vocal folds (adduct to abduct) and /hʌ/ measured abduction of the vocal folds (abduct to adduct). Bassich-Zeren (2004) and Leeper, Heeneman and Reynolds (1991) authored the only two studies that compared LDDK adductory and abductory tasks.

Measures of LDDK

Laryngeal diadochokinetic tasks can be measured both objectively and subjectively. LDDK is measured objectively by using an oscillogram to evaluate rate and pattern. Rate is the number of glottal syllable repetitions per second (Leeper & Jones, 1991; Ptacek, et al., 1966; Renout, et al., 1995; Shanks, 1966; Verdolini & Palmer, 1997). Many studies measured rate by recording LDDK productions on an oscillographic waveform, then counting the number of peaks and dividing the number by time for production (typically seven seconds) to calculate repetitions per second. In addition to using oscillographic waveform software to calculate rate, Verdolini and Palmer (1997) also used the pen dotting method to calculate rate as the participant performed the task. The clinician marked a pen dot for each glottal syllable for seven seconds then counted the dots and divided the total by seven. This technique accomplishes the same measure of repetitions per second but without the need for the technology. Pattern, the other objective measure used to evaluate LDDK, is defined as the "percentage of abduction and adduction time during productions" (Renout et al., 1995, p. 75). This measure is also calculated using an oscillographic waveform by placing cursors around abducted intervals (voiceless on waveform) and adducted intervals (voiced on waveform) to compute the abducted/adducted ratio. It is a time and labor intensive method of measurement.

In addition to these objective measures, perceptual measures are also used to evaluate LDDK. Perceptual measures include ratings of strength and consistency. These terms are used interchangeably with ‘periodicity’ and ‘rhythmia.’ Perceptual measures were defined by Verdolini and Palmer (1997). They defined the strength of glottal stops as the, “auditorily perceived rise-time and loudness” (p. 223), and described rhythmia as, “glottal stop consistency over time” (p. 223). Both strength and rhythmia were measured in their research perceptually by the dichotomous ratings “good” or “poor” (Verdolini & Palmer, 1997). A simple dichotomy, however, does not seem adequate to measure the wide range from the best produced to the worst produced. Normative data that are more sensitive across several ratings would be a better measure for the wide span from best to worst for these two perceptual measurements.

Not only is there inconsistency in the tasks used to elicit data on LDDK, but studies have used different measures and combinations of measures to evaluate LDDK. Rate, however, is one measurement that has remained consistent across studies. In fact, Bassich-Zeren (2004), Canter (1965), Fung (2001), and Ptacek (1966) only used rate to measure LDDK tasks. Conversely, Verdolini and Palmer (1997) and Gartner-Schmidt and

Rosen (2009) used the combination of rate, strength, and rhythmia to measure objective and perceptual aspects of LDDK. Renout et al. (1995) and Shanks (1966), on the other hand, used rate and rhythmia, but used the objective measure of pattern rather than the perceptual measure of strength. This alternative is perhaps because the complex calculations of pattern would make it difficult and impractical to use clinically. Measures described by Verdolini and Palmer (1997) and Gartner-Schmidt and Rosen (2009) seem like a more logical choice of measurement of LDDK in a clinical setting. The use of an objective measure, however, eliminates inter-rater differences and relies on numerical data rather than perception.

Variables Affecting LDDK Production

Two studies have been conducted to evaluate variables that affect LDDK performance. A study by Leeper and Jones (1991) evaluated the effects of frequency and pitch upon temporal aspects of LDDK in 18 female participants between the ages of 20 and 25 years. Another study by Shanks (1966) looked at the effects of pitch, intensity, and aging on LDDK production in 120 women between the ages of 20 and 80. Both studies discovered that frequency and intensity had a significant impact on the rate of LDDK production (Leeper & Jones, 1991; Shanks, 1966). Shanks (1966) suggested that a lack of restriction on the laryngeal mechanism when producing LDDK tasks at a comfortable pitch and loudness should result in production of maximal performance on

LDDK tasks. This study was limited in generalizability because LDDK data were only collected on female subjects.

In Shanks' (1966) study, aging did not have a significant impact on LDDK performance. However, another study that evaluated phonatory changes related to age revealed opposite findings. Ptacek et al. (1966) suggested lower LDDK rates in a geriatric group than a younger adult group (Ptacek, et al., 1966). These mixed findings could be due to inconsistencies in tasks, population and measurement.

Clinical Implications

Because LDDK is likely to reveal information about vocal fold functioning, it has potential as a clinical measure. However, to date, only a handful of studies have used LDDK to assess laryngeal function across clinical populations. Studies by Bassich-Zeren (2004), Canter (1965), and Verdolini and Palmer (1997) examined laryngeal function using LDDK in patients with Parkinson's disease (PD). Canter's (1965) study evaluated the overall speech adequacy of 17 men (median age 56.8 years old) with PD using the task /ʌ/ compared to a control group of men of the same age without PD. His findings suggested that, compared to controls, patients with PD demonstrated an impaired ability to produce the LDDK task, and some patients were unable to perform the task due to respiratory and vocal fatigue. The patients' ability to produce the task proved a good predictor of overall speech production. Overall speech production was measured by experienced speech-language pathologists who rated pitch, loudness, duration, voice quality, and articulation for oral readings of the "Rainbow Passage" (Canter, 1965). The findings of Verdolini and Palmer's (1997) study were consistent with Canter's (1965) findings. Eight patients with PD showed impairment in the production of /ʌ/ in rate, strength, and rhythmia.

Bassich-Zeren's (2004) study was the only study of the three that used both LDDK tasks, /ʌ/ and /hʌ/, to evaluate laryngeal dysfunction in 12 patients with young onset PD (YOPD). Results from this study (Bassich-Zeren, 2004) suggest that patients with YOPD showed a significantly slower rate for the adductory task (/ʌ/) than the abductory task (/hʌ/) and used a greater number of pauses to maintain the abductory task (/hʌ/) for the entire seven second period. These impairments in LDDK tasks could be due to impairment in laryngeal dysfunction or use of compensatory strategies for producing adductory tasks. Bassich-Zeren (2004) also suggested that perceptual evaluation of LDDK tasks could have the potential to identify laryngeal dysfunction. All three of these studies used small sample sizes to compare patients with PD to normal controls; thus sample size was considered a weakness in this research. However, there are currently limited normative data to use to compare disordered populations. Such normative data could serve as foundational measures for differential diagnostic values for PD and other disorders.

Another neurologic disorder evaluated using LDDK is amyotrophic lateral sclerosis (ALS). Renout et al. (1995) conducted a study specifically measuring LDDK function in 12 patients with bulbar and 14 patients with non-bulbar ALS. The authors used the abductory task (/hʌ/) to measure LDDK. The bulbar group exhibited slower LDDK rates than the non-bulbar group and the non-bulbar group produced fewer adductions than abductions. Overall, both groups produced aperiodic (i.e., arrhythmic) syllables on LDDK tasks. Results of this study suggest that LDDK could help differentiate laryngeal motor deterioration between two subgroups of ALS (Renout, et al., 1995). Researchers evaluated the differences in LDDK performance between bulbar and non-bulbar groups; they were, however, unable to compare the results of both groups to a normative sample due to the lack of normative values available and absence of a control group.

Spasmodic dysphonia (SD) and vocal fold paralysis, two other neurogenically-based voice disorders, have been evaluated through the use of LDDK tasks as well. A meta-analysis on SD suggested that LDDK performance is predictive of botulinum toxin treatment outcomes (Boutsen, Cannito, Taylor, & Bender, 2002). In Verdolini and Palmer's (1997) study, LDDK rate, strength, and rhythmia were all considered poor in five patients with unilateral peripheral paralyses. SD and vocal fold paralysis are two other disorders for which LDDK could potentially be used as a predictive and differentially diagnostic measure if normative data were available.

In addition to neurologic disorders, laryngeal dysfunctions of structural abnormalities of the larynx have been examined through LDDK. Verdolini and Palmer

(1997) used LDDK to screen patients with structural laryngeal abnormalities. Findings indicated that seven participants with vocal fold nodules and five participants with vocal fold granulomas performed at a normal rate, strength, and rhythmia for LDDK tasks. Although Verdolini and Palmer's study (1997) did not indicate poor LDDK rate, strength, and rhythmia in these subpopulations, normative LDDK data could be useful as a differential diagnosis. They used a small sample size for each population making it difficult to generalize these results and use their small control group to represent the normative population. Fung, et al. (2001), however, used LDDK to measure laryngeal function following radiation in patients with laryngeal tumors versus non-laryngeal tumors. This study (Fung, et al., 2001) differentiated laryngeal versus non-laryngeal tumors through LDDK. Patients with non-laryngeal tumors demonstrated decreased LDDK rates. Unfortunately, most studies used small sets of normative data from control groups to compare LDDK performance in patients with neurologic disorders and structural laryngeal abnormalities. Values from a larger normative sample across genders with a wider range of ages would result in a stronger data set for comparison.

Other Assessments of Laryngeal Function

It is well known that other assessments for measuring laryngeal function exist. The most commonly used assessments include endoscopy, electromyography (EMG), and electroglottography (EGG). Endoscopy is a perceptual measure of laryngeal function that visually assesses the glottal closure patterns and gross anatomy of the larynx. Two types of laryngeal endoscopy are used clinically, rigid and flexible. A rigid endoscope is inserted through the oral cavity to assess sustained phonation, and it has better magnifying abilities than flexible endoscopy. Flexible endoscopy is administered through the nasal cavity and is used to assess connected speech. Drawbacks to using either type of endoscopy are that they are an invasive perceptual measures, they require expensive equipment, and they are not readily available to speech-language pathologists (Stemple, et al., 2000). These limitations make them less useful as a clinical measures.

Laryngeal EMG requires inserting needle electrodes percutaneously into the thyroarytenoid and cricothyroid muscles. EMG assesses muscular action patterns of onset and offset, as well as the number and amplitude of muscular potential. Similar to endoscopy, this procedure is invasive, requires expensive equipment, and must be done by a neurologist or otolaryngologist (Stager & Bielamowicz, 2010; Stemple, et al., 2000). This technique is also not likely to be practical as a clinical measure.

Unlike endoscopy and EMG, EGG is a noninvasive assessment. With EEg, electrodes are placed on both sides of the thyroid alae to measure electrical currents that pass through the vocal folds as they vibrate. These electrical currents assess open and closed phases of phonation, and therefore the cycle of phonation. Once again, this assessment requires equipment that is not available in most clinical settings (Childers, Hicks, Moore, Eskenazi, & Lalwani, 1990; Stemple, et al., 2000). Therefore, a screening tool like LDDK does not require expensive equipment and uses both perceptual and objective measures to evaluate laryngeal function.

Interpretive Value of Current Literature

The literature mentioned above highlights the paucity of research on the design and application of the LDDK measure. Many studies that have utilized LDDK focus on LDDK production in populations with laryngeal abnormalities or neurologic disorders (Bassich-Zeren, 2004; Canter, 1965; Leeper, Heeneman, & Reynolds, 1990; Renout, et al., 1995; Verdolini & Palmer, 1997). Unfortunately, these studies compare LDDK rates to a small normative population and, therefore, lack strong normative values for comparison. Studies that examine LDDK production in a normal population lack consistency in LDDK stimuli. Leeper and Jones (1991) and Ptacek (1966) only used the /ʌ/ stimuli, whereas Shanks (1966) limited her study to the use of the /hʌ/ stimuli. Another factor that adds to the limitations of the literature on LDDK is gender. Leeper and Jones (1991) and Shanks (1966) restricted their studies to female participants only. Ptacek's (1966) study, on the other hand, included both male and female participants, but limited the age groups to between 18 and 38 years and between 66 and 93 years of age. Therefore, age presents another limitation in the literature on LDDK. Inconsistencies across studies in tasks and measurements used to assess LDDK performance make it difficult to compare the results of one study to the next. Although these studies fail to provide clinicians with normative data to use clinically, they do provide initial evidence that LDDK has the potential to be used clinically to assess laryngeal function in a noninvasive way that requires little more than waveform software and a trained ear. Because the literature on LDDK is inconsistent; the tasks and measurements used to elicit LDDK should be examined to determine the best methods to elicit LDDK for future clinical use. An objective, perceptual assessment of laryngeal function such as LDDK could become a valuable clinical tool to support the differential diagnosis of laryngeal disorders, if the task is standardized and supported by normative data.

CHAPTER II

PURPOSE

Considering the inconsistencies in LDDK tasks in the existing literature, the purpose of this study was to compare data for both tasks, /ʌ/ and /hʌ/. The procedures for tasks were standardized to allow for replication by other researcherss. Normative values in an age-and-gender controlled participant set allow for better comparisons to data in matched-disorder groups. The data offer a clinically simple, noninvasive, and inexpensive method of assessing laryngeal function. Collecting normative LDDK values for the adult population is important to assess laryngeal function in adults before the process of presbylaryngis begins to take effect. For this purpose the following questions were posed:

1. Is there a difference between LDDK rates for the adductory task /ʌ/ and the abductory task/hʌ/ in adults between the ages of 40 and 60 years?
2. What are the normative values for LDDK rate for the adductory task /ʌ/ and the abductory task/hʌ/ in adults between the ages of 40 and 60 years?
3. Is there a difference between normative values of LDDK rate for male and female subjects?

CHAPTER III

RATIONALE

Adequate phonatory abilities require structural integrity of the vocal folds and uninterrupted neurological innervation from the vagus nerve to control abduction and adduction of the intrinsic laryngeal muscles (Sulica, et al., 2006). The LDDK tasks /ʌ/ and /hʌ/ are produced by the intrinsic laryngeal muscles, primarily the vocal folds. Therefore, it is logical that LDDK tasks reflect the status of laryngeal functioning (Ptacek, et al., 1966). Although researchers have used LDDK to evaluate laryngeal function in the past, the studies were inconsistent in tasks, measurement, and population. None of the studies had strong, diverse normative values to compare their participants' results. Findings from these studies indicate that LDDK could have the potential to be used as a tool for differential diagnosis, early detection of disorders, and a simple screening tool for laryngeal function (Bassich-Zeren, 2004; Boutsen, et al., 2002; Canter, 1965; Fung, et al., 2001; Renout, et al., 1995; Verdolini & Palmer, 1997). It seems most important to collect normative data for individuals between the ages of 40 and 60 years because this age group has begun the aging process but has not yet experienced the full effects of presbylaryngis. Comparing the rate of men and women also seems important considering the differences in the vocal folds between genders.

CHAPTER IV

METHOD

Design

Laryngeal diadochokinetic rate for adductory and abductory LDDK tasks were compared using a differential research design. This type of research design is useful in comparing two or more groups that were defined before the study was conducted. In differential research, dependent variables are measured and compared between the two groups. These two groups represent the independent variables which are nonmanipulated. Gender, serves as the independent variable and the LDDK tasks serve as the dependent variables in this study (Graziano & Raulin, 2007).

Participants

Recruitment

Family members, friends, neighbors and coworkers of the investigators were recruited to participate in this study. Individuals who met the inclusion criteria to participate in the study were provided a copy of the *Informed Consent Form* (Appendix A). This form identifies the risks, benefits and requirements for participating in the study. To indicate their agreement to participate in the study, each participant was required to sign the *Informed Consent Form* to indicate that they understand the risk, benefit and requirement to participate. The protocol and *Informed Consent Form* were reviewed and approved by the Indiana University of Pennsylvania Institutional Review Board.

Inclusion and Exclusion criteria

To be included in the study, participants were required to have typical vocal quality. This was an auditory-perceptual judgment made by the expert through the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V; "Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V)," 2006). Participants with scores of 20 or less on the CAPE-V (2006) were included in the study. Individuals who exhibited the following were excluded from the study: a) vulnerability, b) symptoms of cold or illness on the day of testing, c) history of respiratory, laryngeal, or neurologic disease, d) previous surgeries of the larynx, e) history of structural or dynamic laryngeal abnormalities, f) profound hearing loss, or g) lack of comprehension of the task.

Subject Selection

A total of thirty-seven participants between the ages of 40 and 60 years were selected to participate in this study. Two individuals did not meet inclusion criteria and were eliminated from the study. Individuals that met the inclusion criteria were required to complete the *Informed Consent Form* in order to participate in the study.

Final Sample

The final sample comprised 35 healthy normal participants, 14 male participants and 21 female participants between the ages of 40 and 60 years. Participants had a mean age of 51.6 years (range= 41-59 years; *SD*=5.1). Male participants had a mean age of 53.4 years (range=46-59 years; *SD*= 4.4). Female participants had a mean age of 50.38 years (range=41-58 years; *SD*= 5.2).

Data Collection Procedures

Documentation of informed consent and agreement to participate in the study were collected from each participant prior to beginning data collection. Data collection were conducted in a quiet room at the home or place of work of the participant or investigator. Individuals who agreed to participate in the study were required to complete four tasks: a) produce LDDK tasks /ʌ/ and /hʌ/ for seven seconds, three times each; b) sustain the vowels /a/ and /i/ for five seconds, three times each; c) read six sentences; d) maintain natural conversation for 30 seconds. All four tasks were recorded using a Roland CD-2 CF/CD Recorder and recordings were copied onto a compact disk. Participants were seated six inches (Leeper & Jones, 1991) from a Audio-Technica ATR20 Dynamic Cardioid Low Impedance Professional Microphone and presented with the following verbal instructions modeled after the instructions used in Fletcher's study (1972):

> "I want you to say some sounds for me. They aren't words, just sounds. I'll show you how to make it first, then you can say it with me. Then you try it yourself repeating the sound as quickly and consistently as you can. The first sound is . . . (/ʌ/ or /hʌ/). Try it with me. (Have participant practice to ensure they are producing the task correctly).

> Now I want you to do it once more. I am going to have you repeat the sound as quickly and consistently as you can for 7 seconds three times. I'll tell you when to start. Don't stop until I tell you. Ready. (Start recording).
>
> Now I would like you to perform the same task, but this time with the sound . . . (/ʌ/ or /hʌ/)."

These instructions were used for the /ʌ/ and /hʌ/ tasks. The investigator first demonstrated the task at approximately 5-6 repetitions per second for three seconds, producing precise and distinct adductory and abductory glottal syllables. The participant was then given an opportunity to practice the task to make certain they understood the instructions. Finally, three trials of each task were performed with randomized presentation of the two tasks (Bassich-Zeren, 2004).

After completion of the LDDK tasks, the participants were required to complete three tasks from the CAPE-V to assess phonatory function ("Consensus Auditory-Perceptual Evaluation of Voice [CAPE-V]," 2006). LDDK tasks were performed first to ensure that vocal fatigue was not a factor in the results of LDDK production. The first CAPE-V (2006) task required participants to sustain the low lax vowel /a/ and the high tense vowel /i/ for five seconds three times. Next, the participants read six sentences to measure various laryngeal behaviors: (a) The blue spot is on the key again; (b) How hard did he hit him? (c) We were away a year ago; (d) We eat eggs every Easter; (e) My mama makes lemon muffins; (f) Peter will keep at the peak. Finally, the participants were prompted to maintain natural conversation for 30 seconds using standard questions including: “Tell me what you did yesterday” or “Tell me a little about yourself” ("Consensus Auditory-Perceptual Evaluation of Voice [CAPE-V]," 2006).

Measurement Procedures

To determine eligibility, an expert with 16 years of experience in evaluating and treating voice disorders completed the CAPE-V (2006) for each participant to screen participants for voice disorders. Two participants were excluded from the study secondary to receiving a disordered rating of 20 or more.

Measurements to evaluate LDDK tasks included rate, strength, and consistency. The first measurement, rate, was measured objectively by converting the track for each LDDK task into a oscillogram using the Multidimensional Voice Program™ software (MDVP) (Shanks, 1966). All three repetitions of both tasks for each participant were converted into an oscillogram for analysis. Once the audio file was converted into an oscillogram, the first .5 second was eliminated from the beginning of the track to eliminate artifact from instability at the onset of a new task. The subsequent five seconds was used for analysis. The number of peaks (representing one repetition of /ʌ/ or /hʌ/) on the oscillogram for each five second segment was counted to calculate repetitions per second (Leeper & Jones, 1991; Ptacek, et al., 1966; Renout, et al., 1995; Shanks, 1966). The number of peaks was divided by five to determine repetitions per second.

Ethical Use of Data

All data collected were used only for the purpose of this study and a larger study from which these data are a subset. Participant identities or identifying information were not used on recordings or data collection paperwork. All personal identifying information was stored in a locked office and available only to the investigators of this study and the larger study. No identifying information was recorded or published. Upon completion of the larger study, all data and recordings will be destroyed.

Statistical Analysis

All statistical analyses were conducted using IBM® SPSS® Statistics Data Editor software (SPSS Statistics Data Editor, 2010). The first analysis was to determine if there is a difference between LDDK rates for the adductory task /ʌ/ and the abductory task/hʌ/ in adults between the ages of 40 and 60 years. A mixed between-within subjects analysis of variance (ANOVA) was used to compare rates of the adductory task /ʌ/ and the abductory task/hʌ/ (Graziano & Raulin, 2007). Interaction effect, main effect, and between-subjects effect were also analyzed and reported as Wilks' lambda (Λ) values at the *alpha level* (0.05 level of confidence; Silverman, 1998). The interaction effect assessed the change in scores over time for the two groups and identified whether the null hypothesis, which states, "the observed differences or relationships are due to chance, or random fluctuation," could be rejected (Silverman, 1998).

Also using the mixed between-within ANOVA, mean, range, and standard deviation of LDDK tasks and trials were analyzed to determine normative values for the adductory task /ʌ/ and the abductory task/hʌ/ in adults between the ages of 40 and 60 years. The two LDDK tasks and the six LDDK trials represented the categorical independent variables within-subjects. LDDK trials were analyzed in total repetitions per five seconds and repetitions per second. Both sets of results were analyzed due to the chance of repetitions per second masking any trends in the results. It was important, however, to report repetitions per second to compare results with other studies.

To answer the third question, “Is there a difference between normative values of LDDK rate for male and female particiapnts?” the same mixed between-within ANOVA was used to determine the effect of gender on LDDK tasks and trials. Gender represented the categorical independent variable between subjects.

CHAPTER V

RESULTS

Results revealed no statistical significance between the adductory and abductory LDDK task stimuli (.869, *F*(5.00,29.00)= .871, *p*=.512). No statistical significance was noted for gender (*p*=.252). Range, mean, and standard deviation for LDDK rates was calculated.

The main ANOVA results were used to answer, “Is there a difference between LDDK rates for the adductory task /ʌ/ and the abductory task /hʌ/ in adults between the ages of 40 and 60 years?” Results revealed no statistically significant interaction effect or main effect for LDDK rate using an alpha of .05, Wilks’ Lambda = .87 *F*(5.00,29.00)= .87, *p*=.51. Results are summarized in Table 1, *Multivariate Tests for Production Rates.*

Table 1

Multivariate Tests for Production Rates

Effect	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
ProductionRates						
Wilks' Lambda	.87	.87[a]	5.00	29.00	.51	.13

Next, the question, “What are the normative values for LDDK rate for the adductory task /ʌ/ and the abductory task/hʌ/ in adults between the ages of 40 and 60 years?” was answered. Normative values for /ʌ/ in male participants was *M*=4.52 repetitions per second (range=1.8-6.4 repetitions per second; *SD*=0.94) and for female participants *M*=3.40 repetitions per second (range=3.2-6.8 repetitions per second; *SD*=0.71). Normative values for /hʌ/ in male participants was *M*=4.42 repetitions per second (range=2.6-6.8 repetitions per second; *SD*=0.99) and for female participants *M*=4.76 repetitions per second (range=3.6-6.4 repetitions per second; *SD*=0.62). Mean, standard deviation, and range of each trial for both LDDK tasks in total repetitions per five seconds is summarized in Table 2, *Descriptive Statistics for Total Repetitions per Five Seconds by Task and Gender*. Mean, standard deviation, and range of each trial for both LDDK tasks in repetitions per second is summarized in Table 3, *Descriptive Statistics for Repetitions per Second by Task and Gender*. Total repetitions per five seconds were included to observe any trends in the data.

Table 2

Descriptive Statistics for Total Repetitions per Five Seconds by Task and Gender

Trial	Gender	Mean	Std. Deviation	Range	N
/ʌ/ 1	m	24.36	5.18	13-32	14
	f	25.19	3.11	17-30	21
	Total	24.86	4.02	13-32	35
/ʌ/ 2	m	21.43	4.60	10-30	14
	f	24.05	3.40	18-31	21
	Total	23.00	4.07	10-31	35
/ʌ/ 3	m	22.36	6.32	9-32	14
	f	23.33	4.15	16-34	21
	Total	22.94	5.06	9-34	35
/ʌ/ Total	m	22.71	4.54	9-32	14
	f	24.19	3.41	16-34	21
	Total	23.60	4.07	9-34	35
/hʌ/ 1	m	23.71	5.14	16-34	14
	f	24.29	3.44	18-32	21
	Total	24.06	4.14	16-34	35
/hʌ/ 2	m	22.29	5.27	13-32	14
	f	24.29	3.38	19-31	21
	Total	23.49	4.28	13-32	35
/hʌ/ 3	m	21.29	5.30	15-31	14
	f	23.48	3.61	18-31	21
	Total	22.60	4.43	15-31	35
/hʌ/ Total	m	22.43	4.48	13-34	14
	f	24.02	4.80	18-32	21
	Total	23.38	4.05	13-34	35

Table 3

Descriptive Statistics for Repetitions per Second by Task and Gender

Trial	Gender	Mean	Std. Deviation	Range	N
/ʌ/ 1	m	4.87	1.04	2.6-6.4	14
	f	5.04	0.62	3.4-6.0	21
	Total	4.97	0.80	2.6-6.4	35
/ʌ/ 2	m	4.21	0.81	2.0-5.6	14
	f	4.81	0.68	3.6-6.2	21
	Total	4.57	0.78	2.0-6.2	35
/ʌ/ 3	m	4.47	1.26	1.8-6.4	14
	f	4.67	0.83	3.2-6.8	21
	Total	4.59	1.01	1.8-6.8	35
/ʌ/ Total	m	4.52	0.94	1.8-6.4	14
	f	4.88	0.71	3.2-6.8	21
	Total	4.73	0.82	1.8-6.8	35
/hʌ/ 1	m	4.53	0.94	3.2-6.8	14
	f	4.81	0.68	3.6-6.4	21
	Total	4.70	0.80	3.2-6.8	35
/hʌ/ 2	m	4.42	1.06	2.6-6.4	14
	f	4.81	0.62	3.8-6.2	21
	Total	4.66	0.83	2.6-6.4	35
/hʌ/ 3	m	4.30	1.07	3.0-6.2	14
	f	4.65	0.65	3.6-5.8	21
	Total	4.51	0.84	3.0-6.2	35
/hʌ/ Total	m	4.42	0.99	2.6-6.8	14
	f	4.76	0.62	3.6-6.4	21
	Total	4.62	0.80	2.6-6.8	35

Finally, “Is there a difference between normative values of LDDK rate for males and females?” was answered. The main ANOVA results were used to determine effect of gender on LDDK tasks and trials. Results revealed no statistically significant effect of gender for LDDK rate (*p*=.25). Results are summarized in Table 4, *Test of Between-Subjects Effects*.

Table 4

Test of Between-Subjects Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	109797.33	1	109797.33	1263.18	.00	.98
SEX	118.25	1	118.25	1.36	.25	.04
Error	2868.40	33	86.92			

CHAPTER VI

DISCUSSION

Previous studies have suggested the potential for LDDK to reflect laryngeal function. The studies that use LDDK as a clinical measure have been inconsistent in the tasks, measurement, and population. Results of this study suggest that there is no significant difference between the adductory and abductory LDDK tasks. The study provides normative data for the LDDK rates for a controlled population of adults between the ages of 40-60 years. In addition, gender influences on LDDK rates were evaluated with no significant differences identified.

This study sought to identify the differences between the normative rates of an adductory task versus an abductory task. Results indicate there is no significant difference between the rate for /ʌ/ and /hʌ/. Bassich-Zeren (2004) and Leeper, Heeneman, and Reynolds (1990) are the only two studies that used both LDDK tasks. Neither of these studies reported whether the results for the two tasks were significantly different. It is conceivable that the offset-onset motion of the vocal folds versus onset-offset of the vocal folds does not impact the rate of production. Perhaps the precise initiation and termination for /ʌ/ (Ptacek, et al., 1966) and the continuous airstream used to control /hʌ/ (Canter, 1965) require the similar levels of laryngeal coordination and, therefore, result in statistically similar LDDK rates. Bassich-Zeren (2004) revealed that the YOPD group in her study performed significantly different on the adductory and abductory tasks. For the abductory task, the YOPD group required a significant number of breath pauses to complete the task. Although the abductory task required more breath pauses, the mean number of repetitions per second for the two tasks was not statistically different. These findings support the idea that the two tasks, although one involves precision and the other a continuous airstream, require a similar amount of laryngeal coordination and, therefore, produce repetitions per second that are not statistically different.

Another purpose of this study was to determine normative values for abductory and adductory LDDK tasks for adults between 40 and 60 years of age. The inconsistencies of the current literature on LDDK limit the ability to compare the normative rate for LDDK tasks of this study to others. Canter's (1965) male control group had a mean age of 56.8 years of age and produced the abductory task /hʌ/ from 4.1 to 7.6 repetitions per second with a mean of 5.6 repetitions per second. In this study, the male participants range was 2.6 to 6.8 repetitions per second with a mean of 4.42 repetitions per second for the abductory task. The mean repetitions per second are much higher in Canter's (1965) study than the male /hʌ/ group from this study. Women in the 40-60 years of age group in Shanks' (1966) study produced the abductory task /hʌ/ at a range of 3.75 to 6.94 repetitions per second (1966). Shanks' (1966) results were similar to this study's range for the female abductory task which was 3.6 to 6.4 repetitions per second with a mean of 4.76 repetitions per second. The mean for /ʌ/ was 4.4 repetitions per second and the mean for /hʌ/ was 4.2 repetitions per second in Bassich-Zeren's (2004) control group which included male and female participants with a mean age of 47.9 (2004). This study's mean repetitions per second did not differ much from Bassich-Zeren's (2004); the mean for /ʌ/ was 4.73 repetitions per second and the mean for /hʌ/ was 4.62 repetitions per second. The main inconsistency that could contribute to differing rates between the studies is the sample population composition. All four studies differ in age and gender. This study, Bassich-Zeren's (2004), and Shanks' (1966) study all required three trials of the LDDK task where Canter's (1965) study only required one trial. All studies used an oscillogram to count repetitions per second but, the amount of time for which repetitions per second was calculated, differed. This study used a five second period to calculate repetitions per seconds, where as Bassich-Zeren (2004) used seven seconds, Canter (1965) used variable periods of five seconds or less, and Shanks (1966) used a period of three seconds. Another inconsistency that could explain variance in LDDK rates include instructions in which participants were given. Explicit instructions were given to participants in this study and in Shanks' (1966) study; Bassich-Zeren (2004) and Canter (1965) did not report instructions given to participants.

Interestingly, numerical trends for LDDK repetitions per second show a gradual decrease in rate as the trials progress. This trend was also reported in Renout's (1995) study of LDDK production in ALS patients. In Renout's (1995) study, the bulbar group began at a mean of 3.19 repetitions per second for the first trial, 2.94 repetitions per second for the second, and 2.69 repetitions per second for the third; the nonbulbar group began at a mean of 5.00 repetitions per second for the first trial, 4.96 repetitions per second for the second, and 4.40 repetitions per second for the third. All other studies that used multiple trials of LDDK reported rates as a total average of the three trials. Perhaps this finding suggests that breath control or vocal fatigue could affect participants' ability to maintain a steady state of laryngeal function. Further analysis should be conducted to determine if the decrease in the number of repetitions per trial is statistically significant.

Finally, LDDK rates of male and female participants were compared. Again, the results indicated no significance difference between the two groups. The lack of significant group differences may be a result of methodological shortcomings in which the ratio of male to female participants was not equal. Or perhaps gender simply does not influence LDDK production. It does, however, seem logical that male and female participants would display a difference in LDDK rate due to differences in size, shape, and hormonal influences of the vocal folds. On the other hand, perhaps LDDK rates are more a reflection of physiology and innervation rather than structural differences of the vocal folds. This assumption would be consistent with Verdolini and Palmer's (1997) study on vocal fold lesions that found no significant differences in LDDK performance in patients with structural abnormalities.

CHAPTER VII

LIMITATIONS

Several factors were controlled to establish internal and external validity. The first factor was sample population. The population chosen for the study was adults between the ages of 40 and 60 years because, at this age, the larynx has fully matured but has not yet experienced presbylaryngis. In order to screen for healthy controls, this study eliminated participants who demonstrated poor vocal quality as rated by the CAPE-V (2006) or had illness, disease, or abnormalities that could compromise laryngeal function. Also, to increase internal validity, instructions to participants and recording procedures were standardized. Trials of the adductory and abductory tasks were alternated in presentation to eliminate vocal fatigue as a contributory factor.

Numerous factors, however, contribute to the limitations of this study. The first limitation is sample size. The total sample size for this study was 14 male participants and 21 female participants for a total of 35 participants. A larger sample size would provide for more powerful data and strengthen external validity. The restricted age group of 40 to 60 years strengthens normative data for that particular age group but also limits the population to which the results can be applied.

Perceptual ratings of strength and consistency of LDDK repetitions are often collected along with the objective measurement of rate. Rate, however, was the only measurement analyzed in this study. Utilizing ratings of strength and consistency in addition to rate would create a more complete profile of normative LDDK task results. It would be interesting to determine if perceptual judgments would be consistent with rate results.

Calculating repetitions per second by counting peaks on an oscillogram limits the ability for this tool to assess laryngeal function in a clinical setting. Not all clinical settings have the capabilities of transferring audio files into an oscillogram. Perhaps the 'pen dot' method (Verdolini & Palmer, 1997) would have better appeal for efficiency of calculating LDDK repetitions per second in a clinical setting without the need for additional equipment.

Although this study controlled for healthy individuals with no previous medical history significant to laryngeal function, the susceptible makeup of the vocal folds can be affected by other factors. Systemic influences on the larynx can compromise laryngeal functioning. These systemic influences include: respiratory disease, gastroesophageal reflux, allergies, hormones, and pharmaceuticals (Stemple, et al., 2000). Alcohol, smoking, and caffeine may also cause negative effects on the vocal mechanism. Controlling for these influences would eliminate the likelihood that a systemic influence could alter the results. Without limitation of chronic illnesses, diseases, and environmental stimuli, however, the implications of this study can be applied to a larger variety of the population. Eliminating participants with neurological impairments limits the population in which the results can be applied. In the future, normative LDDK rates should be compared with LDDK rates of groups with neurological impairment and laryngeal abnormalities.

CHAPTER VIII

IMPLICATIONS

The current study established the groundwork for a more comprehensive study to evaluate normative values for LDDK. These findings should be considered preliminary. In the future, further research should be conducted to address the limitations of this study. Studies in the future should focus on: a) expanding the sample size, b) broadening the age group across the age continuum, c) examining the measures of consistency and strength, d) analyzing the difference in LDDK rate among trials, e) investigating the pen dot method (Verdolini & Palmer, 1997) to calculate repetitions per second without an oscillogram, and f) comparing normative LDDK rates with LDDK rates of groups with neurological impairment and laryngeal abnormalities. The normative values for rate should be used tentatively until further research is undertaken.

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Appendices

Appendix A

Informed Consent Form

Project Title: **Laryngeal Diadochokinesis: Clinical measurement and age related values.**

You are invited to participate in this research study. The following information is provided in order to help you to make an informed decision whether or not to participate. If you have any questions please do not hesitate to ask. You are eligible to participate because you are an adult with no known laryngeal or neurological disease.

The purpose of this study is to identify your performance on a voice production task. We want to identify how your performance varies with differences in task complexity. We also want to identify your overall voice quality and your perception of your voice and swallowing function using questionnaires. We will compare your performance to other adults of varied age ranges. Participation in this study will require approximately 20 minutes of your time. All data will be collected in one session. The study involves two questionnaires and a voice recording. First you will complete a questionnaire about swallowing symptoms and another about voice symptoms. Each questionnaire has approximately 30 questions. Then we will record your voice to a CD as you: 1) repeat an 'uh' and 'huh' several times, 2) hold out an 'ah' and 'e' for 5 seconds, 3) read six sentences, and 4) answer a brief question about yourself. You will be seated approximately 6 inches from a microphone.

There will be no personal identifying information about you recorded on the CD. The recordings will be kept in a locked cabinet in 437 Davis Hall at the Indiana University of Pennsylvania. Only the principal and co-investigators involved in this study will have access to your recording and questionnaire responses. Your measurements will be considered only in combination with those from other participants. All data will be held in strict confidence. The information obtained in the study may be published in scientific journals or presented at scientific meetings but your identity will be kept strictly confidential. There are no known risks or discomforts associated with this research. The possible benefit is for you to have access to measurements of your voice and swallowing function. No other compensation is available for your participation.

Your participation in this study is voluntary. You are free to decide not to participate in this study or to withdraw at any time without adversely affecting your relationship with the investigators or IUP. Your decision will not result in any loss of benefits to which you are otherwise entitled. If you choose to participate, you may withdraw at any time by notifying the Project Director or informing the person administering the data collection. Upon your request to withdraw, all information pertaining to you will be destroyed. If you choose to participate, all information will be held in strict confidence. If you have any questions or concerns, please feel free to contact the principal investigator:

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This project has been approved by the Indiana University of Pennsylvania Institutional Review Board for the Protection of Human Participants (Phone: 724/357-7730)

VOLUNTARY CONSENT FORM:

I have read and understand the information on the form and I consent to volunteer to be a subject in this study. I understand that my responses are completely confidential and that I have the right to withdraw at any time. I have received an unsigned copy of this informed Consent Form to keep in my possession.

Name (PLEASE PRINT)

____

Signature

____

Date ___________________________

Phone number or location where you can be reached:

____

Best days and times to reach you:

____

I certify that I have explained to the above individual the nature and purpose, the potential benefits, and possible risks associated with participating in this research study, have answered any questions that have been raised, and have witnessed the above signature.

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Date **Investigator's Signature**