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Laryngeal Diadochokinetic Strength in the Geriatric Population

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LARYNGEAL DIADOCHOKINETIC STRENGTH IN THE
GERIATRIC POPULATION

A Thesis

Submitted to the School of Graduate Studies and Research
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

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May 2015

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Laryngeal diadochokinesis (L-DDK) is a measurement used by speech-language pathologists to identify and assess laryngeal function. The current research on L-DDK, however, is lacking normative data to make it clinically useful for evaluations. There are also several inconsistencies found in the current research that limit the reliability of L-DDK measures. This research study aims to bridge this gap in the research by establishing normative data on L-DDK strength measurements in the geriatric population (60-90 years of age). Twenty participants (10 male and 10 female) produced two laryngeal tasks, adductory /ʌ/ and abductory /hʌ/, for a period of seven seconds for three trials each. Normative L-DDK data including mean, standard deviation, and range were collected for two different strength measurements, rise time and average amplitude. Results revealed no statistically significant differences in L-DDK strength values between the adductory task/ʌ/ and the abductory task /hʌ/, nor between male and female participants.

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TABLE OF CONTENTS

Chapter	Page
I	REVIEW OF LITERATURE 1
	Diadochokinesis 2
	Oral Diadochokinesis..... 3
	Laryngeal Diadochokinesis 5
	Tests of Laryngeal Function 10
	Endoscopy 11
	Electromyography (EMG)..... 14
	Electroglottography (EGG)..... 15
	Anatomy and Innervation of the Larynx..... 17
	Impact of Aging..... 20
	Diseases Affecting Laryngeal Function..... 22
	Parkinson’s Disease..... 22
	Amyotrophic Lateral Sclerosis 24
	Clinical Reliability of Laryngeal Diadochokinesis..... 25
II	PURPOSE 27
III	METHODS..... 28
	Design 28
	Participants 28
	Recruitment..... 28
	Inclusion and Exclusion Criteria..... 29
	Final Sample Size..... 29
	Data Collection Procedures 30
	Measurement..... 32
	Ethical Use of Data..... 33
	Statistical Analysis..... 33
IV	RESULTS..... 35
V	DISCUSSION 38
VI	LIMITATIONS..... 41
VII	IMPLICATIONS..... 44
	REFERENCES..... 45
	APPENDICES..... 48
	APPENDIX A – Consent Forms 48

LIST OF TABLES

Table		Page
1	Descriptive Statistics for Strength of LDDK Production	36
2	Mann-Whitney U Test Statistics for Laryngeal Tasks	37
3	Mann-Whitney U Test Statistics for Sex.....	37

CHAPTER I

REVIEW OF LITERATURE

According to the *Merriam-Webster dictionary online* (2014), a diagnostic tool is defined as “of, or relating to, or used in diagnosis: used to help identify a disease, illness, or problem” (Diagnostic tool, 2014). Speech-language pathologists currently have a small variety of diagnostic tools to study the basic motor function of the speech mechanism. One of the most widely used tests to study the speech mechanism is oral diadochokinesis (DDK). This diagnostic test uses the sound productions of /pʌtkʌ/ to analyze the functioning of the lips, velum, tongue, and other oral peripheral structures, along with the overall motor movements of the mouth. There has been an extensive amount of research done on oral DDK, which provide normative data, and reliability and validity information of the measure as a diagnostic tool (Gadesman & Miller, 2008; Ergun & Oder, 2008; Fletcher, 1972; Langmore & Lehman, 1994; Williams & Stackhouse, 2000).

Another assessment speech-language pathologists use in practice is laryngeal diadochokinesis (L-DDK). This assessment tool uses the productions of /ʌ/ and /hʌ/ to examine laryngeal function, specifically the strength, rate, and consistency of vocal fold movement. Although L-DDK is used frequently in today’s clinical setting to assess laryngeal function, it has not been thoroughly researched, and there are no normative data for the results of the assessment. Normative L-DDK results are necessary to assist speech-language pathologists in diagnosing and measuring treatment changes in patients’ with degenerative, neurological diseases who demonstrate voice disorders. The results of L-DDK would provide a basis for

comparison when evaluating data from a patient with a possible disorder. As a result, the current research will establish normative data, particularly measurements of the rise time and amplitude of the acoustic signal, in the geriatric population (ages 60-90) to examine the strength of their laryngeal movements through L-DDK results.

The remainder of this chapter will review the literature and provide an in depth analysis of the following subjects: oral DDK and L-DDK measurements, alternate tests of laryngeal function, anatomy and innervation of the larynx, the impact of aging on the strength of the larynx, progressive diseases affecting laryngeal function, and the current clinical reliability of L-DDK as a diagnostic tool. All of these topics are important to consider when establishing normative data for L-DDK measurements, so that it can be used as a reliable clinical tool in assessing and diagnosing laryngeal abnormalities.

Diadochokinesis

As mentioned earlier, speech-language pathologists use both oral diadochokinesis and laryngeal diadochokinesis to examine perceptual aspects of motor control of the anatomic structures necessary for speech and voice production. Both of these assessment tools are non-invasive and provide significant information on the articulatory and phonatory systems of a patient. It is important to understand both of these measurements and how they are performed, because they are critical in assessment of articulation and voice disorders.

Oral Diadochokinesis (DDK)

According to Seikel, King, and Drumright (2010), oral DDK refers to “the number of productions of a single or multiple syllables an individual produces per second” (p. 254). Oral DDK is often referred to as alternating motor rate, because it tests the alternation of the articulatory system, specifically the motor capabilities of the tongue, lips, and velum (Seikel, King, & Drumright, 2010). Oral DDK tasks are performed by having the patient produce the single sounds /pʌ/, /tʌ/, /kʌ/, and sound combination /pʌtʌkʌ/, as rapidly and accurately as possible for seven seconds. After the client has produced the sounds, the total numbers of syllables produced for each sound or sound combination are then divided by seven (the total number of seconds) to provide the oral DDK results. Oral DDK results can also be measured by determining how long it takes the patient to produce a given number of syllables (Gadesmann & Miller, 2008).

One aspect of oral DDK results that can be affected in disordered populations is strength. Often, a patient may have a weakened oral-motor system that results in decreased strength of articulatory movements. A study by Langmore and Lehman (1994) studied the strength of oral DDK in patients with amyotrophic lateral sclerosis (ALS) and dysarthria. This progressive disease results in weak orofacial structures, impaired tongue movements, and decreased speech intelligibility. The study examined the physiological deficits and the severity of those deficits in fourteen participants with three different types of ALS, as compared to fifteen patients without any type of degenerative diseases. The fourteen disordered patients were perceptually assessed on strength and rate using oral DDK by

producing the diadochokinetic repetitions /pʌ/ and /tʌ/ as many times as possible on one breath. Inter-judge reliability was determined to be high, with 67-99% agreement across judges, which assured consistency among the perceptual ratings.

Overall, the results of this study demonstrated that the patients with ALS had oral movements that were significantly weaker during oral DDK assessments. Langmore and Lehman (1994) concluded that subjects with ALS and dysarthria exhibited reduced strength, as well as reduced speed, in the movement of orofacial structures. More specifically, tongue strength was severely decreased in patients' with ALS, as compared to the control group. In addition to this research study, there are more studies that have identified decreased strength in disordered populations as demonstrated by oral DDK results.

Ergun and Oder (2008) studied oral DDK strength results in fifteen patients with dysarthria after severe closed head trauma with diffuse axonal injury. The purpose of their study was to determine if oral DDK results correlated with contextual speech impairments. All of the participants in the study were capable of oral motor movements and retained oral sensitivity of the lips, tongue, and pharynx since their accident. The patients with head injury were compared to a control group of fifteen non-injured participants. No information was provided on the health of the control participants, which could have affected reliability measures if there were any previous brain damage or oral structural abnormalities. During the oral diadochokinetic testing, the participants were asked to take a deep breath and repeat the productions /pʌ/, /tʌ/, /kʌ/, /pʌtʌkʌ/, and /tana/ as long and fast as possible (Ergun & Oder, 2008).

The results of the study demonstrated both decreased strength and decreased rate in the rapid repetitions of the oral DDK productions in patients who had suffered a severe head injury compared to normal controls. The patients had an overall weakened oral-motor system as compared to healthy age-matched participants. The dysarthric speech in patients with head injuries resulted in “impaired motor control...using greater force and overshooting articulatory targets at habitual speaking rate to meet the demands of communication” (Ergun & Oder, 2008, p. 777). Overall, this study found that patients with dysarthria following a traumatic brain injury had reduced oral DDK results, especially with regard to strength and rate of productions, due to a weakened oral-motor system and inability to move their articulators with as much force, accuracy, and promptness as patients without dysarthria (Ergun & Oder, 2008).

Evidently, strength is one of the many factors that can be assessed during oral DDK examinations. Oral DDK is a valid measure of strength, rate, and accuracy of articulatory productions (Langmore & Lehman, 1994; Ergun & Oder, 2008). Oral DDK is often used in conjunction with L-DDK to obtain a more comprehensive evaluation of the vocal mechanism, as the sound source for articulation, with L-DDK results providing information regarding the strength of laryngeal function.

Laryngeal Diadochokinesis (L-DDK)

As previously stated, L-DDK is an assessment that speech-language pathologists use to examine the vocal mechanism. Unlike oral DDK, which focuses on the oral cavity and articulation, L-DDK concentrates on the larynx and properties of phonation. L-DDK is also often referred to as vocal fold diadochokinesis since it

primarily measures the activity of the vocal folds. Shanks (1966) described L-DDK as “the maximum ability to rapidly abduct and adduct the vocal folds while repeatedly uttering a syllable containing a glottal fricative and a vowel” (p. 1). During L-DDK tasks, patients are asked to produce and repeat the sounds /hʌ/ and /ʌ/ as many times as possible for seven seconds. After the productions are recorded, the examiner divides the total number of syllable repetitions by the total amount of time of the sample (seven seconds). This number will provide the L-DDK rate result for the patient. Less commonly, L-DDK can also be assessed by measuring the amount of time that it takes to produce a given number of repetitions, or by counting how many repetitions the patient can produce on a single breath.

Similar to oral DDK, we can also measure the strength of the sound productions during L-DDK tasks. However, in L-DDK, the tasks are measuring the strength of vocal fold closure and the phonatory system, rather than articulatory movements in the oral cavity. Substantially fewer studies have been performed on the strength of L-DDK results than on oral DDK results. However, two studies are available that provide results on the strength of L-DDK.

First, Verdolini and Palmer (1997) conducted a study that attempted to develop a “profile” approach for measuring voice disorders. The authors wanted to discover patterns of errors during voice screenings to create “profiles” for different types of voice disorders. These patterns would provide a simple way to determine what organic abnormalities patients with voice disorders might have during the screening process. This study consisted of forty-five adult participants, including patients with “nodules, granulomas, unilateral abducted [vocal fold] paralysis,

Parkinson's disease, functional voice disorder, and normal voice and larynx" (Verdolini & Palmer, 1997, p. 217). The participants performed S:Z ratio and L-DDK tasks to assess strength, rate, and consistency of laryngeal function. The participants produced the glottal stop /ʌ/ for seven seconds during the L-DDK task. The examiners used an auditorily perceived "good" versus "poor" rating to measure the strength of the glottal stops (Verdolini & Palmer, 1997). Although this rating was reliable based on "intrajudge, interjudge, and judge-vs.-oscilloscopic stability of measures" (Verdolini & Palmer, 1997, p. 224), this measurement was considered a weakness of the study because the good/poor dichotomy did not capture the full range of vocal strength. The examiners were blind to the patient's diagnosis and the hypotheses of the study, which was a strength of the research and controlled for examiner bias.

Prior to the study, Verdolini and Palmer (1997) predicted which organic pathologies in the study would have "good" or "poor" strength results during L-DDK tasks. The authors agreed that all organic pathologies except Parkinson's disease and abducted vocal fold paralysis would have "good" strength results. The predictions stated that adduction strength in participants with Parkinson's disease would be poor "because of hypometria related to acceleration phenomena or rigidity" (Verdolini & Palmer, 1997, p. 220). Also, adduction strength might be poor in participants with Parkinson's disease due to vocal fold bowing, which is a common glottal configuration in patients with Parkinson's disease. In participants with abducted paralysis, the predictions stated that strength results would be poor

due to weakness in the paralyzed vocal fold. The paralyzed fold would not be able to fully adduct and create a strong glottal stop (Verdolini & Palmer, 1997).

The results of this study demonstrated that the authors' predictions were accurate on the strength of L-DDK results for different laryngeal pathologies. Both abducted vocal fold paralysis and Parkinson's disease resulted in decreased strength during L-DDK results, as well as decreased rate and consistency. Due to overall vocal fold weakness and bowing, these patients were unable to fully adduct the vocal folds to produce a perceptually strong, glottal sound in the larynx (Verdolini & Palmer, 1997). Although the strength rating mechanism was limited to two categories (i.e., good vs. poor) and was perceptual in nature, this study is an example of how L-DDK results can be informative and reveal the strength of the larynx for different vocal fold pathologies and degenerative diseases.

Another study by Leeper and Jones (1991) also focuses on the strength of L-DDK results, this time regarding the breath stream and respiratory support behind the strength of the larynx in a normal population. The authors of this study believed that examining the amount of airflow used during rapid opening and closure of the vocal folds would be "useful in determining the functional integrity (efficiency) of the voice-producing system" (Leeper & Jones, 1991, p. 880). Eighteen female participants between the ages of 20 and 25 with no history of respiratory, neurological, or hearing difficulties participated in this study. During the data collection, each participant inhaled deeply and produced the vowel /ʌ/ as rapidly as possible for five seconds at three different intensity and frequency levels. A

facemask-pneumotachograph system was used to measure acoustic and aerodynamic properties objectively (Leeper & Jones, 1991).

The results demonstrated a significant difference in transglottal airflow rate when intensity levels were varied. For example, when a participant was making productions at a higher intensity, more airflow was escaping between the vocal folds, causing the sound to be louder and stronger. On the other hand, when a participant was speaking at a lower intensity, they were using less airflow creating a weaker sound. This study found that vocal intensity, or loudness, was the controlling factor during L-DDK results, affecting both the rate of repetition and the amount of airflow traveling through the glottis during speech. Leeper and Jones (1991) stated that “these results support earlier research which demonstrated that at low vocal frequency, glottal resistance functioned to vary intensity, while at high frequency phonation, intensity was controlled by airflow rate via expiratory muscle force” (p. 882). This study showed that muscle force and strength are vital components to laryngeal regulation and functioning. Although this study provided useful information regarding normative data for L-DDK results, it contained an extremely small sample size and included only female participants. In order to functionally use normative L-DDK results, more diverse populations need to be included. Additionally, a facemask-pneumotachograph system was utilized to obtain the data, which may be a device that all speech-language pathologists do not have readily available, making it difficult to use in a clinical setting. However, this study did use a more reliable, objective measurement of strength as compared to

Verdolini & Palmer (1997), and therefore provided more concrete data on the strength of laryngeal movement.

These studies by Leeper and Jones (1991) and Verdolini and Palmer (1997) are two of the few that have been conducted on L-DDK results, and only one of them yields normative information. However, the normative information from Leeper and Jones (1991) only included females in a narrow age range. In order for L-DDK to become a clinically useful tool, research is needed to obtain normative data for L-DDK tasks for both genders, across a full range of adult ages. A reason behind this lack of research could be because there are several other tests of laryngeal function that can be used to measure a patient's phonatory system.

Tests of Laryngeal Function

In addition to L-DDK tasks, there are several other tests of laryngeal function that can be used to assess the larynx in both disordered and normal populations. These tests include endoscopy, electromyography (EMG), and electroglottography (EGG). These three measures provide visual imaging or graphic output of laryngeal function. Stemple, Glaze, and Klaben (2000) stated that "Laryngeal imaging offers the greatest potential for detection, severity assessment, and diagnosis in patients with voice disorders" (p. 219). All of these diagnostic tools have been thoroughly developed and are valued measures of laryngeal performance. The following sections will provide more information and previous research that has been conducted on each of these evaluation tools.

Endoscopy

Endoscopy is one of the most widely used evaluations of laryngeal function. This measurement is invasive, yet provides a sharp view of the anatomy and physiology of the vocal folds. Seikel, King, and Drumright (2010) described endoscopy as a technology that uses fiber optics to visualize different areas of the body. Endoscopy is beneficial to view glottic closure patterns, mucosal wave, structural appearance, supraglottic hyperfunction, amplitude, vocal fold symmetry, and the regularity of vocal fold vibration (Stemple, Glaze, & Kladen, 2000). In order to visualize the vocal folds, endoscopy involves either a rigid scope that is passed through the oral cavity, or a flexible scope that is passed through the nasal cavity.

During rigid endoscopy, the clinician inserts a scope with a camera on the end directly into the oral cavity of the patient. The scope is pressed firmly on the tongue and progressed backward until the larynx appears on the corresponding camera monitor (Stemple, Glaze, & Klaben, 2000). One advantage to using rigid endoscopy is that it provides a sharper, brighter, and larger picture of the vocal folds. It is extremely useful in viewing the anatomy of the larynx, especially recognizing lesions on the vocal folds. It also provides a clear image of vocal fold vibratory patterns and mucosa. Another advantage of rigid endoscopy is that it is less invasive than flexible endoscopy, and only enters the oral cavity (Stemple, Glaze, & Klaben, 2000).

There are also many disadvantages to using rigid endoscopy. One disadvantage is that it limits the patient to the production of the sustained vowel /i/, and does not allow for conversational speech. Also, unlike flexible endoscopy, it

does not allow the clinician to view the patient's swallow. Another disadvantage is that if a patient has a hypersensitive gag reflex, this option may not be tolerable and they may refuse the procedure. The clinician must be extremely cautious to avoid contact with the back of the pharynx and the faucial pillars while inserting the rigid endoscopy to minimize the gag reflex (Stemple, Glaze, & Klaben, 2000). Although rigid endoscopy definitely has some disadvantages, it is a valued method of examining the larynx with visual imaging.

Flexible endoscopy, also known as a nasoendoscopy, is the other type of endoscopy used by speech-language pathologists. During flexible endoscopy, the clinician inserts a flexible camera scope into the nasal cavity above the inferior nasal concha until it enters the larynx (Seikel, King, & Drumright, 2010). Anesthetic is used in the nasal cavity for easier insertion. One advantage to using flexible endoscopy is that it allows visual imaging of the velopharynx, vocal tract, and larynx. Beyond examining the vocal folds, it also offers the option of viewing the patient's swallow. Unlike the rigid scope, the flexible scope allows the patient to speak conversationally and in a more natural context. Flexible endoscopy can also be used for diagnosis and treatment purposes. The "onscreen image allows biofeedback" so the clinician can practice voice techniques and treatment targets (Stemple, Glaze, & Klaben, 2000). Several clinicians use this diagnostic tool because it has so many diverse purposes.

Despite the numerous advantages, a flexible endoscopy also has some disadvantages. According to Stemple, Glaze, and Klaben (2000), "flexible endoscopy is slightly more invasive...[and] is subject to disruptive vertical movements as the

patient alters position of the velum, base of tongue, and swallows” (p. 227). This being said, it is much harder to obtain a stable, clear image while using a flexible endoscopy. The camera on the end of a flexible scope is also smaller in diameter resulting in an overall darker image (Stemple, Glaze, & Klaben, 2000). Due to the duller, darker images this measure often provides, it is more useful in viewing the physiology of the larynx rather than the anatomy. Despite the disadvantages, the flexible endoscopy tends to have greater advantages and is used more readily by speech-language pathologists.

In addition to the two different types of scopes, there are also different lighting and video techniques that are utilized during endoscopy. The first type of lighting option is called steady light. Steady light is a simple lighting option using a halogen bulb to brighten the larynx and obtain a sharper view of the anatomy (Stemple, Glaze, & Klaben, 2000). The second type of lighting, stroboscopy, is based on of Talbot’s Law. This lighting option is used more frequently by speech-language pathologists than the steady lighting option. During stroboscopy, “a strobe light illuminates the larynx at a pulse rate faster than five images per second, [and] the result is a visual-perceptual composite of the images, perceived as continuous motion” (Stemple, Glaze, & Klaben, 2000, p. 222). The combination of a steady halogen light and a flashing xenon light are used during stroboscopy. The timing of the flashing light nearly matches up with the fundamental frequency of the vocal folds to provide a continuous image of the vibrating vocal folds. The benefits of using stroboscopy are that the clinician can examine the vibratory patterns of the

vocal folds, as well as, mucosal wave and periodicity (Stemple, Glaze, & Klaben, 2000).

A mixture of stroboscopy and video instrumentation can also be implemented during endoscopy. This type of endoscopy is also known as videostroboscopy. In this kind of endoscopy, the laryngeal imaging is video recorded and can be viewed again after the endoscopy is completed. This video imaging is useful in persistently dysphonic patients, professional voice users, and patients who are undergoing phonosurgery, to obtain a sample of the larynx before and after treatment/surgery (Stemple, Glaze, & Klaben, 2000). Evidently, endoscopy is an effective way for speech-language pathologists to view the larynx. It is a valuable way to examine the anatomy, physiology, and make perceptual judgments of laryngeal strength from images.

Electromyography (EMG)

Electromyography (EMG) is a type of procedure that measures the activity of the laryngeal muscles. More specifically, EMG studies the electrical activity in these muscles by measuring the motor unit action potentials within the muscles (Behrman, 2007). Surface electrodes are placed on the skin outside the muscle to measure the electrical activity. This type of electrode often results in unsuccessful results because the muscle is not close enough to the skin to pick up the electric signals. Needle and hooked wire electrodes are another method used to measure the electrical signals. These electrodes are inserted directly into muscle to obtain more precise signals (Behrman, 2007). The neurologist or otolaryngologist that performs this procedure is unable to see the placement of the electrode once it is inserted into

the muscle. Because of this, speech-language pathologists will confirm that the electrodes are in the correct muscles by having the patient perform various speech tasks (Stemple, Glaze, & Klaben, 2000).

This type of laryngeal examination is extremely useful in measuring laryngeal muscle strength. The electrical activity indicates how much muscle effort is being used during speech tasks and provides an objective measurement of the strength and ability of the muscle. An EMG also provides diagnostic and prognostic information on neurological deficits of the vocal folds including paralysis, dystonia, and muscle fixation (Stemple, Glaze, & Klaben, 2000). Some of the disadvantages of EMG are that the patient may feel general discomfort during the procedure. If correct electrode placement is not achieved during EMG testing, the results will be inaccurate (Behrman, 2007). Additionally, only a trained otolaryngologist or a neurologist can perform the invasive method of this procedure. Despite disadvantages that make it impractical for clinical use by speech-language pathologists, EMG is an excellent test of laryngeal function and strength as it measures the electrical activity of the laryngeal nerves that innervate the vocal folds.

Electroglottography (EGG)

Electroglottography (EGG) is another test of laryngeal function that is similar to EMG in that it utilizes electrodes for measurements, but EGG is a noninvasive technique. EGG measures vocal fold contact by measuring electrical current that passes through the larynx during speech (Stemple, Glaze, & Klaben, 2000).

According to Stemple, Glaze, & Klaben (2000), “two electrodes are placed on either

side of the thyroid alae, with a small electrical current passing through as the vocal folds vibrate” (p. 235). The results of the EGG are presented as waveforms that represent the vibratory closure patterns of the vocal folds. The waves demonstrate the change of resistance during speech while the vocal folds are opening and closing. During the closing phase, resistance is decreased since tissue conducts electricity well. During the opening phase, resistance is increased because air is not a good conductor of electricity (Behrman, 2007). EGG estimates the strength of the vocal folds by identifying the adduction and abduction patterns during vocal fold vibration. There are many advantages and disadvantages that have been associated with the use of EGG.

Some advantages of using EGG are that it is easy to use and non-invasive, so the patient does not feel any discomfort during the assessment. The instrumentation is also readily available and the evaluation is fairly inexpensive. EGG also provides immediate, objective data, which is easy to interpret and provides the patient with quick results (Behrman, 2007). On the other hand, EEG has many disadvantages. If a patient has a small larynx, which is often true of women and children, it is more difficult to acquire the appropriate signal strength. Also, with growing obesity in our country, it is often difficult to obtain adequate signal strength for patients with excess fat or muscle in the neck region. In addition, in people with voice disorders, excess mucosa on the vocal folds and muscular hyperfunction can affect the resistance of the results. Due to these problems, the waveforms will often appear normal when the patient actually has a vocal pathology (Behrman, 2007). The

disadvantages associated with EGG outweigh the advantages for patients with voice disorders.

Endoscopy, EMG, and EGG are all commonly used tests of laryngeal function that have advantages and disadvantages. It is necessary to decide which test will be the best for the individual patient based on their voice deficits and physical attributes. However, most of these tests are either invasive or require expensive equipment not easily accessible to speech-language pathologists. If normative data were established, L-DDK would provide an inexpensive, non-invasive, reliable way to assess and diagnose our clients with vocal dysfunction. L-DDK could be used with many more people than other measures because it is easy to administer in the speech-language pathologist's office, and it is simple and comfortable for the patient. It could serve as an important method for screening patients and lead to earlier diagnoses for clients since it is so readily available.

Anatomy and Innervation of the Larynx

The anatomy of the larynx is extremely intricate and needs to be intact and functioning properly to obtain normative L-DDK results. The larynx is the primary structure that accounts for phonation and voice production. This structure sits on top of the trachea and comprises both muscle and cartilage. The thyroid cartilage is the largest laryngeal cartilage and is connected to the cricoid cartilage at the cricothyroid joint. The cricothyroid joint allows the two cartilages to articulate for greater mobility, and come together in the front of the larynx. The paired arytenoid cartilages are another type of laryngeal cartilage that forms the posterior attachment point for the vocal folds. The arytenoids are also connected to the

cricoid cartilage at the cricoarytenoid joint. This joint assists in the adduction and abduction of the vocal folds (Seikel, King, & Drumright, 2010). In addition to the cartilages and joints of the larynx, there are also several intrinsic muscles that perform different functions. The intrinsic laryngeal muscles responsible for adducting the vocal folds are the lateral cricoarytenoid and the interarytenoids. The posterior cricoarytenoid muscle is the only muscle responsible for abducting the vocal folds. The cricothyroid and thyrovocalis muscles tense the vocal folds while the thyromuscularis relaxes the vocal folds. The cartilages, joints, and muscles are essential in creating the framework of laryngeal movement. In addition, the structure of the vocal folds is imperative for creating sound and measuring the strength of the voice.

The vocal folds are made up of five layers of tissue. The most superficial layer of tissue is known as the epithelium. It is a protective layer of squamous cells that is about 0.1 mm thick with binding properties to attach to the next layer. According to Seikel, King, and Drumright (2010), this layer assists in fluid retention and maintains moisture. The next layer of tissue is the superficial lamina propria (SLP), which is composed of elastin fibers. These fibrous, elastic properties allow this layer to be stretched and cushion the vocal folds. The intermediate lamina propria (ILP) is the next layer of tissue that lies deep to the SLP. It is approximately 1-2 mm thick and is also made up of elastin fibers. The elastin fibers of the ILP run in the opposite direction of the SLP, creating a cross layer of fibers. The combination of these two layers provides flexibility and strength to the vocal folds. The next layer is the deep lamina propria (DLP), which is roughly 1-2 mm thick, composed of supportive

collagen fibers. Together, the ILP and DLP create the vocal ligament. The fifth and deepest layer of the vocal folds is the thyroarytenoid muscle (thyrovocalis and thryromuscularis). The thyroartenoid muscle composes most of the vocal fold. This layer accounts for the active elements of the vocal folds, while the lamina propria accounts for the passive elements of the vocal folds, providing strength, cushioning, and elasticity (Seikel, King, & Drumright, 2010). Although the size of a thumbnail, the vocal folds are a complex structure that involve many layers to correctly create sound. The structural makeup of the vocal folds is extremely important because these layers provide the moisture, elasticity, strength, and cushion that allow the vocal folds to vibrate and produce sound.

Nerve innervation also plays an important role in sound production and motor control in the larynx. The vagus nerve, also known as cranial nerve X, innervates the larynx as it travels from the skull to the abdomen. This nerve gives two branches, the recurrent laryngeal nerve (RLN) and the superior laryngeal nerve (SLN), which together supply all of the sensory and motor information to the larynx. Stemple, Glaze, & Klaben (2000) stated that “the RLN supplies all sensory information below the vocal folds and all motor innervation to the posterior cricoarytenoid, thyroartenoid, lateral cricoarytenoid, and interarytenoid muscles” (p. 49). This being said, the RLN provides motor innervation to adduct, abduct, tense, and relax the vocal folds. Without this innervation, the laryngeal muscles would not be able to move the vocal folds properly to produce sound. The RLN also supplies sensory information below the vocal folds, which allows people to feel if they have aspirated a substance into their airway. The SLN provides all sensory

information to the larynx by the internal branch and motor innervation to the cricothyroid muscle by the external branch. Since the SLN only provides motor innervation to the cricothyroid, it allows the vocal folds to stretch and alter pitch. It also supplies all sensation to the larynx to prevent laryngeal penetration. Together, the SLN and RLN provide the ability for the intrinsic laryngeal muscles to move rapidly with fine motor control (Stemple, Glaze, & Klaben, 2000). Both the anatomy and innervation of the larynx are extremely dynamic. The anatomy and innervation of the larynx can be highly influenced by aging throughout the lifespan. Especially, in the geriatric population, L-DDK results will vary greatly in strength due to aging properties of the anatomy and innervation of the larynx.

Impact of Aging

As apparent by the intricate anatomy of the larynx, aging highly affects the properties of laryngeal function. According to Ferrand (2012), age related changes of the larynx begin to appear near thirty-years of age for males and forty-years of age for females. One of the first signs of an aging larynx during the third and fourth decade is the ossification of cartilage. When the cartilages of the larynx ossify, the movements decrease in flexibility, which can affect vocal fold vibration. Ferrand (2012) continued to explain that joints undergo degenerative changes, such as thinning, eroding surfaces that articulate with other structures, and collagen fiber breakdown. Additionally, muscle fibers inside tissues degenerate, causing tissue to decrease in size and efficiency. This atrophy causes the remaining muscle tissue to work harder to produce sound (Ferrand, 2012). These degenerative qualities are especially evident in the geriatric population and result in decreased strength of

laryngeal function. The lack of flexibility and bulk makes it difficult for the vocal folds to properly adduct and vibrate, creating a weak, breathy vocal quality.

In a study by Pontes, Yamaski, and Behlau (2006), the authors found additional degenerative processes that affect voice strength in the geriatric population. Vocal fold bowing and spindle shaped glottal closure patterns related to atrophy were identified in their study. Due to the bowing, the vocal folds were unable to fully adduct during phonation resulting in a weak voice or no voice at all. In addition, this study found asymmetry in the phase and amplitude of the mucosal wave of the vocal folds. This asymmetry causes insufficient approximation of the vocal folds and reduced phonation. Vocal tremor was also present in the geriatric participants, resulting in inconsistent productions (Pontes, Yamasaki, & Behlau, 2006). These laryngeal changes need to be accounted for in current L-DDK research because although L-DDK results may reveal decreased laryngeal strength, the results may actually be due to the normal aging process in the geriatric population and not indicative of a disease or a disorder.

Besides structure and function of the larynx itself, respiratory properties are also affected in speech production in the geriatric population. In adult populations, and especially geriatric populations, the costal cartilages of the rib cage ossify and experience calcification similar to the laryngeal structures (Ferrand, 2012). Also, the thorax takes a more convex shape, the respiratory muscles lose strength, and overall lung size decreases. All of these changes decrease the elastic recoil of the lungs and decrease the ability to speak with a large lung volume (Ferrand, 2012). These respiratory changes make it difficult to create a strong, powerful voice since the

speech chain is initiated by respiration. Ptacek, Sander, & Maloner (1966) validated this evidence by demonstrating that reduced respiratory muscle power and lack of elasticity in the lungs result in reduced vital capacity and decreased intraoral pressure. These changes also resulted in decreased vowel duration and intensity during the study (Ptacek, Sander, & Maloner, 1966). Another study by Gregory et. al (2010) found that one of the most common voice complaints of geriatric patients was decreased volume and inability to project their voice due to comorbid pulmonary disease. Evidently, aging causes reduced strength of respiration, which affects the strength of vocal intensity. All of these normal aging factors are important to keep in mind when establishing normative data for L-DDK. A normative sample will reveal what degree of laryngeal and respiratory weakness is related to normal aging process in the geriatric population so that when using L-DDK clinically, patients are not misdiagnosed as having abnormal vocal function.

Diseases Affecting Laryngeal Function

In addition to normal aging that decreases the strength of voice production in the geriatric population, laryngeal strength is also affected by certain diseases. These diseases, such as Parkinson's disease and amyotrophic lateral sclerosis (ALS), often cause neuromotor deficits and degeneration.

Parkinson's Disease

Parkinson's disease is a degenerative disease that results in serious speech disorders, such as dysarthria and "slurred articulation" (Canter, 1965). People with Parkinson's disease also often experience hoarseness, vocal tremors, a monotone voice, and hypophonia resulting from decreased strength (Bassich-Zaren, 2004).

Previous studies have measured the strength of the larynx in patients with Parkinson's disease.

In a study by Verdolini and Palmer (1997), the authors researched the rate, rhythm, and strength of laryngeal movement and compared these factors in three different categories: (a) structural abnormalities (nodules and granulomas), (b) dynamic abnormalities (Parkinson's disease), and (c) nonorganic conditions (functional voice disorder and no disorder). The investigators used an S:Z ratio and L-DDK to measure the laryngeal function of these participants. There were a total of 11 participants in the structural abnormality category, 14 participants in the dynamic abnormality category, and 20 participants in the nonorganic conditions category. As hypothesized by the authors, participants with structural abnormalities and nonorganic abnormalities demonstrated normal or better results for the S:Z ratio, as well as, the rate, rhythm, and strength of L-DDK results. The participants with Parkinson's disease produced a normal or better than normal S:Z ratio, but demonstrated poor results in rate, rhythm, and strength. Rhythm and strength yielded the poorest results with seven out of ten impaired participants (Verdolini & Palmer, 1997). One of the limitations to this study was that the authors did not have any normative data with which to compare the patients' L-DDK scores. Therefore, they had no way to indicate that the results for these patients were indeed considered disordered. The authors could only indicate that these participants produced poorer perceptual responses than other types of laryngeal abnormalities. Despite the lack of normative data, this study demonstrates that laryngeal strength declines in persons with Parkinson's disease.

Amyotrophic Lateral Sclerosis

Amyotrophic Lateral Sclerosis (ALS) is another degenerative disease that results in significant speech problems. Some of the characteristics of speech deficits in patients with ALS include imprecise articulation, hypernasality, strained, breathy quality, slow speaking rate, and a low vocal pitch and amplitude (Renout et al., 1995). These characteristics occur at different times and at varying levels of severity depending on the individuals' progression with the disease. However, in most cases of ALS, vocal strength is decreased.

In a study by Renout et al. (1995), researchers used L-DDK, which they referred to as vocal fold diadochokinesis, on patients with ALS to measure the deterioration of acoustical laryngeal characteristics in both bulbar and nonbulbar types of ALS. The study included 26 participants who had a neurologically confirmed diagnosis of ALS and were between the ages of 40 and 78. The subjects were assessed in two thirty-minute sessions over an 18-month period to measure the progression of their laryngeal characteristics. The data indicated decreased L-DDK results for both bulbar and nonbulbar types of ALS. Decreased motor ability was demonstrated in all of the participants, resulting in "flaccidity, weakness, slowness of movement, fasciculations, and atrophy of these muscles" (Renout et. al, 1995, p. 76). Variations in pattern, rate, and amplitude were all found in this study. Overall, all of the participants demonstrated changes in laryngeal motor control due to the degeneration of ALS (Renout et. al, 1995). Once again, there were no normative data in this study to allow comparison with their results. It is clear that

the L-DDK results were poor, but the authors were unable to say if the results were actually indicative of a disorder.

Clinical Reliability of Laryngeal Diadochokinesis

Although there are some strong studies that demonstrate the usefulness of L-DDK measures, there is no research conducted on the reliability of L-DDK measurement. L-DDK is often analyzed perceptually and, therefore, clinicians can vary in their procedures and definition when rating strength, rate, and consistency of productions. In order to become a more reliable measure, productions need to be standardized with objective acoustic analysis to increase the usefulness and replicability of the measure.

Additionally, most of the previous studies that have been conducted on L-DDK limit their research to only cover a few criteria. For example, much of the research that has been done focuses on only one of the two L-DDK tasks. In Canter (1965) and Renout et al. (1995), only the abductory task /hʌ/ was researched, whereas in Leeper and Jones (1991) and Verdolini and Palmer (1997), the research was limited to the adductory task /ʌ/. Both tasks are necessary in order to analyze the true strength of vocal fold adduction versus abduction. Samples have also been limited related to sexes in previous L-DDK research. Ptacek's (1996) study investigated both female and male subjects, where other studies by Leeper and Jones (1991) and Shanks (1966) only included female participants. This lack of diversity can lead to decreased reliability because male and female laryngeal properties are different and change at different rates throughout the lifespan.

L-DDK measures have also not been widely researched in normal populations, but there has been L-DDK research done on several disordered populations. Langmore and Lehman's (1994) study and Canter's (1965) study researched patients with amyotrophic lateral sclerosis, Ergun and Oder's (2008) study investigated patients with dysarthria related to traumatic brain injury, and Verdolini and Palmer's (1997) study looked at patients with a variety of structural and neurological voice disorders. However, only one study by Leeper and Jones (1991) researched the results of L-DDK in normal adult and geriatric populations. Also, a more recent study by Modolo et al (2010) measured L-DDK in normal developing children but not the adult and geriatric populations. Without normative data for the full range of adult and geriatric ages, clinicians will not have the data they need to properly diagnose patients.

Overall, L-DDK has proven to be useful in previous studies regarding disordered populations and children, but without normative data, the application of L-DDK is questionable in the normal geriatric population. If normative data were available for L-DDK measures in the geriatric population, it could be a valuable tool for assessing vocal function and diagnosing or ruling out various laryngeal abnormalities.

CHAPTER II

PURPOSE

Currently, there is no research that provides normative data for the strength of laryngeal function based on L-DDK results in the geriatric population. Normative data on L-DDK strength would facilitate the speech-language pathologist's assessment of laryngeal motor control and function in geriatric clients who have Parkinson's disease, ALS, and other degenerative diseases that affect vocal production. All of these disorders decrease the strength of the larynx, but currently, there are no data to determine when decreased strength is still considered to be within normal limits, or considered disordered. Normative L-DDK results regarding strength in the geriatric population would allow speech-language pathologists to make assessments of those patients who indeed have a voice disorder, and improve evaluation of motor control of the vocal folds. Due to the gap in the literature, the following questions were addressed in the current research:

1. What are the normative values for L-DDK strength measures for the adductory task /ʌ/ and the abductory task /hʌ/ in the geriatric population between the ages of 60-90 years?
2. Is there a difference between L-DDK strength measures for the adductory task /ʌ/ and the abductory task /hʌ/ in the geriatric population between the ages of 60-90 years?
3. Is there a difference between normative values of L-DDK strength measures for males and females in the geriatric population between the ages of 60-90 years?

CHAPTER III

METHOD

Design

This study is a subset of an existing Indiana University of Pennsylvania (IUP) Institutional Review Board (IRB) approved study (11-131) by Dr. Lori Lombard to obtain normative data on rate, consistency, and strength of L-DDK values across the adult lifespan (20-90 years of age). The co-investigator on the present study collected and analyzed L-DDK strength measures in the normal geriatric population (60-90 years of age) in both males and females.

A differential research design was used to compare the strength of vocal fold movement in both adductory and abductory L-DDK tasks. The study used two groups, males and females, to measure and compare the dependent variable. In this study, the independent variable is gender, and the dependent variables are the L-DDK tasks.

Participants

Recruitment

Both males and females between the ages of 60 and 90 years old who met the inclusion criteria were recruited to be participants in this study. Investigators recruited friends, family members, neighbors, and co-workers to participate in the study. Prior to the study, participants were provided a copy of the *Informed Consent Form*, which outlined the risks, benefits, process, and purpose of the study. Individuals were also required to sign the *Voluntary Consent Form* prior to participating to acknowledge that they understood the requirements and gave their

consent to participate in the study. The IUP IRB approved both of these forms and the study procedures (Log No. 14-197).

Inclusion and Exclusion Criteria

Inclusion criteria for the study required that the participants have a perceptually clear vocal quality and no known laryngeal anomalies. An experienced speech-language pathologist specializing in voice disorders evaluated each participants' vocal quality using the Consensus Auditory-Perceptual Evaluation of Voice ("Consensus Auditory-Perceptual Evaluation of Voice [CAPE-V]", 2006). Participants who received a rating of 20 or lower demonstrated a clear vocal quality and were eligible to participate in the study.

Exclusion criteria for the study included the following conditions: (a) a rating of greater than 20 on the CAPE-V (2006); (b) vulnerability; (c) symptoms of cold or illness on the day of participation; (d) history of respiratory, laryngeal, or neurologic disease; (e) previous laryngeal procedures; (f) history of structural or functional laryngeal abnormalities; (g) profound hearing loss; and (h) inability to comprehend the task. Any participant who met one or more of the exclusion criteria was not included in the study.

Final Sample Size

The final sample of the study included a total of 20 participants between the ages of 60 and 89 years. Of the 20 participants, 10 were female and 10 were male. The mean age of all 20 participants was 72 years. The mean age of female participants in the study was 78 years, and ranged from 60 to 89 years of age. The

mean age of male participants in the study was 66 years, and ranged from 61 to 88 years of age.

Data Collection Procedures

Data collection began after each participant had read the *Informed Consent Form* and signed the *Voluntary Consent Form*, providing consent and agreement to participate in the study. Data collection procedures were conducted in a quiet room at the participant or investigators' home or place of work. Participants completed four tasks: (a) produce L-DDK adductory /ʌ/ and abductory /hʌ/ for seven seconds, three times each; (b) sustain the vowels /a/ and /i/ for five seconds, three times each; (c) read six predetermined sentences; and (d) speak in a conversational manner for thirty seconds. As referenced by Leeper & Jones (1991), each participant was positioned six inches from the Audio-Technica ATR20 Dynamic Cardioid Low Impedance Professional Microphone. The four tasks were recorded using a Roland CD-2 CF/CD Recorder and recordings were copied onto a compact disk.

Data collection began with the L-DDK tasks. The instructions given to the participants were adapted from Fletcher's (1972) study:

I want you to say some sounds for me. They aren't words, just sounds. I'll show you how to do 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 seven 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/).

Before the participant performed the task, the investigator demonstrated the L-DDK tasks by producing both /ʌ/ and /hʌ/ as quickly, consistently, and precisely as possible. Participants then practiced the glottal sounds with the investigator and independently before the task was recorded. After practicing, each participant completed three trials of each task with a randomized order of presentation between each participant to eliminate possible fatigue or test practice effects (Bassich-Zeren, 2004).

After completing six trials of the LDD-K tasks, each participant was assessed for vocal quality and phonatory function using three tasks derived from the CAPE-V (2006). The first task from the CAPE-V required the participants to produce and sustain the lax vowel /a/ and the tense vowel /i/ for five seconds, three times each. The second task measured various laryngeal behaviors by requiring the participants to orally read six sentences. These sentences were as follows: (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; and (f) Peter will keep at the peak. Lastly, in order to maintain a natural conversation for 30 seconds, participants were instructed to respond to the prompt: "Tell me what you did yesterday" (CAPE-V, 2006).

Measurement

Upon completion of L-DDK tasks, syllable production rate was calculated and strength values were evaluated objectively using the Kay Pentax Multidimensional Voice Program™ (MDVP) digital software. Each of the seven second L-DDK audio recorded trials of /ʌ/ and /hʌ/ were converted into oscillograms to calculate the syllable production rate. The first 0.5 seconds of each trial was eliminated from the calculation to prevent outliers and vocal instability at the beginning of the task (Bassich-Zeren, 2004; Ptacek et al., 1966; Verdolini & Palmer, 1997). After eliminating the first 0.5 seconds, the next 5 seconds of each trial were used for analysis. Each amplitude peak on the oscillogram, representing one repetition of a glottal pulse, was counted in the 5-second sample to obtain the syllable production rate (Leeper & Jones, 1991; Ptacek et al., 1966; Renout et al., 1995; Shanks, 1966). Of the three trials, the one with the greatest number of glottal pulse repetitions per 5-second sample was considered the best performance and was used for further analysis. After each participant's best performance trial was determined for both the adductory task /ʌ/ and the abductory task /hʌ/, they were then evaluated for strength.

Strength values of the laryngeal tasks were evaluated by using the oscillograms to determine the rise time and mean amplitude. For each glottal pulse on the oscillogram, the voice onset time and the peak time, or the highest point of intensity, were determined to calculate the rise time of each laryngeal production. Next, the amplitude for each glottal pulse was calculated in millivolts, which was then converted into a mean amplitude for all of the repetitions combined. Outliers in

the data were identified for two female and three male productions of /ʌ/. Outliers were attributed to difficulty distinguishing between extraneous spectrographic markings and true amplitude peaks in the acoustic signal. Outlier samples were eliminated from statistical analysis for the /ʌ/ task, but those participants' /hʌ/ trials were still included in the study.

Ethical Use of Data

Data collected for this study was used only for the purpose of this study and the larger IRB approved study of which this study is a subset. Identifying personal information found on the *Voluntary Consent Form* was viewed and used only by the investigator of this study and the investigators of the larger study. The content on this form was not recorded or published. Participants were assigned alternate participant numbers, which were used on all other paperwork and audio file recordings during the data collection procedures. All identifying information and data were securely locked throughout the duration of the study and were only accessible by the investigators. This information will be destroyed once the larger study is completed.

Statistical Analysis

Statistical analyses were concluded using ISPPSS® Statistics Data Editor software (SPSS Statistics Data Editor, 2010) by completing three separate statistical analyses. The three separate statistical analyses answered the questions researched in this study: (a) What are the normative values for L-DDK strength measures for the adductory task /ʌ/ and the abductory task /hʌ/ in the geriatric population between the ages of 60-90 years; (b) Is there a difference between L-DDK strength

measures for the adductory task / \wedge / and the abductory task / $h\wedge$ / in the geriatric population between the ages of 60-90 years; and (c) Is there a difference between normative values of L-DDK strength measures for males and females in the geriatric population between the ages of 60-90 years?

The analysis used to answer the first question, which determined the normative values for L-DDK strength measures for the adductory task / \wedge / and the abductory task / $h\wedge$ /, was a descriptive statistics analysis. These descriptive statistics summarized the mean, standard deviation, minimum values, and maximum values for the rise time and amplitude of the participants. The next analysis used was a non-parametric Mann-Whitney *U* Test due to the small sample size. This analysis compared strength measurements between adductory task / \wedge / and the abductory task / $h\wedge$ / to answer the second research question. The third question, which was if sex affected L-DDK strength measures, was also analyzed using a Mann-Whitney *U* Test. Male and female subjects were the two independent groups, where the normative data values were the dependent variables.

CHAPTER IV

RESULTS

Results were determined for each of the research questions proposed in this study. No statistically significant differences were found between LDDK strength for the production of the adductory task / \wedge / and the abductory task / $h\wedge$ /. Additionally, no statistically significant differences were revealed between LDDK strength values for male and female participants based on mean, standard deviation, and range values.

The first analysis determined the normative LDDK strength values for the normal geriatric population between the ages of 60 and 90 years for both the adductory task / \wedge / and the abductory task / $h\wedge$ /. Rise time was the first LDDK strength variable calculated. For male participants, the normative value for / \wedge / rise time was $M=0.0589$ ($SD=0.0130$, range=0.0424-0.0775), and the normative value for / $h\wedge$ / rise time was $M=0.0485$ ($SD=0.0105$, range=0.0233-0.0594). For female participants, the normative value for / \wedge / rise time was $M=0.0442$ ($SD=0.0131$, range=0.0277-0.0586), and the normative value for / $h\wedge$ / rise time was $M=0.0446$ ($SD=0.0154$, range=0.0216-0.0652). Next, the mean amplitude was determined. For male participants, the normative value for / \wedge / mean amplitude was $M=7691.17$ ($SD=4612.61$, range=3584.31-17453.10), and the normative value for / $h\wedge$ / mean amplitude was $M=8034.46$ ($SD=3951.18$, range=3679.00-14751.83). For female participants, the normative value for / \wedge / mean amplitude was $M=7728.61$ ($SD=3463.65$, range=3933.57-13872.20), and the normative value for / $h\wedge$ / mean

amplitude was $M=7058.53$ ($SD=3439.07$, range=2810.00-12003.77). These results are summarized in Table 1, *Descriptive Statistics for Strength of LDDK Productions*.

Table 1

Descriptive Statistics for Strength of LDDK Production

Strength Variable	Task	Gender	N	Minimum	Maximum	Mean (M)	Standard Deviation (SD)
Rise Time	/ʌ/	Male	8	0.0424	0.0775	0.0589	0.0130
		Female	7	0.0277	0.0586	0.0442	0.0131
		Total	15	0.0277	0.0775	0.0511	0.0147
	/hʌ/	Male	10	0.0233	0.0594	0.0485	0.0105
		Female	10	0.0216	0.0652	0.0446	0.0154
		Total	20	0.0216	0.0652	0.0466	0.0130
Mean Amplitude	/ʌ/	Male	8	3584.31	17453.10	7691.17	4612.61
		Female	7	3933.57	13872.20	7728.61	3463.65
		Total	15	3584.31	17453.10	7711.14	3888.08
	/hʌ/	Male	10	3679.00	14751.83	8034.46	3951.18
		Female	10	2810.00	12003.77	7058.53	3439.07
		Total	20	2810.00	14751.83	7546.49	3639.79

The Mann-Whitney U test was used to establish if there was a difference between L-DDK strength measures (rise time and mean amplitude) for the adductory task /ʌ/ and the abductory task /hʌ/. This analysis resulted in a Mann-Whitney U of 125.00, a Z -value of -0.833, and a p -value of 0.405 for rise time. For the mean amplitude measure, the Mann-Whitney U test yielded a Mann-Whitney U of 146.00, a Z -value of -0.133, and a p -value of 0.894. Since the p -value for either measure was not less than 0.05, the null hypothesis was accepted, revealing no significant difference in rise time or mean amplitude between the adductory task /ʌ/ and the abductory task /hʌ/. These results are summarized in Table 2, *Mann-Whitney U Test Statistics for Laryngeal Tasks*.

Table 2

Mann-Whitney U Test Statistics for Laryngeal Tasks

Strength Task	Mann-Whitney U	Wilcoxon W	Z-value	p-value
Rise Time /ʌ/ vs /hʌ/	116.00	287.00	-1.221	0.222
Mean Amplitude /ʌ/ vs /hʌ/	148.00	319.00	-0.165	0.869

The Mann-Whitney *U* test was used again to determine if there was a difference between normative values on L-DDK strength measures (rise time and mean amplitude) for males versus females. This analysis yielded a Mann-Whitney *U* of 116.00, a Z-value of -1.221, and a *p*-value of 0.222 for rise time. For mean amplitude, a Mann-Whitney *U* of 148.00, a Z-value of -0.165, and a *p*-value of 0.869 were calculated. Since the *p*-value for either measure was not less than 0.05, the null hypothesis was accepted, revealing no significant difference in rise time or mean amplitude between males and females for both laryngeal tasks. These results are summarized in Table 3, *Mann-Whitney U Test Statistics for Sex*.

Table 3

Mann-Whitney U Test Statistics for Sex

Strength Task	Mann-Whitney U	Wilcoxon W	Z-value	p-value
Rise Time Males vs Females	125.00	335.00	-0.833	0.405
Mean Amplitude Males vs Females	146.00	356.00	-0.133	0.894

CHAPTER V

DISCUSSION

Prior research studies have attested to L-DDK tasks being a potentially effective way to measure the strength of laryngeal function. However, in order to use L-DDK as a prognostic or diagnostic evaluation tool to assess both normal and disordered populations, reliable and normative data must be collected on strength measurements to use as comparison. In order to fill this gap in the literature, the current study sought to answer the following three questions: (a) What are the normative values for L-DDK strength measures for the adductory task / Λ / and the abductory task / $h\Lambda$ / in the geriatric population between the ages of 60-90 years; (b) Is there a difference between L-DDK strength measures for the adductory task / Λ / and the abductory task / $h\Lambda$ / in the geriatric population between the ages of 60-90 years; and (c) Is there a difference between normative values of L-DDK strength measures for males and females in the geriatric population between the ages of 60-90 years?

First, normative values of minimum, maximum, mean, and standard deviation were determined for both strength measures, rise time and average amplitude. For each strength measurement, data were collected for each L-DDK task (/ Λ / and / $h\Lambda$ /) for both male and female participants, and the total of both sexes combined. In order for the L-DDK tasks to be used clinically, normative values are needed for both sexes. Unlike previous studies that only collected data for one sex, this study strengthened the validity by measuring both sexes and analyzed them

separately and as a whole. For example, Leeper & Jones (1991) and Shanks (1996) only used female participants, limiting their studies validity and potential for clinical use. The current study also strengthened the validity of L-DDK values by evaluating both the adductory task /ʌ/ and the abductory task /hʌ/. Previous research studies noted in the literature review only calculated the adductory task /ʌ/, as opposed to both tasks, which would have strengthened their research (Leeper & Jones, 1991; Verdolini & Palmer, 1997). Evaluating both tasks is necessary to determine the true strength of vocal fold adduction versus abduction.

Next, this study compared L-DDK strength measures for the adductory task /ʌ/ and the abductory task /hʌ/ in the geriatric population. The results revealed no statistically significant difference between the two laryngeal tasks. Because there were only twenty participants included in the study, this lack of difference between the two L-DDK tasks may be due to the small sample size for this study. Alternatively, the absence of a significant difference between the two tasks may imply that degenerative changes, such as collagen fiber breakdown and deterioration of muscle fibers that results in vocal fold weakness, declines equally for both adductory and abductory laryngeal muscles in the geriatric population. These results suggest that L-DDK measures may only need to be executed with one of the laryngeal tasks in the geriatric population. However, until further normative values are established for the remainder of the adult lifespan (20-60 years of age), and a larger sample of 60 to 90 year olds can be obtained, both laryngeal tasks should continue to be analyzed in future research.

Finally, this study compared L-DDK strength measurements to identify any differences in regards to sex in the normal geriatric population. The final analysis found no statistically significant difference for L-DDK strength measurements of rise time and average amplitude between males and females. This absence of difference suggests that both male and female geriatric adults experience the same anatomical and physiological changes as part of the normal aging process. As previous research noted in the literature review suggested, both male and female geriatric adults experience atrophy, decreased bulk, and reduced flexibility in their laryngeal anatomy with aging. Additionally, both male and female geriatric adults undergo respiratory changes, including ossification of costal cartilage and decreased lung size that affects the strength of their phonatory output (Ferrand, 2012). These results could have also been due to a small sample size, which may not have been sufficient to detect a difference between sexes.

CHAPTER VI

LIMITATIONS

Despite accounting for internal and external validity by exercising consistent data collection procedures, using identical recording equipment, and screening the health of the participants, there were some limitations to the current study. One of these limitations included an extremely small sample size. There were 10 male participants and 10 female participants for a total of 20 participants. Additionally, some of the /ʌ/ trials could not be included in the final results due to acoustic analysis difficulties, causing even less data to be included in the normative samples. There were no significant differences found between laryngeal tasks or sex in the results, but had there been a greater sample size, a difference may have been detected. Furthermore, a larger sample size in future research would provide a more representative and reliable sample of laryngeal function in the normal geriatric population.

Previous research studies on the strength of L-DDK have differed in the methods of data collection. For example, Verdolini & Palmer (1997) used a subjective measure of “good” versus “bad” to perceptually rate their participants intensity, where as Leeper & Jones (1991) used a pneumotachograph to objectively measure the airflow and intensity of the tasks. Although the current study used an objective measurement of L-DDK strength values to provide concrete data, it is possibly not the most time-efficient method to use clinically. L-DDK is a quick measurement compared to other tests of laryngeal function, but future research should focus on discovering alternate methods of analyzing objective data to allow

L-DDK tasks to be more usable and practical in a fast-paced clinical setting. Specifically, future research could contrast subjective ratings to the objective ratings in this study to determine if the two types of ratings are consistent.

L-DDK task performance could have also been affected by cognitive factors, behavioral choices, and systemic influences in the current study. Participants were excluded from the study if they did not understand the instructions of the task, however, other cognitive influences (e.g. anxiety, apprehension, attention, or incentive) could have affected the execution of the tasks. Behavioral choices (e.g. alcohol, tobacco, drug, or caffeine intake) may have also altered performance by affecting laryngeal and respiratory function despite receiving a sufficient CAPE-V score. Systemic influences may have influenced laryngeal and respiratory capabilities as well. These influences include gastroesophageal reflux disease, pharmaceuticals, allergies, and hormones. Future studies should increase internal validity by adding these influences to the exclusion criteria, or collecting data on them in order to monitor any cognitive, behavioral, or systemic influences during task performance.

In order for L-DDK to be used widely by speech-language pathologists, the tasks need to be normed for the entire adult lifespan. The current study only analyzed the laryngeal function of the geriatric population for normative strength measurements. Future research should gather and analyze data on the early adult population (20-40 years of age) and the adult population (40-60 years of age). Many degenerative disorders, such as Parkinson's disease and amyotrophic lateral sclerosis (ALS), can begin to appear earlier in the lifespan, so it is important to

discover the normative L-DDK data for predictive and diagnostic purposes (Renout et. al, 1995; Verdolini & Palmer, 1997). After normative data have been determined for the entire adult lifespan, research should begin to determine L-DDK strength measurements in disordered populations. These L-DDK strength measurements could be used as a comparison between the normal population and those with impairments secondary to disease processes. Because these diseases often cause subtle differences in the voice prior to the appearance of other symptoms, L-DDK strength measures may ultimately aid in earlier diagnosis of such diseases.

CHAPTER VII

IMPLICATIONS

The findings of this study should be used as the groundwork in understanding normative strength measurements of L-DDK tasks. These findings are preliminary and should be expanded upon to obtain more concrete, objective measures of L-DDK strength values across the lifespan. Future research studies should address the limitations found in the current study. Studies in the future should concentrate on: (a) expanding the sample size, (b) discovering alternative methods to more efficiently and clinically analyze data, (c) comparing subjective versus objective ratings to determine reliability between scoring methods, (d) examining cognitive, behavioral, and systemic influences on L-DDK task execution, (e) collecting strength data on the normal early adult and adult populations, and (f) comparing normative L-DDK strength values with L-DDK strength values of disordered populations. By establishing a collection of normative data, L-DDK tasks could be an extremely valuable tool that speech-language pathologists use in the early detection and diagnosis of patients with degenerative, laryngeal abnormalities.

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APPENDIX A
CONSENT FORMS

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.

Date

Investigator's Signature

Informed Consent Form

Project Title: Laryngeal Diadokokinesis: 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' several times, 2) read 6 sentences, 3) hold out an 'ah' for 5 seconds, and 4) answer a brief question about your voice. A head-worn microphone will be placed on your head. The microphone will be placed approximately 6 cm from the corner of your mouth.

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 Subjects (Phone: 724/357-7730).