8-2015

Laryngeal Diadochokinetic Consistency in the Young Adult Population

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LARYNGEAL DIADOCHOKINETIC CONSISTENCY IN THE YOUNG ADULT POPULATION

A Thesis

Submitted to the School of Graduate Studies and Research

in Partial Fulfillment of the

Requirements for the Degree

Master of Science

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August 2015

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Laryngeal diadochokinesis (L-DDK) tasks, which use glottal production of syllables to assess laryngeal function and movement, have the potential to be a favorable diagnostic tool due to a noninvasive and easy-to-administer protocol. However, the major disadvantage of using L-DDK is the substantial lack of normative data. The purpose of this study was to establish normative L-DDK consistency values for young adults ages 20 to 40 years, determine if there is a difference in consistency of production between the adductory task /ʌ/ and the abductory task /hʌ/, and determine if there is a difference in consistency of production between male and female participants. Forty-two participants were instructed to produce three trials of /ʌ/ and /hʌ/ for seven seconds each. Each trial was analyzed for consistency. Normative values were recorded. Results indicated no statistical difference in consistency of production between /ʌ/ and /hʌ/, as well as no differences in consistency of productions between sexes. The data established in this study provides a foundation for future research to collect additional data, and to put L-DDK to practical use.

ACKNOWLEDGEMENTS

I am using this opportunity to express my gratitude to everyone who supported me throughout the course of this journey. I am thankful for your advice, words of encouragement, support, and dedication to me. I am sincerely grateful to all of you:

Dr. Lori Lombard

Dr. Shari Robertson

Mrs. Karen Stein

Dr. Lisa Hammett Price

Dr. David Stein

Lauren Yates

Molly Mack

Jackie (Hynson) McKelvy

Maggie Bodenlos

Lauren Azeles

Hanna Gratzmiller

The Grahek Family

John Hogsett

Jan Appolonia

IUP SLP Class of 2015

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CHAPTER I

REVIEW OF LITERATURE

Diadochokinesis

Diadochokinesis tasks (DDK) are rapid repetitions of simple patterns of opposite muscular contractions (Modolo, 2010). Producing rapid repetitions of syllables challenges the neuromotor system. By doing so, clinicians are likely to identify neuromotor breakdown with DDK tasks. In the field of speech-language pathology, there are two types of DDK tasks that are used in a clinical setting. Oral diadochokinesis involves the articulators such as the tongue and lips. Laryngeal diadochokinesis (L-DDK) assesses laryngeal function by "analyzing the control of fast and regular opening and closing of the vocal folds" (Baken & Orlikoff, as cited in Modolo, Berretin-Felix, Genaro, & Brasolotto, 2010). Both diadochokinetic tasks involve the production of syllables as quickly, but as consistently, as possible. Both oral DDK and L-DDK tasks have been used in assessment to help diagnose any abnormalities or changes in speech performance. An explanation of both diadochokinetic tasks below will help explain why they are important clinical tools in the field of speech-language pathology, and how the lack of research is preventing clinicians from using these tasks to their maximum potential.

Oral Diadochokinesis

Oral DDK tasks help assess neuromotor integration, maturation, and coordination. They also provide examiners important information about the function of the structures involved in speech production such as the lips, tongue, and velum (Modolo, 2010).

Having a client repeat the syllables /pʌ/, /tʌ/, and /kʌ/ helps speech-language pathologists gain insight into articulatory coordination. As such, it is important that clients produce these syllables as quickly as they can, but also as clearly and with as much control, or consistency, as possible. These syllables are then counted and a ratio of syllables per second is calculated representing the speed of the repetition. According to Modolo (2010), "DDK development is studied in children as well as adults and in the elderly. The DDK test has been used in the assessment in children with several speech alterations, as well as in adults with neurological diseases" (p. 3). This widely used procedure is important to clinicians because it provides information about communication disorders across the lifespan.

Various authors have collected normative data and conducted studies to highlight that oral DDK can be a predictor of and help facilitate a diagnosis of developmental delays, progressive neurological conditions, and neuromuscular impairments of key articulators (Gadesmann & Miller, 2008). Despite its widespread use, there remains a general lack of knowledge and information regarding oral diadochokinetic tasks.

Gadesmann and Miller (2008) conducted a study on oral DDK tasks that sought to investigate the inter- and intra-rater reliability of perceptual DDK measurements and the possible impact of clinician experience on rating performance. This study was important because studies regarding inter- and intra-rater reliability are lacking. Results suggest that clinicians should use DDK tasks with caution because the inter- and intra-rater reliability of oral DDK was lower than what is considered acceptable in clinical practice. However, this study did provide support for the use of DDK in clinical assessment. More extensive research is needed in order to determine the strength of this potential application (Gadesmann & Miller, 2008).

Although Gadesmann and Miller (2008) suggest using caution with oral DDK, authors like Fletcher (1972) argue that oral DDK is an excellent way to assess the functions of the speech structures. In a study conducted by Fletcher (1972), 48 subjects were assessed on their ability to complete oral diadochokinetic tasks. According to Fletcher (1972), "the results obtained from this study suggested that this approach would indeed generate valid and reliable data" (p. 763). The study conducted by Fletcher (1972) demonstrates that oral DDK is a clinically appropriate way for speech-language pathologists to assess the coordination of a patient's articulatory system (Fletcher, 1972).

Even though the findings of these two investigations differ, they share a common factor. Both suggest that the challenge of oral DDK tasks is a way to help facilitate a diagnosis of developmental delays, progressive neurological conditions, and neuromuscular impairments of key articulators. Both articles also suggest that more research is needed to determine just how effective oral DDK is in the clinical setting.

Laryngeal Diadochokinesis (L-DDK)

Another type of neuromotorically challenging DDK task that is used much less frequently in a clinical setting is laryngeal diadochokinesis (L-DDK). Unlike oral DDK, which uses articulatory placement, L-DDK uses glottal production of the syllables /hʌ/ and /ʌ/. Rapid production of these two syllables requires adducting and abducting the vocal folds on a smooth, controlled exhale. The task isolates the larynx, allowing a clinician to assess laryngeal movement and function.

Although L-DDK is not as widely used by speech language pathologists as oral DDK, it is an important clinical tool to assess laryngeal function and potentially diagnose disordered populations. L-DDK data is obtained by asking the patient to repeat the glottal syllables /hʌ/ and /ʌ/ as quickly, consistently, and accurately as possible. The rate is then calculated as the number of syllables spoken per second. If a patient's rate differs significantly from what is considered normal, then that would help in diagnosing a disorder. Similarly, if their productions of the glottal syllables reveal problems with accuracy or consistency, that could signal a voice problem. When measuring L-DDK, it is important that clinicians examine the rate, consistency, and strength. Typically clinicians just calculate rate, however they may be missing key information by doing so. For example, a neurological disease may affect the rate of production, but not the consistency, or it may affect consistency, but not the rate of production. Rate is important because it provides insight on how quickly a person can produce L-DDK tasks, however consistency also provides key information. Consistency allows the clinician to see how controlled and periodic the client is producing the syllables. Many researchers tend to neglect this measure in their studies; however doing so limits the usefulness of their work. It is necessary to examine all three of these measures in order to assess the entire fine motor coordination of the larynx. Although these measures provide insight into fine motor coordination, there are two major problems with using L-DDK as a diagnostic tool. First, currently there is no standardized procedure for obtaining the data, and second, there is a lack of normative data to which to compare the results.

Attempts to get normative data on L-DDK have been done by various authors. A study conducted by Leeper and Jones (1991) attempted to gather information concerning the timing and amount of air used during rapid voluntary opening and closing of the vocal folds. According to Leeper and Jones (1991), "since few data are available, the present study was designed to examine the characteristics of vocal fold opening and closing rate and the amount of air passing through the vocal folds during vowel /ʌ/ repetition at several rates" (p. 880). Eighteen healthy females were selected to participate in the study. The participants had no history of respiratory, neurological, or hearing difficulties. The results of this study indicated that vocal intensity is the primary controlling factor in L-DDK. Also, syllable rate and regulation of airflow through the glottis play an important role in performance on L-DDK tasks (Leeper & Jones, 1991).

This study provided some important findings, however, the sample size was very small and it included only females. Much more information on L-DDK is needed in order to put it to practical use. When establishing normative data, a very large sample size is required so it is representative of the population. More importantly, the researchers failed to analyze the consistency of the L-DDK tasks. As stated before, consistency must be analyzed to show the variance among productions. Although Leeper and Jones (1991) added important information about the effects of intensity and syllable rate on the results of L-DDK tasks, they also reiterated the need for more research and the development of normative data.

The lack of normative data for L-DDK measures such as rate, consistency, and strength is a substantial problem; specifically, the lack of normative data examining L-DDK consistency. The lack of data makes it difficult to use L-DDK in a clinical setting because clinicians are unable to compare their clients' results to normative data to potentially diagnose a disorder. It is essential to know what is normal in order to recognize and interpret what is abnormal. A review of the anatomy, physiology, and innervation of the larynx will explain why L-DDK can be used as a tool to assess laryngeal function.

Anatomy, Physiology, and Innervation

Anatomy and Physiology

Understanding the anatomy and physiology of the larynx is crucial for understanding how L-DDK tasks are produced because that is where the glottal syllables /hʌ/ and /ʌ/ are produced for laryngeal diadochokinesis. Seikel et al. (2005) provides an accurate description of the larynx so one can better understand this structure.

The larynx is a muscular-cartilaginous structure that houses the vocal folds. As for its location, the larynx is superiorly attached to the trachea. The larynx is made up of paired and unpaired cartilages bound by muscles and ligaments. All of the muscles and structures of the larynx work together to allow a person to produce voice.

In order to understand the importance of L-DDK, it is important to understand phonation (i.e., voice production). According to Seikel et al. (2005), phonation occurs when air is released from the lungs and into the larynx. As the air passes through, the vocal folds adduct (close) and then abduct (open). The vocal folds' ability to open and close smoothly and rapidly depends on motor control (Seikel et al., 2005). Sound is then produced at the level of the vocal folds. During phonation, the arytenoids rock back and forth to move the vocal folds. Adduction of the vocal folds produces voiced sounds, which would be required for the L-DDK task /ʌ/. Abduction of the vocal folds produces a voiceless fricative /h/, which would be required for the L-DDK task syllable /hʌ/. All of these structures must work together in order to open and close the vocal folds. When all of these structures are working properly, this promotes healthy laryngeal movement necessary for normal phonation (Seikel et al., 2005).

The vocal folds themselves, housed in the larynx, are very small, only about the size of a thumbnail. They have special vibrating qualities based on their unique, multi-layered structure. The vocal folds are made up of five histological layers of tissue increasing in density. All of the layers vary with age and sex. The first layer, called the epithelium, is a very thin layer that helps regulate hydration. Lubrication of this layer through adequate hydration is essential for normal vibratory cycles. The epithelium also acts as a 'shell' to help the vocal folds maintain their shape.

The next three layers are called the lamina propria. The first is the superficial lamina propria (SLP), also referred to as 'Reinke's space'. The SLP adds an elastic, loose, gelatin cushion. Both the epithelium and the superficial lamina propria act as the cover of the vocal folds in the body-cover theory. According to Seikel et al. (2005) the body-cover theory describes the wave-like motion of the loose mucosa of the vocal folds, over the stiffer vocal ligament and vocalis muscle. The cover is responsible for the vibratory cycle, or the mucosa wave in the vocal folds. The cover plays a passive role; wherever airflow takes it, it will go. Because the SLP is the layer responsible for vibrating, it is also the area where most benign lesions occur (i.e., nodules, polyps). The second layer in the lamina propria is the intermediate layer. This layer is composed of elastin fibers much like a rubber band. The third layer in the lamina propria is the deep lamina propria. This layer is much more dense than the previous two. The deep lamina propria is made of collagenous fibers that add durability to this layer. The last of the five layers of the vocal folds is the thyroarytenoid muscle. The thyroarytenoid muscle is considered the body in the body-cover theory. The thyroarytenoid muscle is used for strength and movement. This layer is the densest in all layers of the vocal folds. These five layers are each unique with different mechanical properties and qualities. Studying these layers and becoming familiar with their characteristics provides valuable information on vocal fold vibratory properties (Seikel et al., 2005).

It is important to be familiar with the layers of the vocal folds with regard to normative data for L-DDK. The layers of the vocal folds affect how the vocal folds are vibrating and what a patient's voice sounds like to a listener. Damage to any of these layers by vocal lesions and/or other structural changes will cause variations to a person's voice production. Those variations could then affect the person's ability to consistently produce L-DDK tasks due to structural interference with the coordination of the vocal folds and the airstream.

Innervation

Vocal fold mobility depends on adequate neurologic as well as anatomic foundation. Many disorders of the voice may be caused by systemic or cranial nerve damage. Just as studying the vocal fold layers can provide important information, examining the innervation of the larynx also provides significant information. Cranial nerve X, the vagus nerve, is the nerve responsible for laryngeal function. This nerve divides into three primary branches near its exit from the skull (Seikel et al., 2005).

The pharyngeal branch descends between the external and internal carotid arteries. It supplies nerve fibers to the pharynx. Its main function is to innervate all of the muscles of the soft palate. This branch of the vagus nerve is essential for the velopharyngeal seal, critical for swallowing (Seikel et al., 2005).

The next of the three branches is the superior laryngeal nerve (SLN). The SLN descends alongside the pharynx. This branch then divides into two branches: internal and external. The internal laryngeal nerve branch supplies laryngeal sensory and secretory innervation. This is the branch that provides sensation of the larynx. This branch will trigger a cough when food or liquid has penetrated the larynx. A cough or sensation to the larynx is again critical for a safe swallow. The external laryngeal nerve branch innervates the cricothyroid (i.e., the pitch muscle). Damage to this nerve branch may be difficult to detect because it may not have a perceptual affect on speech. During normal speech, one does not need a wide range of fundamental frequency, only pitches appropriate for normal conversation. However, a singer does need a wide range of pitches in order to reach the high notes to the very low notes of a song. Therefore, only a singer would notice damage to this nerve branch (Seikel et al., 2005).

The third and final branch of the vagus nerve is called the recurrent laryngeal nerve (RLN), also known as the 'wandering nerve.' This nerve is divided into two parts. The left descends to lower neck and chest, under the arch of the aorta, then between the esophagus and trachea. The right arises in front of the subclavian artery and ascends along the carotid artery between the trachea and esophagus. The RLN is responsible for innervating all of the intrinsic laryngeal muscles (except the cricothyroid). This nerve is the motor innervation for the vocal folds. The RLN is very susceptible to damage and injuries because of its length. Patients undergoing thyroid gland and/or neck surgery have a high incidence of RLN damage due to its location in the area of the surgical procedure. Damage here can result in paralyzed vocal folds because the RLN controls the muscles in the larynx that open and close the vocal folds (Seikel et al., 2005).

Neurologic impairment in the larynx can result in major changes to voice production. With the development of its research, L-DDK could potentially be used to indicate nerve damage and provide early referrals for patients. This early diagnosis could lead to better and more effective treatment. Without normative data though, it is not possible to identify potential nerve damage through consistency of L-DDK productions at this time (Seikel et al., 2005).

Aging of the Larynx

Just as all body systems change throughout the lifespan, the larynx changes with age. Ferrand (2012) perfectly described the lifespan changes in her article by stating, "the voice changes dramatically over the lifespan, from the high-pitched crying of an infant to the thin, quivery voice of the very old" (p. 3). All of these changes occur due to development, maturation, and then decline of the respiratory and laryngeal mechanisms. In addition, other factors can influence the voice over time such as smoking, alcohol consumption, and amount of voice use. It is important to be able to distinguish a voice disorder from the normal aging process in order to diagnose disorders of the larynx (Ferrand, 2012).

The vocal folds change in length as well as in their histological composition over the lifespan. During childhood, the vocal folds are shorter, resulting in a higher fundamental frequency of about 300 Hz (i.e., pitch). Childhood vocal folds also have a much simpler histological structure. A pre-pubescent child only has three layers, compared to the adult vocal folds of 5 layers.

Once a child's body begins to undergo pubescent changes, the vocal folds begin to lengthen and tissue differentiation starts to develop. Female vocal folds lengthen to about 11-15mm, adding more mass to their vocal folds and decreasing their fundamental frequency to about 200 Hz (Ferrand, 2012). Males, on the other hand, experience much more drastic growth and change. Their vocal folds lengthen to about 17-21mm, adding much more mass to their vocal folds, drastically decreasing their fundamental frequency to about 100 Hz (Ferrand, 2012). The change in pitch of 300 Hz from a pre-pubescent child to 100 Hz in a pubescent child explains why males experience 'pitch breaks' while going through puberty. They experience a much more significant drop in fundamental frequency than females do. As mentioned previously, males experience a change in their thyroid cartilage during this time as well. Their thyroid cartilage begins to descend to 90°, creating a notch known as the 'Adam's apple,' whereas females' thyroid cartilage becomes more rounded (Ferrand, 2012). All of these changes can occur up to the age of 18. Once the larynx is fully mature, fundamental frequency and growth will stabilize. This stability of the larynx occurs when one reaches young adulthood.

The young adult population was particularly important to the current study. This population, ages 20-40, was examined closely in this study because it provided valuable information regarding L-DDK tasks. The young adult population represents the larynx at its most stable and healthiest developmental time frame. Pubescent changes have ceased, and the aging process has not yet begun in this population. L-DDK tasks from this age population are essential when gathering normative data because they show how a normal larynx should be functioning at its developmental peak. This population provides a baseline for documenting age related changes to the larynx.

Although the larynx is at its most stable and healthiest developmental time frame, during this period some changes do occur. For example, hormonal changes, especially in females, can cause fluctuations in vocal fold vibration. These hormonal changes can be attributed to menstruation and pregnancy. During menstruation, a heightened amount of estrogen increases the amount of secretions in the glandular cells both above and below the vocal folds, causing reduced mucosal viscosity (Ferrand, 2012). Progesterone reduces the amount of secretions, dehydrating the mucosa. These changes can all lead to vocal fatigue, loss of voice power, and the inability to hit high harmonics. However, these changes are not present in all women. Oral contraceptive pills have been shown to help regulate fluctuations of hormones during the menstrual cycle, and have been reported helping vocal quality during this time (Ferrand, 2012). It is important to note that these fluctuations due to hormones are normal, and not considered to be an atypical voice disorder. When looking at L-DKK measures during a time when a female is menstruating or pregnant, the data may suggest a voice disorder. It is important to keep in mind these fluctuations to avoid a misdiagnosis. These fluctuations also highlight why it is important to analyze normative data on males and females separately. Aside from these fluctuations, the larynx is the most stable at this time frame, and the vocal folds are functioning at their finest.

Once the larynx stabilizes post-puberty, it is only a matter of time before changes begin again. These changes related to the aging process are known as presbylarnygis. The larynx begins its aging process as early as between 30 and 40 years old. However, these changes do not come on suddenly. Changes can occur any time between the third and eight decade of life; it varies from person to person (Ferrand, 2012). Structural changes in the larynx can affect the cartilages, joints, muscles, and some layers of the vocal folds (i.e., epithelium and lamina propria).

Laryngeal cartilages consist of a substance called hyaline, which ossifies with age. The ossification of this cartilage causes movements of the vocal folds to be less flexible, which can impact vocal fold vibration. Some researchers have said that ossification may be more prominent and extensive in men than women (Ferrand, 2012). The joints in an aging persons' life become stiffer, and this happens to the laryngeal joints as well. However, one cannot have a larynx replacement, like one can have a knee replacement when the joints are not functioning properly any longer. The cricoarytenoid and the cricothyroid joints are subject to surface erosion, thinning of the surfaces, and breakdown of collagen fibers (Ferrand, 2012). These changes highly limit the degree of vocal fold adduction and abduction. The limit in opening and closing of the vocal folds can result in a breathy, weakened voice. As laryngeal muscles age, they begin to atrophy. With such muscle tissue breakdown, the thyroarytenoid muscle will not be able to function as efficiently as it once did. This breakdown will in turn affect the consistency of L-DDK tasks.

Changes in the vocal fold layers also occur with aging. In females, the epithelium is known to thicken. This thickening may be caused by hormonal changes associated with menopause. A thickened epithelium may also cause superficial dehydration, causing a change in vocal fold vibration. Changes in the lamina propria cause the vocal folds to have a bowed-like appearance. This appearance is a signature look of presbylaryngis. The medial edges become bowed due to fiber separation. The fiber separation results in a breathy, weak voice because the vocal folds are not able to make direct contact for proper adduction (Ferrand, 2012). It is important to understand the process of presbylaryngis to distinguish normal aging from a disordered voice.

Normative data with regard to L-DDK will help a clinician analyze the aging larynx, and make possible diagnoses and referrals.

Ptacek et al. (1966) completed a study that investigated changes in phonatory tasks due to aging. The researchers selected participants and divided them up into two groups. They were assessing the performance of early adults (under age 40) and geriatric subjects (over age 65) on the following tasks: pitch rate, oral DDK, L-DDK, vowel intensity, vowel duration, intraoral breath pressure, and vital capacity (Ptacek et al., 1996). The oral DDK tasks consisted of /pʌ/, tʌ/, /kʌ/ and /pʌtʌkʌ/. The L-DDK task consisted of the glottal syllable /ʌ/. On each of these tasks, the geriatric group showed reduced scores when compared to the young adult group. The study revealed statistically significant differences ($p< .01$) in the L-DDK scores among the geriatric and young adult subjects (Ptacek et al., 1966).

The results of the Ptacek et al. (1966) study showed that both oral and laryngeal DDK tasks were produced at a slower rate among the geriatric group. While this study highlighted the differences between age groups on phonatory tasks, it revealed a much larger problem; the lack of normative data on L-DDK. There is no way of knowing if the geriatric groups' rate of syllable production was normal or abnormal. The same issue arises for the young adult group. Without normative data, it is impossible to determine if the rate of syllable production was normal or not. Also, the study neglected the consistency measure. As mentioned previously, consistency needs to be analyzed as well as rate in order to provide the most thorough assessment of the larynx. Another flaw in the Ptacek et al. (1966) study was that the authors compared participants under 40 and over 65 years of age, neglecting the 40-65 year old age group. This is a substantial gap, and consequently, the results do not represent laryngeal aging and phonatory tasks over the entire adult lifespan. Even though this study revealed statistically significant results, they need to be interpreted with caution. Without normative data on diadochokinetic rates and consistency of productions, it is just an assumption that the geriatric groups' scores were abnormal (Ptacek et al., 1966).

In another study conducted by Shanks (1996), the researcher investigated the effects of pitch, intensity, and aging upon L-DDK tasks. Laryngeal diadochokinesis samples were taken from 130 female participants. The participants varied on many different levels, especially their age. To complete the task, the participants were asked to repeat the laryngeal syllable /hʌ/ only. Results from this study revealed that the aging population performed worse on the L-DDK tasks than the young adult population. The results are highlighting the fact that laryngeal aging plays a role in the performance of L-DDK tasks, and that the young adult population represents the larynx at its most stable time.

Although the results of this study indicated that the aging population performed worse on L-DDK tasks, this information needs to be interpreted with caution. Important factors that need to be taken into consideration when looking at L-DDK were not investigated specifically. The participants only produced the syllable /hʌ/ when completing the L-DDK task. This method of collection is problematic because /hʌ/ does not provide both adductory and abductory patterns of the vocal folds. In order to collect a true laryngeal diadochokinesis sample, both /hʌ/ and /ʌ/ must be measured. Another weakness is that Shanks (1996) only collected data on female participants. Consequently, results can only be generalized to the female population. As mentioned before, the female and male larynx differs during the aging process. Lastly, the lack of normative data on L-DDK limited this study. Again, without normative data, it is impossible to determine whether a person in performing within a normal range for their age (Shanks, 1996).

Diseases Affecting the Larynx and Laryngeal Function

As stated previously, presbylaryngis is a natural aging process that affects an individual's larynx. However, aside from aging, many neurologic diseases can also affect the larynx in a negative way. Diseases such as Parkinson's disease and amyotrophic lateral sclerosis affect laryngeal function. With the use of normative data on L-DDK, speech-language pathologists may be able to make early referrals to physicians when patients begin to show signs and/or symptoms of these diseases.

Parkinson's Disease

Patients with Parkinson's disease experience changes to their vocal quality as a symptom consistent with the disease. For instance, patients may often sound monotone and have difficulty maintaining loudness when speaking. Their phonatory patterns will also be weak. This phonatory weakness could lead to difficulty with L-DDK tasks. A research study conducted by Canter (1965), highlighted Parkinson's patients' inability to complete diadochokinetic tasks. Canter (1965) selected 17 male participants who were diagnosed with mild-moderate Parkinson's disease. The participants were asked to repeat the syllable /hʌ/ as quickly as possible for 5 seconds. Participants had difficulty producing rapid articulatory movements (Canter, 1965). The participants who demonstrated difficulty with L-DDK tasks also had difficulty with other articulatory tasks. The results of the study suggested that there is a correlation between the severity of Parkinson's disease and L-DDK tasks (Canter, 1965).

This study provided crucial information regarding Parkinson's disease and the patients' inability to complete L-DDK tasks. However, flaws in the study were present. One flaw was that Canter (1965) only collected data on /hʌ/. In order to see the opening and closing patterns of the vocal folds, both /hʌ/ and /ʌ/ need to be measured. Another weakness in the study is that Canter (1965) had no normative data for comparison. Therefore, although the patients had difficulty with the L-DDK task, it was not possible for Canter (1965) to compare their performance to normative data that could show how much their performance deviated from normal controls of the same age.

Amyotrophic Lateral Sclerosis

Amyotrophic lateral sclerosis (ALS), like Parkinson's disease, has been an area of interest in terms of L-DDK tasks. Because ALS causes loss of control in the movement of muscles, the disease has a highly negative impact on the vocal folds and other laryngeal structures. Persons with ALS exhibit weak, breathy phonatory patterns. They have difficulty maintaining loudness when speaking. Persons with ALS have a weakened speech system characterized by reduced amounts of strength in the laryngeal area (Seikel et al., 2005).

These voice characteristics have been shown consistently in studies conducted on persons with ALS. One study by Renout et al. (1995) looked at the changes in vocal fold opening and closing in patients with ALS. The researchers selected both males and females to participate in the study. Twelve participants had been diagnosed with bulbar ALS and then the other 14 had been diagnosed with nonbulbar ALS. Bulbar refers to the presence of cranial neuromotor symptoms, whereas nonbulbar refers to the absence (Renout et al., 1995). The participants were asked to repeat the syllable /hʌ/, and the researchers evaluated the rate, pattern, and periodicity of the repetition. The findings revealed that participants diagnosed with bulbar ALS showed significantly slower rates than the participants with nonbulbar ALS. The study also revealed that reduced rates of L-DDK tasks increased with the amount of time a participant had been diagnosed with the disease (Renout et al., 1995).

The results of this study are important because they show that ALS negatively affects the larynx and vocal fold adduction/abduction. The results are significant because L-DDK could be used as a tool to detect early symptoms of neural deterioration. Specifically, consistency of productions can show how well the patient is able to control the syllables and how much variance is present. However, again, the lack in normative data for L-DDK makes clinicians unable to use this tool. Without normative data there is no means of comparison (Renout et al., 1995).

Collection of normative data is crucial for diseases such as Parkinson's and amyotrophic lateral sclerosis. Normative data for L-DDK could help speech-language pathologists detect early signs and/or symptoms, make a referral, and possibly lead to an early diagnosis. L-DDK tasks could be used as a clinical tool to identify disordered populations. However, much more research must be done and normative data must be collected in order for L-DDK to be relevant in a clinical setting.

Tests of Laryngeal Functioning

Much like L-DDK can assess laryngeal function, there are a few popular protocols that can be used to assess laryngeal function and provide a diagnosis of a voice disorder. The most widely used protocols are explained below.

Endoscopy

Endoscopy is considered to be the gold standard in assessing laryngeal function. During this procedure, an endoscope is inserted through the nose or mouth until the larynx visible. A flexible endoscope is administered through the nose. During this procedure, velopharyngeal movement and laryngeal movement are assessed. This type of endoscope is very useful because the patient is able to sustain phonation, speak, and swallow normally. The only disadvantage to using a flexible endoscope is that the endoscope is much smaller, in order to fit through the nasal passages, making the magnification not as high (Seikel et al., 2005).

Unlike a flexible endoscope that is administered through the nose, a rigid endoscope is inserted into the mouth. This endoscope uses stroboscopy, which slows the perceived rate of vocal fold vibration so that the human eye can see it. Along with vocal fold vibration, a speech-language pathologist would also be able to assess vascularity of the vocal folds, the mucosal wave, and the structures of the larynx with a rigid endoscope. Because this endoscope is wider, it has a much higher magnification than a flexible endoscope. However, the disadvantage to using the rigid endoscope is that the patient is only able to sustain phonation due to the endoscope in their mouth (Seikel et al., 2005).

Electroglottography (EGG)

Electroglottography (EGG), like endoscopy, is used to assess laryngeal functioning. EGG involves placing electrodes on the surface of the skin on each side of the thyroid cartilage. This assessment is used to provide a graphic representation of the vocal fold closure patterns, and potentially predict abnormal function. Unlike endoscopy, which is invasive by inserting an endoscope into the nose or mouth, EGG is not invasive at all. However, because endoscopy is considered to be the gold standard in assessing laryngeal function, EGG is used much less in a clinical setting (Seikel et al., 2005).

Limitations to Current Measurement Options

Both endoscopy and electroglottography provide clinicians with important information regarding laryngeal function. However, both of these protocols present with weaknesses that make them difficult to use in a clinical setting. First, endoscopy protocols are very expensive. The equipment and maintenance of the equipment are costly. Also, the equipment may not be readily available for clinicians who do not work in a medical setting. In some states, a physician must be on site with the speech-language pathologist during endoscopic procedures. All of these necessities make endoscopy less desirable because fewer speech-language pathologists will be capable of meeting all of these requirements.

Another limitation of endoscopy is that the procedure is invasive and a patient may be uncomfortable. The endoscope must go into the oral or nasal cavity while the patient is awake and phonating. The insertion of the endoscope may cause the patient some discomfort, and they may not want to continue with the procedure. EGG is less invasive, but is not used as frequently because it is not the gold standard.

Lastly, both endoscopy and EGG require training to interpret both the perceptual and objective findings. This expertise requirement can create an issue with reliability and validity. Each clinician may interpret the findings in a different way, creating inconsistent results that may or may not be a valid judgment of the patient's vocal function. It is difficult to use these protocols as a reliable measure due to the lack of reliability and consistency across speech-language pathologists (Seikel et al., 2005).

The limitations listed above highlight the clinical potential of L-DDK. Laryngeal diadochokinetic tasks provide the information on laryngeal function similar to procedures that the previous protocols do, however at a much lower cost and without invasive techniques. If a patient could produce glottal syllables with their larynx, and it would yield similar results to visualization and graphing techniques, clinicians everywhere could use it. It would be noninvasive and patients would be more willing to complete the assessment. Also, a clinician in any type of setting would be able to use L-DDK as an assessment tool because it requires no equipment. The development of normative data is crucial for assessing laryngeal function in a more efficient way.

Validity and Reliability of L-DDK

Although it is clear that speech-language pathologists need normative data in order to use L-DDK clinically, there are two additional issues that must be dealt with in order to ensure that L-DDK can be used as a valid and reliable clinical tool. There are currently two threats to the validity and reliability of L-DDK. The first threat to validity is that there are many inconsistencies in the tasks that the participants are asked to perform. For example, in the studies conducted by Shanks (1966), Canter (1965), and Renout et al. (1955) data were only collected on the syllable /hʌ/. In studies such as

Ptacek et al. (1966), the participants were measured on the syllable /ʌ/ only. The collection of only one syllable makes the studies difficult to compare because of the inconsistent protocol. To eliminate this discrepancy, both glottal syllables /hʌ/ and /ʌ/ need to be measured. By doing so, it will provide the most valid information on L-DDK tasks.

A second threat is with the reliability of L-DDK. Some researchers are measuring the tasks perceptually, whereas other as measuring the tasks more objectively. The inconsistency in the method of judging each patient's performance decreases the reliability of the results. In order to eliminate this flaw, the L-DDK tasks should be measured both perceptually and objectively.

Few studies have been conducted to show the reliability of L-DDK tasks. It is important to collect normative data on three laryngeal diadochokinetic tasks to demonstrate that this tool is a valid and reliable measure for speech-language pathologists to use.

Statement of the Problem

L-DDK has shown to be a promising measure of laryngeal function, and has potential to identify abnormalities in vocal fold function. To date, there is such a lack in normative data regarding laryngeal diadochokinetic tasks. Clinicians are unable to use this quick, non-invasive, and inexpensive tool to assess laryngeal function because there is nothing to which results can be compared. The studies that have collected normative data have focused on small samples of only one age group, and have only measured rate of L-DDK tasks. The goal of the current study is to collect normative L-DDK consistency data from across the adult lifespan.

CHAPTER II

PURPOSE

L-DDK is a diagnostic tool that has many advantages in a clinical setting. It is non-invasive, inexpensive, and easily administered, unlike many of the procedures currently being used in a clinical setting today. However, the major limitation of L-DDK is the substantial lack in normative data and the inconsistent procedure used for collecting data. The current study is part of a larger investigation to collect normative L-DDK data for rate, consistency, and strength in normal adults between the ages of 20-90 years. The purpose of the current study was to collect and compare L-DDK production tasks of /ʌ/ and /hʌ/ in normal young adults between the ages of 20 and 40 years using standardized procedures. Specifically, this study seeks to identify normative values for the consistency of L-DDK productions in individuals grouped by sex and age (20-40 years). For this purpose, the following research questions were addressed in this study:

1. Is there a difference between laryngeal diadochokinetic production consistency for the adductory task /ʌ/ and the abductory /hʌ/ in the young adult population between the ages of 20 to 40 years?
2. What are the normative values for laryngeal diadochokinetic consistency of production for the adductory task /ʌ/ and the abductory task /hʌ/ in the young adult population between the ages of 20 and 40 years?
3. Is there a difference between normative values of laryngeal diadochokinetic consistency of production for male and female participants?

CHAPTER III

METHOD

Design

This study is a subset of an existing Indiana University of Pennsylvania (IUP) Institutional Review Board (IRB) conducted by Dr. Lori Lombard (primary investigator). A differential research design was used to compare consistency of production of the adductory /ʌ/ and the abductory task /hʌ/ L-DDK tasks. This study also aims to bridge the gap in previous literature by collecting and comparing normative data on participants across the adult lifespan. This student investigator has been a co-investigator on the larger study since Fall, 2014. This current study is focused upon the consistency of L-DDK tasks in the young adult population (ages 20-40). The participants are grouped by sex, which was the independent variable in this study. Whereas, the dependent variables are the L-DDK tasks /ʌ/ and /hʌ/.

Participants

Selection

Participants chosen for this study were males and females between the ages of 20-40 years old. All participants read and signed a consent form prior to participation.

Recruitment

Friends, family, and coworkers of the investigator were recruited as participants of this study. All participants who met the inclusion criteria (as described below) to participate in the study were provided with a copy of the *Informed Consent Form.* This form explained the risks, benefits, and procedures for participating in the study. Following review of that document, participants were then asked to review and sign the

Voluntary Consent Form to confirm that they understand the risks, benefits, and requirements for participation in the study. The Indiana University of Pennsylvania Institutional Review Board reviewed and approved the *Informed Consent Form, Voluntary Consent Form*, and the protocol (Approval ID: 11-131).

Inclusion and Exclusion Criteria

In order to be considered for partaking in this study, participants were required to have a perceptually normal vocal quality and no known laryngeal abnormalities. An experienced speech-language pathologist determined whether or not the participant's voice was perceptually normal by using the Consensus Auditory-Perceptual Evaluation of Voice ("Consensus Auditory-Perceptual Evaluation of Voice [CAPE-V]," 2006). Participants who received a score of 20 or below were considered for the study. Exclusion criteria included the participant demonstrating one or more of the following conditions: (a) a score of over 20 on the CAPE-V; (b) vulnerability as designated by IRB protocol; (c) symptoms of a cold or illness on the day of participation; (d) history of respiratory, laryngeal, or neurologic disease; (e) previous surgeries of the larynx; (f) history of structural or dynamic laryngeal abnormalities; (g) reported hearing loss of a profound degree; and (h) lack of comprehension of the task. Consequently, participants who displayed any of these criteria were excluded from the study.

Final Sample Size

The final sample size included 42 participants between the ages of 20 and 40 years old. Of the 42 participants, 29 were females and 13 were males.

Data Collection Procedures

After receiving informed consent and willingness to participate, data collection began. Data was collected in a quiet room in either the participant's home or workplace. Participants were required to complete four tasks: (a) produce L-DDK tasks /ʌ/ and /hʌ/ for 7 seconds, three times each; (b) sustain the vowels /a/ and /i/ for 5 seconds, three times each; (c) read six predetermined sentences; (d) produce natural conversation for 30 seconds. All four tasks were recorded using a Roland CD-2 CF/CD Recorder and copied to a compact disk. In order to ensure that all recordings were the same, participants were placed six inches from the Audio-Technica ATR20 Dynamic Cardioid Low Impedance Professional Microphone based on the recommendations of Leeper & Jones (1991). The investigator gave the participant verbal instructions for the LDDK tasks. These instructions were modeled after Fletcher's (1972) study and were as follows:

> "I want you to say some sounds for me. They aren't words, just sounds. I'll show you how to do it first, and 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/)."

After receiving the instructions, the participants completed three trials of each glottal syllable. The order of the two L-DDK tasks was randomized across participants (Bassich-

Zeren, 2004). For example, alternating participants to produce /ʌ/ or /hʌ/ first prevents the possibility of fatigue or practice effects on performance results. Following the completion of the two L-DDK tasks, participants were asked to complete three additional voice tasks derived from the CAPE-V (2006). First, participants were asked to sustain the lax vowel /a/ for 5 seconds three times each. The participants were asked the same for the tense vowel /i/. Second, the participants were required to read the following six sentences: 1) The blue spot is on the key again; 2) How hard did he hit him; 3) We were away a year ago; 4) We eat eggs every Easter; 5) My mama makes lemon muffins; and 6) Peter will keep at the peak. The final task required participants to produce a conversational language sample for 30 seconds, responding to the prompt "Tell me what you did yesterday/today" (CAPE-V, 2006).

Measurement Procedures

After data collection was complete, the audio recordings were converted into oscillogram audio file tracks using the KayPentax Multidimensional Voice Program™ (MDVP) software. All three repetitions of /ʌ/ and /hʌ/ for each participant were converted into an oscillogram for analysis. The first .05 seconds of each repetition was deleted to ensure consistency of the task. By deleting the first .05 seconds, it reduced the effect of instability of a new task (Bassich-Zeren, 2004; Ptacek et al., 1966; Verdolini & Palmer, 1997). The following 5 seconds were then used for analysis of rate and consistency. The greatest number of amplitude peaks recorded in a five-second period was identified and measured for consistency. Consistency was measured using a ratio of voiced segment to the total of voiced and the voiceless segments of the acoustic signal. Voiced segments were measured placing one cursor at the onset of the phonatory pulse of one peak, and placing the second cursor at the end of the phonatory pulse. The time was then recorded in milliseconds. Voiceless segments were measured by recording the time between phonatory pulses, with one cursor at the end of a phonatory pulse and the second cursor at the onset of the next phonatory pulse. The total of voiced and voiceless segments was a sum of the two segments. The ratio of voiced segment to total segment was calculated by dividing the total by the voiced segments. The variance of voiced ratio was calculated using IBM® SPSS® Statistics Data Editor software (SPSS Statistics Data Editor, 2010). Decreased levels of variance indicate low variability, and therefore increased consistency.

Ethical Use of Data

All data collected were only used for the purpose of this study and the larger study from which it is drawn. All participants were given a file number, and no identifying information was included in the recordings or data collection paperwork. Paperwork that did contain identifying information was stored in a locked office and only made available to the investigator of this study and the larger study. Upon completion of the larger study, all data and recordings with identifying information will be destroyed.

Statistical Analysis

Statistical analyses were completed using IBM® SPSS® Statistics Data Editor software (SPSS Statistics Data Editor, 2010) to obtain answers to the three research questions posed: 1) Is there a difference between laryngeal diadochokinetic consistency of production for the adductory task /ʌ/ and the abductory task /hʌ/ in young adults between the ages of 20 and 40 years; 2) What are the normative values for laryngeal diadochokinetic consistency of production for the adductory task /ʌ/ and the abductory task /hʌ/ in young adults between the ages of 20 and 40 years; and 3) Is there a difference between normative values of laryngeal diadochokinetic consistency of production for male and female participants?

To address the first question of whether there is a difference between laryngeal diadochokinetic consistency of production for the adductory task /ʌ/ and the abductory task /hʌ/ in young adults, consistency of production data for the two L-DDK tasks were compared using a mixed- between-within subjects analysis of variance (ANOVA; Haynes & Johnson, 2009). Interaction effect, main effect, and between-subjects effect were analyzed and reported as Wilks' Λ (Lambda) values with a probability level of p=0.05. These effects were analyzed to determine if ANOVA results were influenced by other independent variables, such as chance or sex (Haynes & Johnson, 2009). This analysis was performed to determine if the two L-DDK tasks /ʌ/ and /hʌ/ (i.e. the two independent groups), differed significantly on the consistency of production (i.e. the dependent variable) (Haynes & Johnson, 2009).

To address the second question of what are the normative values for /ʌ/ and /hʌ/, summary statistical values of mean, range, and standard deviation were determined for each L-DDK task. The independent groups were the two tasks, sex, and variance, while the dependent variables were the summary values (Haynes & Johnson, 2009).

To address the third question of the effect of sex on L-DDK tasks, /ʌ/ and /hʌ/ were analyzed using a mixed-between-within subjects ANOVA. The independent groups were the male and female participants, and the dependent variables were the normative values. This analysis determined if the male and female participants differed significantly in their normative values.

CHAPTER IV

RESULTS

In order to address, “Is there a difference between laryngeal diadochokinetic production consistency for the adductory task /ʌ/ and the abductory task /hʌ/ in young adults between the ages of 20 and 40 years?” the data from both male and female participants were combined, and an independent sample t-test was performed to compare task differences. Results indicated that a difference in variance was not found between /ʌ/ and /hʌ/ (t-statistic = 0.362, p-value = 0.719>0.05). Because the p-value is greater than 0.05, there is no difference in variance. See Table 1 for descriptive data from L-DDK tasks. Results of the independent sample t-test are summarized in Table 2.

Table 1

L-DDK Tasks

Consistency Variable	Task	N	Mean	Std. Deviation	Std. Error Mean
Variance	/ʌ/	42	0.0069	0.004	0.001
	/hʌ/	42	0.0066	0.004	0.001

Table 2

Independent Sample t-test for Task Comparisons

Variance	t-test for Equality of Means						
	t	*df*	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Equal Variances Assumed	.362	82	.719	0.002	0.0003	-.002	0.002
Equal Variances Not Assumed	.362	81.953	.719	0.002	0.0003	-.002	0.002

In order to address the second question, “What are the normative values for laryngeal diadochokinetic consistency of production for the adductory task /ʌ/ and the abductory task /hʌ/ in young adults between the ages of 20 and 40 years” normative values were calculated. The normative value for male participants regarding consistency of /ʌ/ productions was M = 0.0061 (range = 0.002-0.016; SD = 0.005). For male participants, the normative value for consistency of /hʌ/ productions was M = 0.0057 (range = 0.001-0.014; SD = 0.004). For female participants, the normative value for consistency of /ʌ/ productions was M = 0.0073 (range = 0.002-0.016; SD = 0.004). For female participants, the normative value for consistency of /hʌ/ productions was M = 0.0070 (range = 0.0008-0.019; SD = 0.005). Results are summarized in Table 3, *Descriptive Statistics for Consistency of -LDDK Production Tasks.*

Table 3

Descriptive Statistics for Consistency of L-DDK Production Tasks

Consistency Variable	Task	Sex	N	Minimum	Maximum	Mean (M)	Standard Deviation (SD)
Variance	/ʌ/	Male	13	0.002	0.016	0.0061	0.004
		Female	29	0.002	0.016	0.0073	0.004
	Total		42	0.002	0.016	0.0069	0.004
	/hʌ/	Male	14	0.001	0.014	0.0057	0.004
		Female	28	0.0008	0.019	0.0070	0.004
	Total		42	0.0008	0.019	0.0066	0.004

In order to address the third question, “Is there a difference between normative values of L-DDK consistency of production for male and female participants?” the dataset from both tasks were combined, and an independent sample t-test was performed to compare sex differences. Results indicated that there is no difference in variance, or consistency of L-DDK productions, between males and females (t-statistic = 1.261; p-value = 0.211>0.05). Because the p-value is greater than 0.05, there is no difference in variance between sexes. See Table 4 for the sex differences dataset. Results of the independent sample t-test for tasks male and female participants are summarized in Table 5.

Table 4

Sex Differences

Consistency Variable	Sex	N	Mean	Std. Deviation	Std. Error Mean
Variance	Male	27	0.0059	0.004	0.0008
	Female	57	0.0072	0.004	0.0006

Table 5

Independent Sample t-test for Sex Differences

Variance	t-test for Equality of Means						
	t	*df*	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Equal Variances Assumed	1.261	82	0.211	0.001	0.001	-0.0007	0.003
Equal Variances Not Assumed	1.274	52.450	0.208	0.001	0.001	-0.0007	0.003

Overall, the results from this study revealed no statistical difference between laryngeal diadochokinetic consistency of production for the adductory task /ʌ/ and the abductory task /hʌ/ in young adults between the ages of 20 and 40 years. Normative values were collected and identified for laryngeal diadochokinetic consistency of production for the adductory task /ʌ/ and the abductory task /hʌ/ in young adults between the ages of 20 and 40 years. Lastly, no statistically significant differences were found in consistency of L-DDK productions between male and female participants.

CHAPTER V

DISCUSSION

Previous literature regarding laryngeal diadochokinesis has been conducted using inconsistent protocols, small sample sizes, and shifting measurement techniques. Although it is known that L-DDK would be ideal in a clinical setting due to its readily available protocol, inexpensive, and noninvasive nature, clinicians are currently unable to use this diagnostic tool. The lack in literature and normative data keep clinicians from using this easy and quick assessment tool because they have nothing to which to compare the results. In order to highlight that L-DDK could be a useful tool to assess both normal and disordered populations, this current study addressed the following questions: (a) Is there a difference between laryngeal diadochokinetic production consistency for the adductory task /ʌ/ and the abductory /hʌ/ in the young adult population between the ages of 20 to 40 years?; (b) What are the normative values for laryngeal diadochokinetic consistency of production for the adductory task /ʌ/ and the abductory task /hʌ/ in the young adult population between the ages of 20 and 40 years?; (c) Is there a difference between normative values of laryngeal diadochokinetic consistency of production for male and female participants?

The results of this study revealed that no statistical significant difference was found in consistency of production between the two tasks /ʌ/ and /hʌ/ in the normal population. These results suggest that fine neuromotor control of the abductory and adductory laryngeal muscles is stable and functioning well in the young adult population (ages 20-40). According to the review of laryngeal anatomy, this is the stage of life when the larynx is at its best, so this data is representative of this concept. Although the results of this study suggest no statistical difference, it is important to continue to collect normative data on L-DDK consistency. The current sample size is fairly small and includes more female participants than male participants; so further research would be beneficial.

Normative values of L-DDK were collected for male and female participants in the young adult population for each task /ʌ/ and /hʌ/, and then combined. The normative values were calculated for variance and include minimum, maximum, mean, and standard deviation. Previous studies showed inconsistencies in the method of collection of the two tasks. Some studies only collected data on /ʌ/ and some studies only collected data on /hʌ/. By examining both tasks, it increases the validity of the L-DDK data collected in the current study. Another way that this study strengthened the validity of L-DDK data was by measuring the L-DDK tasks objectively. Previous literature has shown that most researchers measure the tasks perceptually. While this method of measurement is quick and used in clinical settings, objective measures allow the tasks to be examined in a more specific manner. Because there are such substantial gaps in literature regarding consistency of L-DDK tasks in the young adult population, this study helped bridge some of those.

Lastly, this study addressed the difference between normative values of laryngeal diadochokinetic consistency of production for male and female participants. The results from the analyses indicated that there were no significant differences between the sexes. As previously stated in the review of laryngeal anatomy, males and females have structural differences. These results are slightly unforeseen due to the vocal differences between the sexes. However, this result may suggest that L-DDK tasks are more representative of neuromotor control, rather than anatomy. This current study had a fairly small sample size, with an uneven ratio of males to females. To gain more insight into the normative values of consistency of production between sexes, more research is needed with a larger sample size, with an even male to female ratio.

CHAPTER VI

LIMITATIONS

Before L-DDK can be used as a quick and noninvasive assessment tool, adequate normative data must be established. Without normative data, there would be nothing to which to compare results. Although this current study provided fundamental normative data for the young adult population, there were some limitations to consider. A major limitation, that has been previously mentioned, is the small sample size. The sample size for the current study was only 42 participants. Of the 42 participants, 29 were females and 13 were males. With a sample size of 42, it is difficult to generalize this study to the entire young adult population. A larger sample size would better represent this population, and improve the confidence in the findings.

Not only was the sample size small, the sample lacked participant diversity. Because the investigator recruited the participants from home, school, and work, the participants do not represent the entire young adult population well. A sample with further participant diversity would be more representative of the population, and make the results easier to generalize.

In addition to the sample size and diversity limitations, this current study only examined the L-DDK measurement of consistency. According to previous research, measuring rate, consistency, and strength provide the most information regarding vocal fold function (Verdolini & Palmer, 1997). Normative data needs to be gathered on all three L-DDK measurements to ensure that it is a valid and reliable diagnostic clinical tool.

CHAPTER VII

IMPLICATIONS

This current study provides fundamental normative data for the L-DDK measurement of consistency. In order for these tasks to be used as a diagnostic tool, future studies should address: (a) increasing the sample size with equal male and female group sizes; (b) targeting additional age groups; (c) increasing participant diversity; and (d) continuing to measure consistency as well as strength and rate of L-DDK. Because L-DDK is quick, noninvasive, and readily available it has potential to be a favorable assessment tool. It may also help in the detection of a neurological disease in its early stages because of the effects it may have on the larynx. The development of normative data will continue to highlight and strengthen the usefulness of L-DDK as a clinical diagnostic tool.

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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' 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).

APPENDIX B

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**