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Laryngeal Diadochokinetic Strength in the Young Adult Population

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LARYNGEAL DIADOCHOKINETIC STRENGTH IN THE YOUNG ADULT POPULATION

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Laryngeal Diadochokinesis (L-DDK) is widely used by speech-language pathologists as a method of assessing laryngeal function during evaluations. Although this method has proven to be a beneficial screening approach, a lack of normative data weakens the use of L-DDK as a clinical tool. This study aims to strengthen research on L-DDK by providing normative data on L-DDK strength measurements in the young adult population (age 20-39 years old). These measurements were collected from 99 participants (55 females and 44 males). Participants were instructed to complete two L-DDK tasks, the rapid repetition of /ʌ/ and /hʌ/, for seven seconds each across three trials. The strength of production of both L-DDK tasks was analyzed. Normative data including minimum and maximum L-DDK strength values, mean, and standard deviation were calculated. The results indicated a statistically significant difference in productions of /ʌ/ and /hʌ/. However, there was no significant difference between males and females.

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CHAPTER I

REVIEW OF LITERATURE

Speech-language pathologists currently do not have a variety of options for objective assessment of the speech mechanism, including the systems and structures that are required for speaking. Oral diadochokinesis (DDK) and laryngeal diadochokinesis (L-DDK) are two tasks currently used in clinical settings. Oral diadochokinesis is a commonly used method for evaluating the motor control of the articulators. While there is a considerable amount of research on oral diadochokinesis and the development of the tasks, less research is available on laryngeal diadochokinesis (Fletcher, 1972).

L-DDK tasks aim to examine the rapid movement and coordination of the vocal folds instead of the articulators as in oral DDK. L-DDK tasks involve the repetition of glottal plosives, including /ʌ/ and /hʌ/. The speech-language pathologist then calculates the rate of adduction and abduction of the vocal folds. Rate is calculated by dividing the total number of repetitions by the amount of time allotted to complete the task, which is typically seven seconds. L-DDK tasks are equally as important as oral DDK during an evaluation because the rate, strength, and consistency of vocal fold adduction and abduction are indicators of normal laryngeal functioning. Examining laryngeal function using L-DDK tasks as a screening tool could potentially identify the presence of neurological disorders due to the nature of innervation in the larynx. Normative data is required in order to provide professionals with reliable data in order to compare an individual with a possible laryngeal abnormality to a normal individual without an abnormality.

The continuation of this chapter will concentrate on past literature and analyze the following topics: oral DDK, L-DDK, alternative tests of laryngeal function, neuromotor control of the larynx, the effects of natural aging of the larynx on laryngeal strength, degenerative diseases and the impact they have on laryngeal function, and the clinical implications of L-DDK measurements. The preceding list of topics is crucial to acknowledge when developing normative data for L-DDK assessment. Such normative data increases the reliability of using L-DDK as a diagnostic tool for identifying and assessing deficits in the laryngeal system.

Diadochokinesis

Diadochokinesis tasks are frequently included as a component of an oral-mechanism examination during a speech and language evaluation to assess motor function and coordination of the speech mechanism. Oral DDK and L-DDK are both noninvasive and efficient assessment procedures. The use of both measures has proven to be an indicator of the integrity of the systems used for speech. Therefore, it is necessary to discuss the tasks and the factors that influence their measurement in order to have a better understanding of how they may be used clinically and the limitations that exist.

Oral Diadochokinesis

Oral diadochokinesis (DDK) is often used by speech-language pathologists as part of the initial evaluation of a client to screen for appropriate motor control including coordination and regularity of movement of the articulators. This task involves the rapid repetition of syllables, particularly /pʌ/, /tʌ/, /kʌ/, and the alternation of /pʌtʌkʌ/. The data are then analyzed perceptually by the speech-language pathologist to calculate rate of repetition (Ruscello et al., 1982, Fletcher, 1972). Fletcher (1972) described two procedures for assessing rate of oral DDK activities: count-by-time and time-by-count. The count-by-time technique requires clinicians to count the syllables produced during the activity, and divide the total number by the amount of time used for the activity. This technique is commonly used by clinicians; however, it divides their attention between tracking the time and tallying syllables produced. The time-by-count approach decreases the demand on the clinician by having the client produce a predetermined number of syllables. The only task for the clinician is to start and stop a stopwatch to determine the rate of production.

St. Louis, Grofic, Ford, and Ruscello (1981) conducted a study using oral DDK as a portion of an oral speech mechanism examination. Participants included two groups of children, ages 4-6 and 7-9, with an articulation deficit and a control group of children with typically developing articulation. The children completed an oral speech mechanism screening as well as a subtest of the Goldman-Fristoe Test of Articulation to confirm the presence or absence of an articulation disorder. The oral DDK tasks included a time-by-count approach where participants were timed to see the amount of time required to produce a predetermined number of syllables of /pʌ/, /tʌ/, /kʌ/, and /pʌtʌkʌ/.

The results of the study concluded the children with a confirmed articulation disorder were slower in producing monosyllables and trisyllables than the participants without an articulation disorder. In addition, oral DDK productions were less rhythmic for this group than the group with typical articulation. While the study did not report a statistical significance of these differences noted, the results provide support for the diagnostic capability of oral DDK (St. Louis et al., 1981).

In addition to rate and consistency, strength is another measurement of oral DDK tasks. Perceptually, strength refers to the force or loudness of a syllable production. Acoustically, strength refers to the amplitude of the glottal peaks on a waveform. Similar to rate and consistency, strength of DDK is compared across populations to identify the possibility of a neurological impairment. The patient may experience weakness in articulatory movement as a result of the disorder, which alters the strength of oral DDK performance. Therefore, weakness in the production of oral DDK tasks can be an indicator of a disordered speech mechanism. Langmore and Lehman (1994) completed a study which analyzed the strength of oral DDK in individuals with amyotrophic lateral sclerosis (ALS) and an associated dysarthria. Weak articulatory movements and decreased speech intelligibility are known factors found in patients with ALS. The study was designed in order to evaluate the physiological deficits found in the participants and the relation of these deficits to the severity of the disease. Participants included fourteen males who were diagnosed with ALS and fifteen males without ALS or any other degenerative disease. The participants with ALS were divided into three groups based on characteristics of their disease. Participants completed speech tasks including the rapid repetition of /pʌ/ and /tʌ/ and the strength and rate of productions were evaluated. Inter-rater reliability on perceptual tasks was calculated to be moderately high (67-99%). The results of the oral DDK tasks were compared between the groups with ALS and the control group without a neurological disorder.

Langmore and Lehman (1994) concluded that the oral DDK tasks indicated a decrease in strength and rate of production across all participants with ALS, regardless of what group they were in. When comparing the strength of lip, tongue, and jaw movement during the tasks, tongue strength was most significantly reduced. The results are an indicator that changes in strength and rate of oral DDK are reflected in individuals with this neurological disease. This indication is significant for considering the use of oral DDK as a diagnostic tool. However, limitations exist with using oral DDK clinically.

Gadesmann and Miller (2008) suggest that there are several limitations to using oral DDK in a clinical setting. Reliability is often weak because there is not a single technique for collecting DDK data that all clinicians use. In their study on inter-rater and intra-rater reliability, Gadesmann and Miller (2008) found that reliability of DDK data collection was low between raters. Participants of this study included two different groups: ten experienced speech language pathologists and ten non-professionals with no experience as a speech-language pathologist. The group of non-professionals acted as a control group for the study and allowed the researchers to further analyze the impact of experience on collecting DDK data. Participants listened to twelve recorded DDK speech samples and rated them according to six different features. These features included rate of repetition for the first 5 seconds, rate of repetition of the whole sample, regularity of rhythm, distinctness, and loudness. The final feature was a rating of overall impression. The overall impression was measured on a 5-point interval scale, where "1=

normal/equal throughout and 5= severely impaired/irregular throughout" (Gadesmann & Miller, 2008, p. 45).

Intraclass correlation coefficients (ICCs) were calculated to establish interrater reliability and revealed ICCs were below .70, the value considered acceptable clinically for reliability values. Intra-rater reliability measures revealed only 11 out of 40 total results had a significant correlation. Therefore, participants were not capable of being consistent in their own ratings of the sample. The study concluded that reliability was poor. This study indicates a need for further research in improving DDK as a clinical tool. By improving the measure, speech-language pathologists can learn to administer and score it more consistently and reliably. It is important to consider these limitations of oral DDK because they can be connected to L-DDK tasks as well. Oral DDK and L-DDK are often used within the same evaluation in order to obtain a comprehensive assessment of the entire speech mechanism. In addition, low reliability of measurement of oral DDK may predict similar low reliability of L-DDK tasks.

Laryngeal Diadochokinesis

As mentioned previously, L-DDK tasks are used to examine the coordination and movement of the vocal folds during phonatory tasks. A person's performance on L-DDK tasks provides evidence for their laryngeal functioning similar to the way that their performance on oral DDK tasks provides evidence for the function of their articulators. Specifically, L-DDK measures how the vocal folds are adducting and abducting. There are three important parameters associated with L-DDK: (a) rate, (b) strength and (c) consistency (or steadiness) of the productions over time. Rate, strength, and consistency are important because, used together, they increase the predictive validity of L-DDK. Changes in these three components alert the clinician to possible disruption in laryngeal functioning. For example, one aspect of L-DDK task performance is the indication of arytenoid closure. If an individual does not have complete closure of the vocal folds due to the presence of an organic pathology, it is presumed that they will have a weak L-DDK performance (Tomblin et al., 2000). Even though strength of L-DDK has the potential to provide this valuable diagnostic information, there is little research that provides information or normative data on strength of L-DDK.

One study that incorporated strength of L-DDK was completed by Leeper and Jones (1991), who examined the rate of abduction and adduction of the vocal folds and the amount of air pressure passing through the vocal folds during speech production. Participants of this study included eighteen females from the ages of 20 to 25 years old with no history of respiratory, neurological, or hearing issues. L-DDK tasks included the rapid repetition of /ʌ/ for five seconds across nine different frequency-intensity combinations. Three different frequencies and three different intensities were used to create the frequency-intensity combinations. The authors used a facemask-pneumotachograph system to calculate the transglottal airflow during phonation (Leeper & Jones, 1991).

The results of the study indicated that intensity was the controlling factor in L-DDK rate and airflow regulation traveling through the glottis. When intensity varied during the tasks, there was a significant difference in airflow rate through the vocal folds. The higher the intensity of the signal, the more air there was flowing through the vocal folds and the stronger the production. While this study provides a different insight to laryngeal functioning and offers normative data for clinical use, the small sample size is a major limitation to the study. In addition, participants were selected from a narrow range of ages (20-25 years old) and included only females. This limits the external validity of the study and limits to whom the results can be applied. The results may indicate that L-DDK has an important use as an assessment tool to measure laryngeal integrity by providing normative data. However, replication of this study will be difficult to complete in a typical clinical setting. While the use of objective measurement of L-DDK strengthens the study and the normative data it provides, most professionals do not have immediate access to the equipment included in the procedures of this study. The limitations discussed above support the need for further research that provides normative data which applies to a large and diverse population. Other studies on L-DDK have similar limitations.

Another study which examined strength in L-DDK production, aimed to use the measure as a component of a voice screening to identify the potential presence of an organic pathology. Verdolini and Palmer (1997) used L-DDK strength to reflect the integrity of arytenoid closure. A total of forty-five participants were assigned into groups depending on their diagnosis: (a) structural abnormalities, (b) dynamic abnormalities, and (c) normal larynx as a control group. Researchers examined rate, strength, and rhythm of L-DDK tasks across all participants. An analysis of an S:Z ratio was also included in the study to detect "vocal fold closure characteristics" (Verdolini & Palmer, 1997, p. 219). The L-DDK procedure included the rapid repetition of /ʌ/ for seven seconds. Researchers based the strength of L-DDK on perceptual ratings of “good” and “poor” assigned to each participant at the time of testing.

The authors tested the predictive nature of L-DDK strength by first predicting which rating each diagnostic category would receive prior to the initiation of the study. They predicted that participants in the dynamic abnormalities group would receive a perceptual rating of “poor” following strength L-DDK testing. The rest of the diagnostic groups (structural abnormalities and nonorganic conditions) would receive a strength rating of “good” following testing. These predictions were made based on the nature of the diseases associated with the dynamic abnormalities group. This group consisted of disorders such as Parkinson’s disease and abducted vocal fold paralysis. Such diseases are known to affect the phonatory system. The authors suggested “hypometria related to acceleration phenomena or rigidity” may cause adduction strength to decline in participants with Parkinson’s disease (Verdolini & Palmer, 1997, p. 220). Another suggestion was vocal fold bowing, which could cause a decline in adduction strength in participants with Parkinson’s disease. Participants completed the L-DDK tasks, and researchers assigned a perceptual rating to strength of L-DDK. Researchers were blind to participants’ diagnoses and the hypothesis to reduce bias interfering with the integrity of the results (Verdolini & Palmer, 1997).

The results reflected the predictions made by the authors prior to the start of the study. Participants with Parkinson’s disease and abducted vocal fold paralysis, who were predicted to have “bad” L-DDK strength prior to the study, had decreased

L-DDK strength during completion of the tasks. The laryngeal pathologies found in this group resulted in decreased perceptual strength of phonation during L-DDK tasks. However, the general "good" vs. "poor" perceptual rating does not provide professionals with the normative data that can be applied to clinical practice (Verdolini & Palmer, 1997).

The studies by Leeper and Jones (1991) and Verdolini and Palmer (1997) emphasize the use of strength of L-DDK by speech-language pathologists. However, normative data is seriously lacking. Verdolini and Palmer do not provide normative data as a result of their study. While Leeper and Jones do provide normative data of L-DDK, the sample size limits the opportunity to use this information further as a diagnostic tool. Further research is necessary to fill the gaps in normative data and include a wide range of ages and both sexes.

Additional Tests of Laryngeal Function

In addition to L-DDK, there are other tests of laryngeal functioning that are popularly used within a clinical setting. These tests include endoscopy, electromyography (EMG), and electroglottography (EGG). Stemple, Glaze, and Klaben (2000) identified possible limitations with using these measurements. Such limitations include the complexity of using the method, the limited normative data associated with their use, and the possible equipment error that could potentially influence clinical interpretations. These limitations suggest the benefit of having an alternative test of laryngeal function, such as L-DDK, as an option. The remainder of this section will discuss endoscopy, EMG, and EGG.

Endoscopy

Endoscopy is one type of laryngeal imaging which allows professionals to observe the structure and function of the larynx. This method is one of the most common methods used to assess voice disorders in the field of speech-language pathology (Mehta & Hillman, 2013). Endoscopy provides professionals with an image of the appearance and movement of the vocal folds and possible disturbances which affect vocal production (Stemple, Glaze, & Klaben, 2000). In order to view the vocal folds, two different scopes are used during this procedure: flexible and rigid scopes. Deciding which type of scope to use depends on the purpose of the examination and what structures need to be viewed (Stemple et al., 2000).

A flexible endoscope allows a professional to observe the integrity of the velopharynx, vocal tract, and the larynx. A flexible tube with a smaller diameter is inserted into the nasal cavity, so this procedure may also be referred to as nasendoscopy. The camera located on the end of the scope relays the image to a monitor for the professional to view. The benefit of using nasendoscopy is the patient is able to phonate in a more natural way than when the camera is presented orally. This type of test is beneficial from a diagnostic standpoint because the professional can observe the patient's vocal mechanism while he/she is performing speech tasks. It is also beneficial from a treatment standpoint because the patient can respond to the directions and guidance given by the professional to improve vocal performance. The patient and clinician can also use the monitor as a "biofeedback" tool to make specific adjustments (Stemple et al., 2000, p. 222).

While these advantages make flexible endoscopy a common diagnostic tool, there are disadvantage to this technique. This is a more invasive procedure than using the rigid endoscope. In addition, it is "difficult to achieve a stable image" using a flexible scope because it is very sensitive to movement and position changes of the larynx during conversation and swallows (Stemple et al., 2000, p. 227). Another disadvantage is the images on the monitor are darker because of the small diameter of the camera (Stemple et al., 2000). While a small diameter is beneficial for placement through the nasal cavity, it decreases the clarity of the image. While these disadvantages can hinder the purpose of using an endoscope, flexible endoscopy is still a popular method of instrumentation.

The other type of scope used during endoscopy is a rigid endoscope. Rigid endoscopy allows for observation of the larynx and vocal folds. This procedure involves inserting the scope in the oral cavity to view the vocal folds. The scope is larger in diameter, so the image is brighter and often more stable than in a flexible endoscope. It is often considered more advantageous to use when a close up image of the vocal folds is desired. This close up image also allows for an analysis of the vibratory pattern of the vocal folds (Stemple et al., 2000).

While these advantages make rigid endoscopy an acceptable tool, there are still disadvantages to its use. It may be less invasive than flexible endoscopy, but anesthesia is sometimes used with patients who have a hypersensitive gag reflex. This may cause great discomfort and prevent the procedure from occurring. In addition, the patient is unable to speak at a conversational level and is reduced to simple sustained phonation of /i/ vowel productions. This does not allow for much biofeedback as in flexible endoscopy. These disadvantages may limit the use of rigid endoscopy in certain cases, but it is used frequently.

Both flexible and rigid endoscopy are commonly used techniques to provide laryngeal imaging for diagnostic and therapeutic purposes. Endoscopy procedures are within the scope of practice of a speech-language pathologist; however it requires much knowledge, preparation, and competency to use the endoscope independently (Stemple et al., 2000). In addition, endoscopy is strictly a perceptual procedure which relies on the judgement of the clinician to reach a conclusion about the findings of the evaluation. The perceptual aspect of endoscopy may lead to variability across clinicians. Finally, the clinician must have access to the equipment and completion of the evaluation depends on the location of the equipment. An inexpensive, easily accessible measurement would be most beneficial.

Electromyography (EMG)

Electromyography (EMG) is a technique that "records the electrical activity in muscle" (Tomblin et al., 2000, p. 261). This is a highly invasive procedure and therefore must be performed by a neurologist or otolaryngologist. There are two common types of EMG: surface EMG and deep EMG. In surface EMG, electrodes are placed on the surface of the skin to gather measurement of the muscle activity below the placement of the electrodes (Tomblin et al., 2000). For a more direct measurement, professionals may use deep EMG. In order to directly measure the muscle activity in the larynx, a needle is inserted into the muscles of the larynx (Stemple, et al., 2000). Once it is established that the needle is correctly placed, the recordings reveal onset, timing, and amplitude of the muscle activity. More importantly, these measurements can be used to determine abnormalities in laryngeal muscle function (Stemple et al., 2000). For example, deep EMG can identify the presence of paralysis of the laryngeal muscles (Tomblin et al., 2000). The technique is very beneficial for providing specific information about the strength of muscle function in the larynx which can lead to an appropriate diagnosis and treatment approach.

While this is an objective measurement of laryngeal activity, there are many disadvantages to this technique. First, it is highly invasive and there are risks associated with this procedure. These risks stem from the fact that the professional is going in "blind" as they place the electrodes in the laryngeal muscle. A speech-language pathologist must collaborate with an otolaryngologist and neurologist to complete this procedure. Since this is an invasive procedure, speech-language pathologists cannot place the electrodes themselves (Stemple et al., 2000). Therefore, it is not feasible for use as a clinical measure. This emphasizes the need for a measurement which is noninvasive and easily accessible for the clinician.

Electroglottography (EGG)

Electroglottography is another example of instrumentation that is used to observe laryngeal functioning. Unlike EMG, this is a noninvasive method that uses an electrical current to measure vocal fold contact (Stemple et al., 2000). Stemple, Glaze, and Klaben (2000) describe the procedure as placing two electrodes "on either side of the thyroid alae, with a small electrical current passing through as the vocal folds vibrate (p. 235). Results of the EGG display a waveform of the vocal fold vibratory patterns. Each peak and trough of the waveform represents an open or closed phase of the vocal folds. As the vocal folds open, resistance increases. As the vocal folds close, resistance decreases. EGG is a beneficial method because the waveform displays the vibratory pattern of the vocal fold during phonation.

Along with the benefits of using EGG, there are negative aspects to using this method. Similar to the other instrumentation previously mentioned, expensive equipment is required to complete EGG. In addition, errors in measuring EGG can occur due to tissue thickness, incorrect electrode placement, mucous interference, and other laryngeal movement (Stemple et al., 2000). These factors can easily influence the instrument's reading of the vocal fold adduction and abduction measurement and decrease the reliability of the results.

While these additional tests (endoscopy, EMG, and EGG) provide many benefits of observing laryngeal functioning, they each have their own limitations. Most of the equipment is expensive and not easily accessible in a clinical setting. Some are invasive and have risks associated with the technique. L-DDK offers a noninvasive way to test the integrity of the larynx, without depending on other professionals or expensive equipment that is not readily available. The clinician can perform the L-DDK tasks at any time and any location. L-DDK also has the potential to provide us with an indication of vocal fold abnormalities. Obtaining normative data is the next step to make L-DDK an applicable diagnostic measurement.

Anatomy and Innervation of the Larynx

In order to have a better understanding of how L-DDK measures apply to clinical settings, it is important to understand the anatomy and innervation of the laryngeal system. Given its location between the pharynx and the trachea, the larynx is a highly important component of phonation, respiration, and swallowing (Rubin et al., 2014). The structure of the larynx is composed of primarily cartilage, muscle, and mucous membranes. The framework of the larynx includes the largest cartilage, the thyroid cartilage. The thyroid cartilage connects to the cricoid ring through the cricothyroid joint, forming the base of the larynx. Connected to the cricoid ring are the paired cartilages: the arytenoid, corniculate, and cuneiform cartilages. The cricoid ring and arytenoid cartilages are connected by an important joint, the cricoarytenoid joint. The cricoarytenoid joint provides an important rocking motion anteriorly, posteriorly, and laterally. Since the vocal folds attach posteriorly to the arytenoids, the rocking motion of the cricoarytenoid joint helps the vocal folds to adduct and abduct (Stemple et al., 2000).

Muscles are another important component of the structure of the larynx. Extrinsic and intrinsic muscles are vital for the gross and fine motor movement of the larynx. The intrinsic muscles in particular work to modify the cricoarytenoid and cricothyroid joints previously mentioned by attaching to the cartilage. This modification of the joints is particularly important for the abduction and adduction of the vocal folds (Stemple et al., 2000). There is only one intrinsic muscle that is responsible for the abduction of the vocal folds, the posterior cricoarytenoid. The remaining intrinsic muscles play a role in the adduction of the vocal folds.

This complex combination of cartilage and muscles support the main functions of the larynx: (a) phonation, (b) respiration, and (c) swallowing. Stemple, Glaze, and Klaben (2000) describe this system of muscles and cartilages as three levels of "folds." The upper folds of the larynx, the aryepiglottic folds, are strong membranes that act as protection of the trachea by separating the pharynx from the larynx. The second pair of folds, the ventricular folds, is not often used during phonation. However, they may be used during effortful speech. In addition, the ventricular folds add additional protection to the trachea during swallowing and provide an increase in subglottic pressure during physical tasks (Stemple et al., 2000). Stemple et al. (2000) state the final layer of folds is the vocal folds. The vocal folds are crucial during phonation and close the airway off to prevent food from entering the lungs when swallowing. The system of folds described by Stemple et al. (2000) would not be possible without the neuromotor control of the larynx.

The cranial nerve which innervates the larynx is cranial nerve X, the vagus nerve. The vagus nerve serves the motor and sensory information to the larynx through two branches: the recurrent and superior laryngeal nerves (Stemple et al., 2000). The recurrent laryngeal nerve (RLN) innervates the intrinsic muscles that are important for adducting and abducting of the vocal folds, with the exception of the cricothyroid muscle. This specific innervation is crucial for sound production. In addition, the RLN provides sensory information below the vocal folds which includes the glottis, trachea, and esophagus (Chitkara, 2006). The superior laryngeal nerve (SLN) is responsible for providing sensory information to the larynx. In addition, it does supply motor information to the cricothyroid muscle, an intrinsic muscle that is responsible for changing pitch (Chitkara, 2006).

Stemple et al. (2000) reported characteristics of the RLN and SLN which allow the fine motor control that is necessary for the movement of the intrinsic laryngeal muscles during phonation. The first characteristic is “the nerves have a high conduction velocity" (Stemple et al., 2000, p. 49). The high conduction velocity of the nerves allows for quick contraction. Another characteristic of innervation is "the innervation ratio is low" (Stemple et al., 2000, p. 49). This indicates that one motor unit has the ability to innervate many cells and allows for the fine motor control required by the larynx (Stemple et al., 2000).

The structure and innervation of the larynx is important to consider when developing a diagnostic evaluation to distinguish between a typical and a disordered phonatory system. Verdolini and Palmer (1997) used knowledge about the anatomy and innervation of the larynx to make predictions about the integrity of the phonatory system of each participant. Since the RLN supplies the muscles of adduction and abduction, deficits with RLN involvement would disrupt vocal fold closure. Using a diagnostic tool which measures the control of adduction/abduction would likely indicate the presence or absence of a laryngeal deficit. As discussed in a previous section, the results of the study matched their predictions based on vocal fold closure (Verdolini & Palmer, 1997).

Neurological Diseases Affecting Laryngeal Function

Examining laryngeal function could be particularly sensitive to identifying neurological disorders. For example, it is possible that the early signs of Parkinson's disease and amyotrophic lateral sclerosis could be revealed through changes in laryngeal function. Such neurological diseases cause change in the strength of laryngeal functioning due to interruptions in the coordination and execution of motor movement (Carmichael, 2005). Several studies provide evidence that patients with neurological disorders performed more poorly on L-DDK tasks compared to individuals without a neurological disorder (Bassich-Zeren, 2004).

Parkinson's Disease

Parkinson's disease is a degenerative disease which causes a lack of coordination and strength in the movement of the vocal folds due to a disruption in the neural pathways responsible for controlling laryngeal movement. The perceptual voice quality of an individual with Parkinson's disease is marked by slow rate, reduced loudness, and a monotone voice (Carmichael, 2005). Patients with Parkinson's disease may also experience a bowing configuration of the vocal folds, decreasing the adduction quality of the vocal folds and decreasing strength of phonation (Verdolini & Palmer, 1997). Existing studies reveal the effects of Parkinson's on laryngeal function and whether or not L-DDK tasks can accurately detect an abnormality in the larynx.

Verdolini and Palmer (1997) completed a study which investigated the use of L-DDK tasks as a screener for voice disorders. Researchers in this study, mentioned in a previous section, collected rate, strength, and rhythm of L-DDK tasks across all participants. S:Z ratio analysis was also included in the study to examine the characteristics of vocal fold closure. A total of 45 participants were included in this study. Participants were divided into three groups based on their diagnosis: (a) those having structural abnormalities, (b) dynamic abnormalities, or (c) normal laryngeal functioning. Eleven participants were classified with a structural abnormality, which included nodules and granulomas found on the vocal folds. Fourteen participants were classified with a dynamic abnormality, with included paralysis of the vocal folds and Parkinson's disease. Twenty participants were diagnosed with a normal larynx, which included functional voice disorders and individuals who acted as a control with no abnormalities in the larynx.

The results of this study showed that when compared to other groups, participants with Parkinson's disease had a normal or better S:Z ratio, but poor results in L-DDK measures (rate, strength, and rhythm). Ninety percent of the participants with Parkinson's disease had impairment in L-DDK measures. This confirms that laryngeal function, particularly strength of laryngeal movement, is affected by Parkinson's disease. Further, the results indicate that L-DDK was sensitive enough to identify those differences in laryngeal functioning. The authors of the study also reported the number of false positives and false negatives as relatively low. The screening approach including S/Z ratio and L-DDK analysis had an 80% success rate in detecting an abnormality. Twenty percent of the participants with an actual pathology were missed by the screener and 30% were classified as "false alarms" (Verdolini & Palmer, 1997).

Despite these false alarms, there were strengths to the design of this study. One example of strength included the exclusion criteria for participation in the study. Participants who had other medical conditions not related to the conditions of interest were excluded from participating. The exclusion criteria helped to eliminate possible confounding variables from influencing the results of the study. Another strength of the study is the examiners who lead the study were blind to information about the participant. The examiner who conducted the screening was aware of the results of each test. However, the examiner was blind to the diagnosis of each participant, reducing the chance for researcher bias. The reliability of the testing was another strength of the study. "Intrajudge, interjudge, and judge-vs.-oscilloscopic stability" were assessed to evaluate the reliability of the measures (Verdolini & Palmer, 1997, p. 224). These reliability checks verified the measurement of L-DDK strength was reliable. Examiners randomly selected 12 subjects to test reliability. Agreement was reached for 12/12 subjects (100%). The results do indicate L-DDK strength is influenced by the presences of certain pathologies (Verdolini & Palmer, 1997).

While there were strengths to the design of this study, limitations exist which decrease its applicability to clinical settings. Verdolini and Palmer (1997) reported that one limitation to the study was a limited sample size. A larger sample size with a greater variety of diagnostic conditions would improve the design of this study. Another important limitation to this study is a lack of normative data for the researchers to compare their L-DDK measures. They were limited to comparing the results to each group in the study to determine what was classified as "poor" and "normal". Therefore, the researchers could only conclude that participants were considered disordered compared to the other abnormalities in the study. A broad range of normative data to compare the results of L-DDK testing to would result in more specific diagnostic information for diagnosing the patient.

Amyotrophic Lateral Sclerosis (ALS)

Similar to Parkinson's disease, amyotrophic lateral sclerosis (ALS) is a degenerative disease which impacts the speech mechanisms. The deterioration of laryngeal articulators leads to decreased speech intelligibility. The speech characteristics of an individual with ALS can include: slow rate of speech, harsh and breathy voice, and low amplitude or vocal intensity (Renout et al., 1995). L-DDK measurements are known to be abnormal in patients with ALS secondary to slow, weak laryngeal movements (Duffy, 2013). Further studies aimed to examine the effects of ALS on vocal fold movement and phonation.

One study completed by Renout et al. (1995) examined the deterioration of rate, pattern, and periodicity of L-DDK in individuals with ALS between the ages of 40 and 78. Researchers examined the changes of vocal fold adduction and abduction over time in this disordered population in order to note deterioration patterns. A total of 26 individuals with a confirmed diagnosis of ALS participated in the study. Participants were assigned to one of two groups depending on their signs and symptoms: bulbar group or nonbulbar group. Twelve patients were assigned to the bulbar group, and fourteen participants were assigned to the nonbulbar group. L-DDK tasks, rapid repetitions of /hʌ/, were completed twice during each session. Testing sessions occurred twice, for thirty minutes, over an 18-month period.

The results of the L-DDK testing indicated that both groups experienced a reduced rate and periodicity which is consistent with the degeneration of the laryngeal muscles. The rate of syllable repetition was aperiodic, and the pattern of vocal fold adduction and abduction was irregular in both groups. In addition, a variation of amplitude was found across participants. These results suggest that all participants experienced changes in laryngeal functioning that are consistent with the diagnosis of ALS (Renout, 1995). The L-DDK results reveal deterioration of the laryngeal system that is confirmed by their diagnosis of ALS. While this study was successful in providing additional evidence of the diagnostic potential of L-DDK in a neurological disorder, there were limitations that prevent clinical application. Similar to the Verdolini study mentioned above, there was no normative data available to compare participants' scores to. Without a control, it is difficult to classify whether a participant's scores are considered disordered or within normal limits. Normative data taken from L-DDK tasks from populations without a neurological disease are necessary to obtain as a comparative measure to identify the presence of a neurological disease.

Impact of Aging

Another problem that arises clinically in identifying patients with neurological disorders is that it is difficult to separate what could be an effect of a disorder on laryngeal functioning from what the effects of the natural aging process are on laryngeal functioning. Bassich-Zeren (2004) stated deviations in voicing that are found in patients with Parkinson's disease are similar to deviations caused by aging of the larynx. Stemple et al. (2000) describe a term "presbylaryngeus" which is used to describe an aging larynx (p. 48). The appearance of the vocal folds in the geriatric population are described as having a "bowed" appearance, similar to the appearance of the vocal folds in Parkinson's patients discussed previously (Stemple et al., 2000, p. 48, Verdolini & Palmer, 1997). The general findings from laryngeal imaging have concluded the vocal folds decrease "in flexibility and elasticity" as the aging process continues (Stemple et al., 2000, p. 48). A major limitation in current research is a lack of data of all age ranges from a normal population. Data from a normal population would provide the clinician with a group to compare a patient with a possible disordered system to. In addition, normative data would provide a clear understanding of what the normal effects of aging are. This information could be used clinically as a comparison to rule out or confirm a disordered speech mechanism.

The larynx is subject to multiple changes from birth to geriatrics. Through this span of time the structures of the laryngeal system and respiratory system mature and decline (Ferrand, 2012). As an infant, the larynx is positioned high in relation to the vertebrae. Prior to puberty, laryngeal cartilages are soft and flexible and the vocal folds are smaller in length. During puberty, cartilages grow and increase the overall size of the larynx and the vocal folds extend. Differentiation of the vocal ligament in separate layers continues throughout this stage. Changes in the larynx are driven by levels of hormones in the body. After puberty, the larynx is considered mature. As the individual continues to age, the structures of the larynx continue to change. This change begins between thirty and forty years old. Vocal fatigue, decrease in intensity, and muscular atrophy are a few of the symptoms that are associated with an aged larynx. The changes in structure including the ossification of cartilage, degeneration of joints, and loosened muscle fibers all contribute to the change in vocal fold adduction and abduction (Ferrand, 2012).

It is predicted that as these systems experience changes in structure and function, there will be an effect on the coordination of the vocal folds. L-DDK is sensitive to such changes in the vocal folds, so there should be a change in L-DDK measures as aging occurs over the lifespan. Differences in oral DDK rate have been examined when separating individuals according to their age. In a study designed to examine the effects of aging on speech, Ptacek et al. (1966) found that participants who were over the age of 65 years old had lower oral DDK rates compared to those who were less than 40 years old. In addition to DDK measurements, participants in the geriatric group (over 65 years old) differed significantly in pitch range, intensity, duration, pressure, and vital capacity from the young adult group. Researchers compared the results of testing from two groups of participants representing different age groups. The younger adult group (under the age of 40) included 31 subjects, while the geriatric group (over the age of 65) included 63 subjects. Each group included both males and females. Specific exclusion criteria reduced the risk of confounding variables influencing the results and included the following: (a) hearing loss greater than 35 dB, (b) asthma or respiratory infection, (c) heart disorder, (d) dysphagia, (e) neurological disorders affecting speech, (f) psychopathology, (g) structural abnormalities of the larynx (Ptacek et al., 1966).

When comparing the results of the oral DDK analysis between the two groups, the geriatric group performed lower than the adult group. While this study shows a clear understanding that a difference in DDK performance exists between age groups, the study did not provide reliability data for their results. This may weaken the study, however, it supports the conclusion that normative data from all ages is crucial for accurate comparisons. It is important to consider the effects that aging has on the laryngeal system. By obtaining normative date on L-DDK from nondisordered individuals, the diagnostic tool will be less likely to misdiagnose a patient due to the nature of the laryngeal aging process.

Clinical Reliability of Laryngeal Diadochokinesis

Reliability measurement of L-DDK is seriously lacking. There is no research which examines the reliability of L-DDK to apply to a clinical setting. While the many studies included in this chapter support the use and benefits of L-DDK as a diagnostic tool, the lack of consistency in the procedures, small sample sizes, and overall lack of normative data limit the clinical utility of L-DDK.

While many of the studies that aim to strengthen the data on L-DDK may have strong designs, inconsistencies in the use and administration of L-DDK across the studies weakens the application of L-DDK. Such inconsistencies include the tasks that are used to complete L-DDK testing. Some studies include both adductory and abductory task, while others only include one or the other. For example, Leeper and Jones (1991) and Verdolini and Palmer (1997) only include the use of the adductory task /ʌ/. In order to obtain an overall evaluation of the laryngeal system, both adductory and abductory tasks should be included.

In addition, previous research limited to whom the results could be applied by selecting small sample sizes or limiting populations. For example, a study completed by Shanks (1966) was concerned with the effects of pitch, intensity, and aging on the performance of L-DDK tasks. While this study supported the use of L-DDK clinically and aimed to determine the best way to collect normative data, the sample consisted of only females. This limits the validity of the study and limits the application of his findings.

A portable, inexpensive method which will provide results quickly and reliability is needed in a clinical setting. Normative data would support the use of L-

DDK measurement to determine whether a patient's scores are within what is considered normal for his or her age, or if those scores fall outside that range. Obtaining these data will support the use of L-DDK tasks as a possible predictor of neurological disorders (Leeper & Jones, 1991).

CHAPTER II

PURPOSE

L-DDK is a noninvasive procedure which is inexpensive and easy to perform in a clinical setting. It is useful for testing laryngeal functioning and has potential for distinguishing a normal speech mechanism from a disordered one. Clinicians may use this clinical measure to develop a treatment plan for their patients and track therapy progression. Unfortunately the lack of research and normative data on strength of L-DDK prevents clinicians from using this as a diagnostic tool. Normative data on L-DDK strength in the early adult population would provide speech-language pathologists with a reliable and efficient method of assessing laryngeal function. However, there is a lack of normative data for professionals to use. The data that is available from current research is questionable due to limitations in the studies' designs. Limitations such as small sample size and poor reliability procedures were found. Such limitations challenge the reliability and use of L-DDK as a diagnostic tool, and they do not provide adequate data for comparing L-DDK results. In order to overcome some of the limitations in the previous literature, the following questions were addressed in this study:

1. What are the normative values for L-DDK strength measures for the adductory task /ʌ/ and the abductory task /hʌ/ in the early adult population between the ages of 20 and 39 years of age?
2. Is there a difference between L-DDK strength measures for the adductory task /ʌ/ and the abductory task /hʌ/ in the early adult population between the ages of 20 and 39 years of age?

3. Is there a difference between normative values of L-DDK strength measures for males and females in the early adult population between the ages of 20 and 39 years of age?

CHAPTER III

METHOD

Design

This study is a subset of an ongoing Indiana University of Pennsylvania (IUP) Institutional Review Board (IRB) approved study (11-131) by Dr. Lori Lombard that aims to collect L-DDK data on both men and women throughout the lifespan (20-90 years old). This current subset aimed to collect and analyze L-DDK strength measurements in both males and females of the normal early adult population, which includes ages 20 to 39 years of age.

Normative data on L-DDK strength was analyzed and compared between males and females within the early adult age group. The larger study uses a Level 3 cross sectional research design, comparing different age groups on two L-DDK tasks at one time point (rather than following participants over time). The current study included only one age group, early adults from 20 to 39 years of age. There are two independent variables: (a) a between-groups variable of sex (comparing males to females); and (b) a within-subjects variable of L-DDK task (comparing /ʌ/ to /hʌ/). The dependent variable is strength of production.

Participants

Recruitment

Co-investigators of the larger IUP IRB approved study (11-131) recruited family members, friends, co-workers, and members of the community to participate in the study. An Informed Consent Form and Voluntary Consent Form were completed by each participant prior to participating in the study. The Informed

Consent Form educated participants on the purpose of the study, the process, and the risk and benefits to participating in the study. In order to acknowledge their understanding of the information listed above, participants signed the Voluntary Consent Form to acknowledge their consent to participate in the study. The IUP IRB approved both forms and the study procedure (Approval ID: 11-131).

Inclusion and Exclusion Criteria

In order to participate in this study, certain criteria were established in the protocol. Inclusion in the study required the participant to have a typical voice quality as perceived by the investigator. In additional the participant could not have any known laryngeal abnormalities. Participants were not restricted by sex.

Exclusion from the study resulted if one or more of the following conditions were met: (a) symptoms of a cold or illness; (b) history of respiratory, laryngeal, or neurological disease; (c) previous surgery of the larynx; and/or (d) vulnerable subjects.

Final Sample

A final sample of 99 participants was included in this current study. The sample included both men and women between the ages of 20 and 39 years old. Based on sex, the group was divided as follows: 44 male and 55 female participants. The average age of male participants was 26 years old, with an age range of 21 to 39 years of age. The average female participant was 25 years old, with an age range of 20 to 39 years of age.

Procedures for Data Collection

As part of the larger study, for which this current study is a subset, participants were asked to read and sign the Informed Consent Form and Voluntary Consent Form prior to the start of data collection. The location of the session took place in a quiet room located in the participant's or investigator's home. There were a total of four tasks which participants were instructed to perform: (a) produce L-DDK tasks /ʌ/ and /hʌ/ for seven seconds; (b) sustain phonation of vowels /a/ and /i/ for five seconds; (c) read six sentences; and (d) converse in a conversation for thirty seconds. Production of L-DDK tasks and sustained phonation were both completed three times each. An Audio-Technica ATR20 Dynamic Cardioid Low Impedance Professional Microphone was used during the recordings. Participants were instructed to sit with their mouths six inches from the microphone (Leeper & Jones, 1991). A Roland CD-2 CF/CD Recorder was used to record the completion of the tasks, and the samples were copied onto a compact disk. The disk was then labeled with the appropriate subject number to maintain anonymity.

Specific instructions were presented verbally to each participant prior to recording. Sufficient modeling and practicing of each syllable (/ʌ/ and /hʌ/) was provided before recording began. Before completion of the L-DDK tasks, the following instructions were given based 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/ and /hʌ/).

The next task was to complete sustained phonation of vowels /a/ and /i/ for five seconds, three times each. Then, participants were asked to read six sentences aloud. These sentences were selected in order to observe laryngeal behavior. The following sentences were selected for this task: (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. The final task consisted of the participant maintaining conversation while replying to the prompt: "Tell me what you did yesterday." The concluding three tasks were selected from the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V) in order to provide a perceptual analysis of voice (CAPE-V, 2006).

Measurement Procedures

This current study analyzed the de-identified recordings of the participants included in the larger IUP IRB approved study by Dr. Lori Lombard (11-131). The audio files containing the seven second samples of the recorded L-DDK trials from each participant were uploaded to the Multidimensional Voice Program- Advanced (KayPentax) software program. Of the three trial recordings for each participant, one was labeled "best" performance trial according to the number of repetitions in the sample. Only the recordings with the most repetitions were then converted into waveforms for further analysis. A protocol for trimming the data was utilized in order to keep all samples consistent. First, the beginning 0.5 seconds of the sample was deleted. Then, the five seconds following the new start time was analyzed in the study. Additional time remaining on the sample was deleted. Once the sample was trimmed to the appropriate amount of time, the investigator set a threshold to capture the average peak amplitude and eliminate extraneous noise in the sample. KayPentax Motor Speech Profile (MSP) Model 5141 software was applied to analyze the average peak amplitude, 'strength', of the sample.

Ethical Use of Data

The data used in this current study was only used for the goals of this study and the larger IUP IRB approved study by Dr. Lori Lombard. There was no identifying information used in the recordings or on any form used in data collection. Participants were assigned a subject number which was used as the identifier in the audio recordings and data collection paperwork. The only identifying information was on the Voluntary Consent Form. This form was only used by the current investigator and the investigators of the larger study. This identifying information as well as all other data was securely locked in an office where only investigators could access it. All information and records will be destroyed once the larger study is complete.

Statistical Analysis

The ISPSS® Statistics Data Editor software was used to complete the statistical analysis portion of the study (SPSS Statistics Data Editor, 2010). The investigator applied this software to answer the following research questions of 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 early adult population between the ages of 20 and 39 years of age?; (b) Is there a difference between L-DDK strength measures for the adductory task /ʌ/ and the abductory task /hʌ/ in the early adult population between the ages of 20 and 39 years of age?; and (c) Is there a difference between normative values of L-DDK strength measures for males and females in the early adult population between the ages of 20 and 39 years of age?

A descriptive statistics analysis was used to support the first question of the study by providing normative values of strength of L-DDK in this particular population. The data included the minimum and maximum values of L-DDK strength as well as the mean and standard deviation. The next analysis used to answer the second and third research question was completed by assessing the t-test for Equality of Means. The t-test for Equality of Means compared the two groups, based on sex and trials, to analyze if there is a significant difference between the groups.

CHAPTER IV

RESULTS

The results of the descriptive statistics analysis and t-test for Equality of Means were calculated to answer the proposed research questions. A statistically significant difference was found between L-DDK strength measures for /ʌ/ and /hʌ/ in the early adult group. Also, there was no statistically significant difference in normative values of L-DDK strength found between males and females in the early adult group.

The first descriptive statistics analysis computed the normative values for strength of L-DDK measurements for both males and females. The early adult group includes ages 20 to 39 years old. The normative data for both adductory (/ʌ/) and abductory (/hʌ/) tasks were included in this calculation. In male participants performing the adductory task /ʌ/, the normative value was M = 57.08 (SD =0 7.40), range = 39.37 – 73.71. The normative value for males when performing the abductory task /hʌ/ was M = 56.60 (SD = 8.97), range = 39.65 – 77.47. For female participants, the normative value for /ʌ/ was M = 55.00 (SD = 7.91), range = 38.40 – 70.24. The normative value for females when performing /hʌ/ was M = 53.57 (SD = 8.21), range = 39.41 – 70.24. The normative value for both males and females combined in the early adult group for /ʌ/ was M = 55.93 (SD = 7.72), range = 38.40 – 73.71. For /hʌ/, the normative value for both males and females combined was M = 54.91 (SD = 8.65), range = 39.41 – 77.47. A summary of these statistics can be found in Table 1, *Descriptive Statistics for Strength of L-DDK.*

Table 1

Descriptive Statistics for Strength of L-DDK

Task	Sex	N	Minimum	Maximum	Mean (M)	Standard Deviation (SD)
/ʌ/	Male	44	39.37	73.71	57.08	7.40
	Female	55	38.40	70.24	55.00	7.91
	Total	99	38.40	73.71	55.93	7.72
/hʌ/	Male	44	39.65	77.47	56.60	8.97
	Female	55	39.41	70.24	53.57	8.21
	Total	99	39.41	77.47	54.91	8.65

The next analysis was the t-test for Equality of Means. It was used to analyze the presence or absence of a significant difference between productions of /ʌ/ and /hʌ/ in early adults. The results indicated a significant difference between the strength of productions in /ʌ/ vs. /hʌ/ in early adult population between the ages of 20 and 39 years old (p-value = .004). A summary of these statistics can be found in Table 2, *Descriptive Statistics for /ʌ/ Versus /hʌ/ in Early Adult Males and Females.*

Table 2

Descriptive Statistics for /ʌ/ Versus /hʌ/in Early Adults

	Paired Differences (95% Confidence Interval of the Difference)	T	df	Sig. (2-tailed)
/ʌ/ vs. /hʌ/	1.690	2.969	98	.004

The final analysis computed whether or not there was a significant difference in strength of values of /ʌ/ between males and females, and if there was a significant difference in strength values of /hʌ/ between males and females. The results indicate there was no significant difference in values of /ʌ/ between males and females (p-value = .184). The results also concluded there was no significant difference of /hʌ/ between males and females (p-value = .083). A summary of these statistics can be found in Table 3, *Descriptive Statistics for Strength of L-DDK in Adult Males Versus Females.*

Table 3

Descriptive Statistics for Strength of L-DDK in Early Adult Males Versus Females on the Two L-DDK Tasks

	Df	**Sig. (2-tailed)**	**Mean Difference**
/ʌ/	97	.184	-2.082
/hʌ/	97	.083	-3.033

CHAPTER V

DISCUSSION

Research suggests that L-DDK tasks are potentially beneficial to measuring the laryngeal functioning of the speech mechanism. Specifically, it may be an indicator of strength of laryngeal function. Issues arise in previous research due to their multiple limitations in design that decrease the reliability of using L-DDK as a diagnostic measure. The limitations in previous research provide a need for reliable, normative data which will support the use of L-DDK measurement in a clinical setting. In order to reduce such limitations, the current study aimed to answer the following questions: (a) What are the normative values for L-DDK strength measures for the adductory task /ʌ/ and the abductory task /hʌ/ in the early adult population between the ages of 20 and 39 years of age?; (b) Is there a difference between L-DDK strength measures for /ʌ/ and /hʌ/ in the early adult population between the ages of 20 and 39 years of age?; (c) Is there a difference between normative values of L-DDK strength measures for males and females in the early adult population between the ages of 20 and 39 years of age?

The first research question this study aimed to answer involved obtaining normative data for L-DDK strength for both males and females in the early adult population. Normative data obtained in this study included minimum and maximum values, mean, and standard deviation measures of L-DDK strength. Both males and females were included in the study in order to strengthen the applicability of L-DDK to a wide variety of patients. Strength of L-DDK normative values were computed for males, females, and a combined group of both sexes.

Previous studies that aimed to explore the usefulness of L-DDK in a clinical setting included only one sex. Leeper and Jones (1991) only included females in their study of L-DDK data. This decreases the validity of the results since the conclusions cannot be applied across sexes and, therefore, weakens the use of L-DDK as a diagnostic tool.

The present study not only included both sexes in data collection, but it also included both adductory and abductory tasks (/ʌ/ and /hʌ/) in the completion of L-DDK tasks. Multiple discrepancies are noted in previous research with regard to the tasks selected to perform L-DDK. While some studies have included both /ʌ/ and /hʌ/ as stimuli, other studies only included the adductory task, /ʌ/ (Leeper & Jones, 1991; Verolini & Palmer, 1997). In order for L-DDK to be a reliable tool, both adductory and abductory tasks should be included for full representation of laryngeal integrity.

Next, this study questioned the comparison of strength measures for /ʌ/ and /hʌ/ in the early adult population. The results of the analysis revealed a statistically significant difference between the L-DDK tasks. Since a significant difference in L-DDK strength exists between the stimuli, this indicates that both tasks may be important for evaluating a male or female in the early adult population (ages 20-39 years old). Further research that includes the ages across the entire lifespan, including ages 40 through 90 years old, is needed in order to determine if this pattern is found throughout the lifespan. Until further research can prove otherwise, it is important to consider that both /ʌ/ and /hʌ/ stimuli should be utilized in the application of L-DDK.

The final research question included comparisons in L-DDK strength measurements between males and females in the early adult population. The results of this analysis revealed no statistically significant difference between sexes on both L-DDK tasks. Therefore, the results suggest that normal males and females within this age range, 20 to 39 years old, have similar laryngeal strength. Early adults have similar structure and function of the larynx at this stage of life. As noted previously, Ferrand (2012) described the ossification of cartilage, degeneration of joints, and loosened muscle fibers as a natural part of aging that both men and women experience. Further research aiming to investigate this phenomenon across the entire lifespan is important for the further application of L-DDK in all patients.

CHAPTER VI

LIMITATIONS

This study controlled for numerous factors to relieve reliability and validity concerns. A strict protocol was followed when collecting and analyzing data and strict inclusion and exclusion criteria was included to reduce variability in outcomes. While restrictions were followed, some limitations still exist within this study.

One limitation is the sample size of the early adult group. There were a total of 99 participants used for this study. While that number exceeds many of the studies previously mentioned, a larger sample size would be beneficial to further analyze L-DDK strength. More participants within the age range of 20 to 39 years old would allow to further divide this group into decades instead of the entire span of nineteen years. The examination of decades would further strengthen normative data needed for L-DDK to be a reliable diagnostic method and allow for a more specific analysis of how the structures of the larynx change with each decade the individual ages. The clinical implications would be highly beneficial. An additional limitation to the sample is the lack of diversity amongst participants. This sample consists of primarily white participants living within the same region. Further research is necessary to determine if a lack of diversity in the sample impacts the validity of the results.

Another limitation to the study is the risk of cognitive and behavioral influences affecting the performance of L-DDK tasks during data collection. Like previously stated, exclusion and inclusion criteria were followed when selecting participants. For example, those with a known neurological disorder were excluded from participating. However, this does not account for cognitive and behavioral influences which are known to affect the laryngeal system as well. Stemple et al. (2000) discussed the influences that behavioral factors such as smoking, alcohol abuse, drug use, and coffee intake may have on the speech mechanism, including the larynx. Laryngeal pathologies may even exist as a result of these factors and/or impact voicing (Stemple et al., 2000). Such considerations must be made in order to ensure that performance is being altered without being detected perceptually. In addition to behavioral factors, cognitive and emotional effects of performing L-DDK tasks may influence an individual's performance. These may include "emotional tension, depression, and anxiety" (Stemple et al., 2000, p. 75). These emotional effects can influence the individual's performance on the L-DDK tasks and are difficult to control for.

A final limitation includes the lack of a reliability measure. While a strict protocol was followed in analyzing the data, inconsistencies within the investigator can occur. In order to strengthen the reliability of the data, periodic reliability checks of measurement using the software would be ideal. These reliability checks could occur while performing tasks such as trimming samples and selecting the threshold to calculate the strength measurement. While the protocol explicitly stated how to trim the sample to five seconds, the slightest deviation will change the values of the results. In addition, selecting the appropriate threshold which the strength measurement is based on could result in variability. By occasionally rechecking a previously trimmed sample, a comparison can be made to test the reliability and consistency of the investigator's data trimming and establishment of a threshold. While time consuming, this would improve the reliability of the final results.

CHAPTER VII

CLINICAL IMPLICATIONS

The current study aimed to strengthen the research on L-DDK by providing normative data on L-DDK strength measurements in the early adult population (age 20-39 years old). Normative values for males, females, and the combined group were reported. A statistically significant difference was found between the adductory task /ʌ/ and the abductory task /hʌ/ in the early adult group. There was no statistical difference in L-DDK strength between sexes.

The results of this study can support further development of L-DDK tasks as a diagnostic tool in a clinical setting. Further research should expand on this foundation and apply the L-DDK strength findings to a large sampling across the lifespan. Areas for future study should include the following: (a) expanding the sample size in order to differentiate between decades; (b) examining the possibility of emotional and behavioral factors influencing the results; (c) L-DDK strength values of normal adult and geriatric populations; and (d) comparison of normal and disordered individuals. Normative data of L-DDK tasks will strengthen the reliability of this efficient and inexpensive diagnostic tool which may provide early diagnosis of degenerative disorders affecting the laryngeal mechanism.

References

Bassich-Zeren, C. J. (2004). *Vocal dysfunction in young-onset Parkinson's disease.* (Doctoral dissertation). University of Maryland College Park, MD. Retrieved from http://drum.lib.umd.edu/handle/1903/1823.

Carmichael, C. M. (2005). Instrumental assessment of respiratory and laryngeal function in patients with neurological disorders. *SIG 3 Perspectives on Voice and Voice Disorders, 154,* 16-20.

Chitkara, A. E. (2006). Neuroanatomy of the larynx. In L. Sulica & A. Blitzer (Eds.), *Vocal Fold Paralysis* (pp. 3-16). Berlin, Germany: Springer Berlin Heidelberg.

Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V). (2006). Retrieved from: http://www.asha.org/uploadedFiles/ASHA/SIG/03/affiliate/CAPE-V-Purpose-Applications.pdf.

Duffy, J. R. (2013). *Motor speech disorders: Substrates, differential diagnosis, and management* (3rd ed.). St. Louis, MO: Elsevier Mosby.

Ferrand, C. (2012). *Voice disorders: Scope of theory and practice*. Boston, MA: Pearson Education.

Fletcher, S. G. (1972). Time-by-count measurement of diadochokinetic syllable rate. *Journal of Speech and Hearing Research*, *15,* 763-770.

Langmore, S. E., & Lehman, M. E. (1994). Physiologic deficits in the orofacial system underlying dysarthria in amyotrophic lateral sclerosis. *Journal of Speech and Hearing Research, 37* (1), 28-37.

Leeper, H. A., & Jones, E. (1991). Frequency and intensity effects upon temporal and aerodynamic aspects of vocal fold diadochokinesis. *Perceptual and Motor Skills, 73,* 880-882.

Mehta, D. D., & Hillman, R. E. (2013). Voice assessment: Updates on perceptual, acoustic, aerodynamic, and endoscopic imaging methods. *Current Opinion in Otolaryngology and Head and Neck Surgery, 16* (3), 211-215.

Modolo, D., Berretin-Felix, G., Genaro, K., & Brasolotto A. (2011). Oral and vocal fold diadochokinesis in children. *Folia Phoniatr Logop, 63,* 1-8.

Ptacek, P. H., & Sander, E. K. (1966). Phonatory and related changes with advanced age. *Journal of Speech and Hearing Research, 9*, 353-360.

Rubin, J. S., Sataloff, R. T., & Korovin, G. S. (2014). *Diagnosis and Treatment of Voice Disorders* (4th ed.). San Diego, CA: Plural Publishing.

Ruscello, D. M., St. Louis, K. O., Barry, P. J., & Barr, K. J. (1982). A screening method for evalutation of the peripheral speech mechanism. *Folia Phoniatrica, 34,* 324-330.

Shanks, S. J. (1966). *An investigation of the nature of vocal fold diadochokinesis of adult subjects and of the effect of pitch, intensity and aging upon the performance of this phonatory task.* Available from http://worldcat.org/z-wcorg/database.

St. Louis, K. O., Grofic, D., Ford, S. E., & Ruscello, D. M. (1981). Oral speech mechanism screening results for articulatory defectives and normals. Poster session presented at the Annual Convention of the American Speech-Language-Hearing Association, Los Angeles, CA.

Stemple, J. C., Glaze, L. E., & Klaben, B. G. (2000). *Clincial voice pathology: Theory and management* (3rd ed.). San Diego, CA: Singular.

Tomblin, J.B., Morris, H.L., & Spriestersbach, D.C. (Eds.). (2000). *Diagnosis in speech-language pathology (2nd Edition).* San Diego, CA: Singular.

Verdolini, K., & Palmer, P. M. (1997). Assessment of a 'Profiles' Approach to Voice Screening. *Journal of Medical Speech-Language Pathology, 5* (4), 217-232.