Characteristics of Laryngeal Diadochokinetic Rates in the Normal Aging Population

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CHARACTERISTICS OF LARYNGEAL DIADOCHOKINETIC RATES IN THE NORMAL AGING 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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May 2013
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Laryngeal diadochokinesis (L-DDK) measurements can be used by speech-language pathologists as a clinical tool to assess laryngeal function. Current research, however, is lacking in normative data of L-DDK for the aging population (60 – 90 years) in both men and women. Inconsistencies of collection and measurements of L-DDK data also exist in previous studies. The current research study aimed to bridge this gap in the literature by collecting normative L-DDK data on both men and women in the aging population. Thirty-nine participants (22 female and 17 male) completed the following tasks: 1) produce the syllable /ʌ/ for a period of seven seconds for three trials, 2) produce the syllable /hʌ/ for a period of 7 seconds for three trials, 3) sustain the vowel /a/ for 3-5 seconds, 4) sustain the vowel /i/ for 3-5 seconds, 5) read six sentences, and 6) respond to a to the question: ‘How is your voice functioning?’ for 20 seconds. SPSS-IBM Statistics Software (SPSS) was utilized to analyze the data. Results revealed no statistically significant differences between L-DDK rates for the adductory task /ʌ/ and the abductory task /hʌ/ (.75, F[5.00, 33.00] = .75, p=.08). Normative L-DDK data consisting of mean, standard deviation, and range were collected for both male and female subjects between the ages of 60 and 90. A statistically significant difference was found between gender (p=.02).
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CHAPTER I
REVIEW OF LITERATURE

Laryngeal diadochokinesis (L-DDK) rates have been shown to predict both normal and abnormal functioning of laryngeal, articulatory, and respiratory structures in studies of participants with progressive neurologic disease compared to a healthy control group (Canter, 1965; Renout, Leeper, Bandur, & Hudson, 1995; Verdolini & Palmer, 1997). Currently there is a lack of substantive normative data available for L-DDK tasks across the lifespan. Lack of normative data on L-DDK is a problem because speech-language pathologists are unable to compare L-DDK rates calculated from clinical tasks to normative standards. The absence of standardized results from persons without disease restricts the ability to identify a disordered population. Because many degenerative diseases affect the older population, it is especially important to know whether changes in laryngeal function are consistent with normal aging or degenerative disease. Normative L-DDK data could be used in a clinical setting to assess whether a client has normal function of the laryngeal and respiratory structures necessary for phonation. Therefore, there is a need for normative data to be collected. Normative L-DDK rates in both males and females must be collected in all age groups in order to determine what would be considered normal rates in diagnostic populations. This information could be used to guide speech-language pathologists with their therapeutic goals and objectives for these patients.
In order to understand why L-DDK is important for both diagnosis and intervention of degenerative diseases in the 60 to 90 year-old population, it is important to understand the foundations of L-DDK. The following sections describe the tests of laryngeal function, including L-DDK, anatomy and physiology of phonation, the impact of aging on laryngeal anatomy and physiology, degenerative diseases that can affect laryngeal functioning, and clinical reliability of diadochokinesis.

Tests of Laryngeal Function

Currently, there are both invasive and noninvasive tools that a speech-language pathologist can use to assess laryngeal function. These tools include endoscopy, electroglottography, and electromyography. Speech-language pathologists and otolaryngologists must have training with, and access to, these expensive instruments. Therefore, they are not easily accessible for many clinicians.

Endoscopy

Endoscopy is an invasive clinical tool to help speech-language pathologists and otolaryngologists obtain a view from above a patient’s larynx and vocal folds. Endoscopy is a process in which a tube or scope is inserted through the nose (flexible endoscopy) or oral cavity (rigid endoscopy) to illuminate and record a video of the laryngeal structures and how they function (Ferrand, 2012). Patients are awake during both rigid and flexible endoscopy. This process yields a high-quality image of the larynx in which vocal fold changes at different pitch levels are visualized (Ferrand, 2012). The results can be used to see if there are any structural or functional abnormalities of the larynx.
Although endoscopy is an adequate method in which clinicians can visualize structural and functional changes of the laryngeal mechanism, it is not readily available to clinicians who do not work in a health care environment. Some states require that a physician be on-site during endoscopic procedures. The equipment itself and maintenance of the equipment is expensive as well. Diagnosis made through endoscopy is also a perceptual judgment of changes of shape in the larynx and timing of vocal fold vibration (Stemple, Glaze, & Klaben, 2000). Visualization of the larynx during varied phonatory tasks is helpful, but not always representative of maximum laryngeal performance and phonatory effect. The perceptual judgments of laryngeal function may vary from one speech-language pathologist to another. Although endoscopy is an important and useful clinical tool to visualize structural and functional abnormalities in the larynx, its drawbacks are cost, accessibility, and invasiveness. The clinical implications of the evaluation is not completely consistent with the implications of glottal efficiency that L-DDK offers.

**Electroglottography (EGG) and Electromyography (EMG)**

Electroglottography (EGG, also known as electrolaryngology) is a noninvasive way of visualizing and assessing vocal fold vibration (Stemple et. al., 2000). Two electrodes, placed on both sides of the thyroid cartilage, pass a small electrical current through the vocal folds as they vibrate. These vibrations are then converted into a waveform that is sent to the computer, which the speech-language pathologist can interpret (Ferrand, 2012). As a result, this clinical tool can therefore help speech-language pathologists interpret vibratory patterns of the vocal folds.
Although waveforms can be seen as an objective means of data collection, variations in tissue thickness, electrode placement, mucous interference, and laryngeal movements can produce errors in measurement (Stemple et al., 2000). Clinicians and clients cannot control factors, such as variations in tissue thickness, mucous interference, and laryngeal movements. Furthermore, EGG is not a clinical tool available to all speech-language pathologists. Electroglottography provides information about the rate and amplitude of glottal pulses, but is not typically performed under maximum physiologic effort, as is the case, with L-DDK.

Laryngeal electromyography (L-EMG) is an invasive diagnostic procedure used to assess the health of muscles and nerve cells (“Mayo Clinic,” 2010). According to the Mayo Clinic (2010), a needle electrode that records electrical activity is inserted through the skin directly into a laryngeal muscle. The electrode’s output is then translated into graphs, sounds, or numerical values that are interpreted by a speech-language pathologist to assess muscle function.

Although L-EMG is a low-risk procedure, it is still invasive in nature and must be performed by a neurologist or an otolaryngologist (Stemple et al., 2000). As with EGG, factors that clinicians and clients cannot control such as variations in tissue thickness, mucous interference, and laryngeal movements may produce errors in measurement (Stemple et al., 2000).

Endoscopy, EGG, and L-EMG can all provide useful data on laryngeal function. However, they are all expensive procedures that require equipment not readily available to most speech-language pathologists in clinical settings. Furthermore, both endoscopy
and L-EMG are invasive procedures. It is clear that speech-language pathologists need measures that are more practical for everyday clinical settings. One such measure is the process of collecting both subjective and objective data through L-DDK tasks. Such measures could be beneficial in telling a speech-language pathologist how the larynx is functioning without the use of endoscopy, EGG, or L-EMG.

**Diadochokinesis**

Speech-language pathologists use both oral and laryngeal diadochokinesis to assess function of the articulatory and phonatory systems in their patients. It is important to understand diadochokinesis in order to understand why it is a useful tool with disordered populations for both assessment and intervention. Diadochokinetic tasks require rapidly repeated and coordinated movements. Oral diadochokinetic tasks address articulatory movements in the oral cavity. Laryngeal diadochokinetic tasks evaluate phonatory movements and coordination of respiration and the larynx. Analyzing diadochokinetic activity does not always require equipment. A speech-language pathologist can collect data on diadochokinetic rates simply by counting repetitions and judging strength and timing of the productions. The simplicity of the perceptual tasks allows diadochokinetic measurement to be available to all speech-language pathologists in all clinical settings. Further description of oral and laryngeal diadochokinesis measurement and collection is detailed below.

**Oral Diadochokinesis (DDK)**

Oral diadochokinesis, also referred to as DDK, is a clinical tool used by many speech-language pathologists to assess the coordination of a patient’s phonatory and
articulatory systems (Seikel, King, & Drumright, 2005). According to Seikel et al. (2005), oral DDK is the number of productions of a single syllable or of multiple syllables an individual produces per second. For example, a DDK score could be obtained by asking a patient to repeat /pʌtʌkʌ/ as quickly and accurately as possible for 7 seconds. An average score is calculated by counting the total number of times the patient was able to produce /pʌtʌkʌ/ and dividing by seven. This yields a DDK score, which is essentially how many times the patient was able to produce /pʌtʌkʌ/ in one out of the seven seconds. A 7-second sample is taken to make sure that the patient’s 1-second sample is a true score. Similarly, a DDK score could be obtained by asking a patient to repeat sounds, such as /tʌtʌtʌ/, /pʌpʌpʌ/, or /kʌkʌkʌ/ as quickly and accurately as possible for 7 seconds. The DDK score would be obtained the same way.

Maximum DDK rate performance can only be obtained when one has “ample integration and segmentation of muscle control” (Fletcher, 1972). It is clear that in order to perform DDK tasks clearly and accurately, one must have adequate control of the coordination of the articulators. These factors clearly explain why DDK is a clinically appropriate way for speech-language pathologists to assess the coordination of a patient’s phonatory and articulatory system without the use of expensive equipment or invasive clinical protocols.

**Laryngeal Diadochokinesis (L-DDK)**

Although L-DDK is not as commonly utilized as oral DDK in the field of speech-language pathology, it is an important clinical tool that could also be used to assess laryngeal function. According to Ptacek, Sander, Maloney, and Jackson (1966), L-DDK
involves repeated production of glottal plosives as rapidly and consistently as possible. Laryngeal diadochokinesis demands muscular coordination and control over the adduction and abduction of the vocal folds during an exhale. It also requires coordination and control over the respiratory process to manage the airflow and air pressure generated through phonation.

Laryngeal diadochokineti  

can be obtained by asking a patient to repeat the /hʌ/ or /ʌ/ sound as quickly, consistently, and accurately as possible. Patients are asked to take a deep breath before the task. However, Leeper and Jones (1991) stated that there are few data available on information regarding the timing and amount of air needed to assess the rapid voluntary opening and closing of the vocal folds, or L-DDK. The consistency of syllable production is important to task control. In a study completed by Leeper and Jones (1991), 18 healthy young adult women were assessed on vocal intensity using the adductory task /ʌ/. The study found that acceptable, consistent performance of L-DDK depends heavily on syllable rate and regulation of airflow through the glottis. It is important to note that instructions for production of L-DDK tasks are similar, but not standardized in the literature.

A laryngeal diadochokinetic rate is calculated as the average number of syllable productions per second. Laryngeal diadochokinetic rates can also be measured objectively by using a voice analysis software program. A 7-second sample is taken to make sure that the patient’s 1-second sample is a true L-DDK rate. A recording of the client performing L-DDK tasks can be uploaded to a voice analysis software program to visualize a graphic representation of the glottal pulses. Laryngeal diadochokinetic rates
can also be measured subjectively with the speech-language pathologist auditorily counting the number of abductory and adductory movements of the client.

Perceptual measurement of L-DDK could be used in a clinical setting as a noninvasive way to assess laryngeal function. The use of L-DDK can give a speech-language pathologist both subjective and objective data to assess if the vocal folds are abducting and adducting normally. A review of the anatomy and physiology of the laryngeal structures is crucial to understanding why L-DDK can be used as an important tool to assess laryngeal function.

**Anatomy & Physiology of Phonation**

It is critical to understand the anatomy and physiology of phonation (i.e., voice production) in order to understand how diagnostic assessments such as endoscopy, EGG, L-EMG, and L-DDK measures are clinically obtained.

**Larynx and Vagus Nerve**

Before understanding the physiology of phonation, it is important to lay the foundation of the anatomy and innervation of the larynx. Seikel et al. (2005) gives an accurate and precise description of the anatomy and physiology of the larynx and vagus nerve. The larynx is a musculo-cartilaginous structure that can be found attached to the upper section of the trachea. Normal swallowing and phonation patterns rely on healthy laryngeal functioning. Laryngeal biological functions include abdominal fixation, coughing, and throat clearing. The larynx is composed of a series of both paired and unpaired cartilages that are bound by ligaments and muscles. These cartilages move in unison with each other to contract and relax the vocal folds. The vocal folds are
composed of five layers of tissue, the bottom layer being the thyrovocalis muscle. The layers of tissue above the thyrovocalis muscle serve as a protection mechanism. The larynx is provided with motor and sensory innervations by the recurrent laryngeal nerve (RLN) and the external branch of the superior laryngeal nerve (SLN). Both the RLN and SLN are branches of the vagus nerve, or Cranial Nerve X. The vagus nerve also directs somatic sensation of pain, touch, and temperature to the laryngeal muscles. The structural framework, muscles, and nerves must have structural integrity to coordinate and manipulate the airflow generated during an exhalation. Phonation, or voice production, requires the larynx to make rapid structural and muscular adjustments.

Understanding the anatomical structures of the larynx is also important to understanding how the natural aging process affects the vocal structures and how this process can affect L-DDK rates.

**Physiology of Phonation**

In order to understand L-DDK, it is important to understand how the physiology of the voice structures affects normal voice production. Phonation occurs when air is released from the lungs into the larynx. As the air passes through the larynx, the vocal folds are adducted (brought together) and abducted (pushed apart) by muscular effort and dynamic physical forces of airflow and pressure that create rapid vibration (Seikel et al., 2005). The vocal folds’ ability to abduct and adduct rapidly relies on their elasticity and motor control (Seikel et al., 2005). After sound is produced at the level of the vocal folds, it is modified as the airstream and sound wave travels through the pharyngeal, laryngeal, and oral cavities (Justice, 2010). Anatomical sizes of structures vary from one
person to another, which explains why voice frequencies vary from person to person. This is an important factor to consider because normative data will give us the range and variations that are considered within normal ranges for L-DDK. Without normative data, it is impossible to determine whether a disordered person’s L-DDK rates fall within normal functioning ranges or not. If a person’s L-DDK rates would fall outside of the normative data ranges, a speech-language pathologist could assume an abnormality in the phonatory system and pursue further evaluation. The foundation of the normal anatomy and physiology of voice structures will establish a better understanding of the impact of the aging process on the laryngeal structures and how this process can affect L-DDK rates compared to those with more youthful laryngeal anatomy and physiology.

**Impact of Aging on Laryngeal Anatomy & Physiology**

Natural degeneration of the human body and its systems is a process that occurs in all aging persons. As with normal physical and cognitive development in children, the physiological process of aging will occur at different times depending on the individual. Aging of the phonatory mechanisms occur simultaneously with other organ systems in the human body. As stated above, normal voice production patterns rely heavily on the coordination of respiration and phonation. According to Linville (2004), the aging individual undergoes age-related structural and functional changes in the respiratory, phonatory, and supralaryngeal systems that could alter voice production. These changes provide an example for why normative data on L-DDK proves useful as a diagnostic measure for speech-language pathologists when determining whether a person is disordered or not. It should be noted that although both genders undergo changes in
the speech mechanism as they age, elderly males have been reported to undergo slightly more significant deviations in their speech mechanisms than elderly females (Linville, 2004). This factor makes it important to separately analyze normative data on L-DDK for men and women.

The normal aging process produces many changes within the larynx that can affect the range of ability for the vocal folds to vibrate as they do in normal laryngeal structures. These changes include ossification and calcification of the laryngeal cartilages, atrophy and degeneration of intrinsic muscles, degenerative changes in the layers of the vocal folds, and degeneration of glands in the laryngeal mucosa (Linville, 2004). Ossification and calcification of the laryngeal cartilages may affect the extent to which the vocal folds can adduct. Atrophy and degeneration of the intrinsic muscles of the larynx may affect the laryngeal cartilage’s ability to move fluidly without becoming easily fatigued. Drying of the epithelium may also increase stiffness of the vocal folds (Linville, 2004). Glandular changes may cause drying of the epithelium (Linville, 2004), which could negatively affect the elasticity of the vocal folds. Loss of elasticity in the vocal fold tissue may affect the rate at which the vocal folds adduct and abduct, or vibrate. Ossification and calcification of laryngeal cartilages, atrophy and degeneration of intrinsic muscles, degeneration of the layers of the vocal folds, and loss of elasticity within in the vocal folds will negatively affect L-DDK score ranges. These changes will cause the vocal processes to move less quickly than they within younger individuals.

Another issue that may alter the frequency, or pitch, of an aging individual is the fact that the larynx is also reported to lower as a person ages (Linville, 2004). This
positional change results in a lowering of the frequency of an aging individual’s voice as the larynx drops anatomically. Degeneration of the vocal folds, stated in the previous paragraph, may also alter the frequency of an aging individual’s voice.

Voice quality is another factor to take into consideration when analyzing the changes that one experiences during the normal aging process. Perceptually, increased hoarseness and tremor have been noted as qualities of an aged voice (Linville, 2004). Degeneration of the vocal folds and atrophy of the intrinsic laryngeal muscles may lead to tremor of the voice, as the laryngeal structures may become fatigued and easily spasm (as do muscles in other parts of the body).

Respiratory system changes occur as well as one proceeds through the aging process. Stiffening of the thorax and weakening of respiratory muscles may alter lung volume capacities and respiratory mechanics (Linville, 2004). As a result of these respiratory transformations, elderly speakers may experience a decline in the amount of air that they move in and out of the lungs and the rate at which they let the air escape through the glottis (Linville, 2004). Due to respiratory changes, aging individuals may also begin to fatigue more easily during speech tasks.

Research clearly shows us that there is evidence for such respiratory changes in aging individuals. For example, in a study that compared participants ranging from 18 to 40 years of age to geriatric participants age 65 years and older, changes associated with advanced age in the function of the respiratory, phonatory, and articulatory aspects of speech were found in the geriatric population (Ptacek et al., 1966). The geriatric population was found to have a loss of elasticity in the cartilages and muscles within the
larynx that resulted in lower pitch range scores (Ptacek et al., 1966). The study also found that DDK rates on /ʌ/, /pʌ/, /tʌ/, and /kʌ/ for the geriatric population were lower than the rates of the young adult participants (Ptacek et al., 1966).

The study completed by Ptacek et al. (1966) revealed statistically significant differences (p<.01) in the L-DDK and pitch range scores between the geriatric group and the young adults. Although the study had statistically significant scores that confirm a clear age-related difference in vocal function, there are no L-DDK normative data rates to compare the rates between the young adult and the geriatric participants. It is clear that an assumption cannot be made that the geriatric scores were abnormal, or lower, when compared with young adults because there were no normative diadochokinetic rates to compare to either population. Although the study had a large number of participants (31 young adults and 63 geriatric participants), the fact that the groups were not evenly matched could reduce the internal validity of the study. The authors of the study explain that participants were excluded if they had one or more of the following diagnoses: (a) hearing losses greater than 35 dB in the better ear at 250, 500, or 1000 Hz; (b) bronchial asthma or respiratory infection; (c) emphysema or decompensating heart function; (d) dysphasia; (e) neurological disorders affecting the speech or phonatory mechanisms; (f) senile psychosis or psychopathology; and (g) structural abnormalities of the laryngeal mechanism (Ptacek et al., 1966). Although they clearly defined the exclusions, they failed to explain how any of these exclusions were tested. It seems that participants did not fill out surveys about their health and it is
unclear how the authors knew whether or not the participants should be excluded from their study for medical issues.

In another study by Parnell and Amerman (1987), 20 speech-language pathologists judged oral DDK performances by ten normal adult speakers, ten normal geriatric speakers, and four dysarthric speakers (foils) to investigate age-related changes in speech production. The study found that the performance of elderly normal speakers was rated further from normal on a seven-point scale than those of normal speaking adults. The study also found that the ratings of elderly individuals often mimicked the ratings of the dysarthric participants (Parnell & Amerman, 1987). The results of this study support the early findings that many geriatric adults develop tremor and hoarseness to their voice. This is a fact that needs to be considered when collecting normative data on males and females in the 60 to 90 year-old population.

Although this study reveals age-related changes within the laryngeal system, the use of only ten participants in each group is not an adequate sample size. In order to establish that the data collected in this study contained clinically useful information, more participants would need to be included in further research. It would also be beneficial to have normative L-DDK score ranges in both the young adult and geriatric populations in order to be able to say that their participant pool was of normal health. The authors of this article stated in their discussion section that “additional research should be directed toward definition of normative standards for perceptual evaluation of speech abilities in elderly adults” (Parnell & Amerman, 1987, p. 349).
A third study, conducted by Shanks (1966), looked at the effects of pitch, intensity, and aging on the ability to perform L-DDK. Samples of vocal fold DDK on the /hʌ/ syllable were taken on 40 young adult females with and without auditory masking, ten females before and after undergoing topical anesthetization of the larynx, 40 young adult women varying pitch and intensity of their phonation, and three groups of 40 women, classified according to their age (Shanks, 1966). It was found that all participants who were masked while performing L-DDK had lower scores compared to when they were not auditorally masked. It can, therefore, be inferred that auditory feedback is important in synchronizing laryngeal behavior (Shanks, 1966), or when completing L-DDK tasks. This finding is important to consider when thinking about the aging population concerning L-DDK functioning. The normal aging process occurs in the auditory system, as well as the laryngeal system. Hearing loss occurs as a part of the natural aging process. The findings of this research study suggest that the aging population may perform worse than young adults and adults on L-DDK tasks due to the additional factor of natural loss of hearing in the auditory system.

It is important to note that it is extremely difficult to conduct a study with an adequate sample size when excluding person’s with a hearing loss in the geriatric population. According to the American Speech-Language-Hearing Association (2008), “Hearing loss is the third most prevalent chronic condition in older Americans, and it is the number one communicative disorder of the aged; between 25% and 40% of the population aged 65 years or older is hearing impaired.” The prevalence of presbycusis, or the natural loss of hearing as a result of aging, rises with age, “ranging from 40% to
66% in patients older than 75 years, and more than 80% in patients older than 85 years”

Although the study completed by Shanks (1966) had many components that could be considered clinically useful, there were a few weaknesses that should be addressed. Shanks (1966) collected data from 130 participants, which is considered to be an adequate sample size, but the data were collected on females only. Collecting data from only one gender presents a weakness because the study can only be generalized to a female population. It is also important to keep in mind that the effect of the natural aging process on laryngeal function in females differs from the natural aging process on laryngeal function in males (Linville, 2004). Secondly, Shanks (1966) only collected L-DDK data on the syllable /hʌ/. To collect a true sample of L-DDK, the author should have collected both the /hʌ/ and /ʌ/ syllables. This would account for both abductory and adductory patterns of L-DDK tasks. Although the findings of the research suggest that the aging population may perform worse on L-DDK tasks than the young adult population would perform, L-DDK normative data ranges are lacking. It is difficult to correctly establish whether a client is performing within a normal range for their age without L-DDK normative data.

According to Hall and Sinard (1998), it is crucial for a speech-language pathologist to be able to distinguish the difference between voice changes due to the normal aging process and voice changes in aging individuals due to a disorder. Hall and Sinard (1998) also state that “unfortunately, there are no objective tests that can reliably make this distinction,” (p. 76). Laryngeal diadochokinesis could be a useful,
objective tool for speech-language pathologists to use in their practice to quickly gather information on their patient’s laryngeal function.

Disease Affecting Laryngeal Function in Aged Individuals

Understanding the ways in which degenerative neurologic diseases, such as Parkinson’s disease and amyotrophic lateral sclerosis, affect laryngeal function may help identify the value of normative data for L-DDK tasks. Utilization of normative data on L-DDK can potentially help speech-language pathologists, in the future, make early referrals to physicians for symptoms consistent with these diseases.

Parkinson’s Disease

Parkinson’s disease is a progressive neurological disorder that results from degeneration of neurons that control motor movement (“National Institute of Neurological Disorders and Stroke,” 2004). According to the National Institute of Neurological Disorders and Stroke (2004), at least 500,000 people have been reported to have a diagnosis of Parkinson’s disease in the United States. Around 50,000 new cases of Parkinson’s are reported each year and the incidence rates are expected to rise as the baby boomer population ages (“National Institute of Neurological Disorders and Stroke,” 2004). The rising number of diagnosed Parkinson’s disease cases supports the fact that speech-language pathologists will need a quick and noninvasive diagnostic tool to help diagnose these patients as efficiently and effectively as possible.

Parkinson’s disease patients often experience changes to their vocal quality as one of the first symptoms of the disease. Parkinson’s disease patients frequently have difficulty initiating phonation and often produce short segments of poorly articulated
speech (Yorkston, Miller, & Strand, 2004). Difficulty initiating phonation can lead to difficulty initiating L-DDK tasks. Parkinson’s patients often exhibit impaired communication abilities and a disordered voice (Justice, 2010). The degeneration of neurons in Parkinson’s disease weakens the respiratory system and creates rigid muscular tone (Justice, 2010). A weakened respiratory system results in patients having difficulty producing a strong voice, and rigid muscular tone restricts the movement of the laryngeal muscles. Therefore, a weakened respiratory system may lead to a monotone pitch and hoarseness of the voice (Justice, 2010). A weak respiratory system and rigid muscular tone would inhibit a Parkinson’s patient from being able to accurately complete the rapid articulatory movements needed for L-DDK.

Research has been completed to support the information already known about Parkinson’s patients’ inability to complete L-DDK tasks. In a study comparing the voices of 17 male participants with Parkinson’s with a median age of 56 years to 17 normally speaking males with a median age of 56 years performing rapid syllable repetition, Parkinson’s participants were impaired in their ability to produce rapid articulatory movements (Canter, 1965). Canter defined complete freezing as a speech pattern produced independently for a 30-second period. For example, if the patient was asked to rapidly articulate the /hʌ/ syllable, they would hold the sound out for 30 seconds before repeating the syllable. Complete freezing of speech occurred only among the Parkinson group in this study (Canter, 1965).

A weakness in the design and method of this study is the fact that Canter (1965) only tested the /hʌ/ syllable. In order to have a full perspective of laryngeal functioning
when testing DDK scores, it is important to test both the /hʌ/ and /ʌ/ syllables. This not only gives the clinician more scores to rely on, but it strengthens the test reliability. This weakness, although not fatal, shows that further research on L-DDK in Parkinson’s patients is needed to strengthen these results. Not only is further research needed on Parkinson’s patients with respect to laryngeal function, but it is important to have normative data on L-DDK to compare rates among Parkinson’s patients as well. Being able to compare the L-DDK rates of patient populations with normal subjects is an important and useful tool for speech-language pathologists to be able to identify a disordered population.

In another study, Verdolini and Palmer (1997) researched how s:z ratio and L-DDK measures can accurately detect the presence of organic abnormalities affecting the larynx. The study consisted of 45 adults, ten of which had Parkinson’s disease. The other participants in the study presented either a normal voice and larynx or one of a variety of disorders including nodules, granulomas, unilateral abductor paralysis, Parkinson’s disease, or functional voice disorder (Verdolini & Palmer, 1997). Laryngeal diadochokinesis was scored based on rate, strength, and rhythmia. Rate was measured by calculating the total number of glottal plosives produced by the participant and dividing it by seven (because the rates were collected during 7-second intervals). The authors of the study measured strength and rhythmia perceptually. Verdolini and Palmer (1997) found that nine of ten participants with Parkinson’s disease performed poorly on the rate, strength, and rhythmia of L-DDK rates compared to the other participants in the study. The authors also found that use of s:z ratio and L-DDK rate,
strength, and rhythmia may produce data that could have value in detecting organic
abnormalities of the larynx (Verdolini & Palmer, 1997).

Although the method and design of the study completed by Verdolini and
Palmer (1997) were strong from a research perspective, there were still aspects that
could have been done differently to strengthen their study. First of all, the authors of
the study only collected L-DDK data on the /ʌ/ syllable. To collect a true sample of L-
DDK, the authors should have collected both the /ʌ/ and /ʌ/ syllables. Laryngeal
diadochokinesis rates were also obtained by merely having a speech-language
pathologist dot a piece of paper every time they heard a glottal stop. Although this is a
method that has been accepted in the field, a recording of the L-DDK rates should have
been taken so that more than one person could have counted in order to strengthen
inter-rater reliability. The authors of the article also rated the glottal stops of L-DDK
rates as either poor or good as soon as they collected the data. These labels are
arbitrary and pose a threat to test-retest reliability because they are subjective. These
measures could not be readily replicated by anyone other than the speech-language
pathologists who originally collected the data, which would make it difficult for anyone
to replicate the study.

While these studies clearly show differences in L-DDK tasks for patients with
Parkinson’s disease, it is difficult to apply these findings to new Parkinson’s patients due
to the fact that research on L-DDK lacks normative data ranges for comparison. A
normative sample of L-DDK ranges for the aging population would give speech-language
pathologists definitive numbers to compare patients to in order to diagnose them as disordered.

**Amyotrophic Lateral Sclerosis**

Amyotrophic lateral sclerosis (ALS), also known as Lou Gehrig’s disease, is a rapidly progressing motor-neuron disease that results in severe deterioration of motor systems and muscles in the body (Justice, 2010). As motor neurons within the body degenerate and die, the ability of the brain to initiate and control movement of muscles is lost. According to the ALS Association (2010), ALS affects as many as 30,000 Americans at any time. Approximately 5,600 people are diagnosed with ALS each year (“ALS Association,” 2010).

The inability to control movement of muscles in ALS undoubtedly has a negative impact on the function of the vocal folds and laryngeal structures within the body. Although all persons with ALS experience some type of dysphagia and varying severities of dysarthria, the disease does not typically impact their cognitive awareness (Justice, 2010). Amyotrophic lateral sclerosis patients often develop severely dysarthric speech that progresses over time into completely unintelligible speech (Justice, 2010). Amyotrophic lateral sclerosis patients often exhibit a soft, breathy, low pitched, hypernasal voice (Justice, 2010). Coordination of muscles is often difficult for ALS patients, frequently resulting in poor articulation (Case, 1996). Loss of coordination of muscles will result in loss of coordination of the vocal folds. Loss of control of laryngeal articulation would clearly lead to difficulty or even the inability to complete L-DDK tasks.
The statements above have been supported by research on L-DDK rates of ALS patients. In a study completed by Renout et al., (1995), 26 men and women with bulbar and nonbulbar ALS were examined on the rate, pattern, and periodicity of vocal fold diadochokinesis (also known as L-DDK) tasks. These participants were recorded and asked to repeat the /hʌ/ syllable as many times as possible within one breath. It was found that reduced L-DDK rates and aperiodic vocal fold function increased with the length of time that the participants had been diagnosed with the disease (Renout et al., 1995).

Although this study completed by Renout et al. (1995) supports the fact that ALS patients have difficulty due to their loss of muscle coordination and control, there are weaknesses to the study. First, a larger sample size would have strengthened the external validity of the study. Secondly, the authors of the study only tested the participants on the /hʌ/ syllable, when the /ʌ/ sound can be considered a diadochokinetic measure as well. Normative L-DDK data would serve as an important clinical tool to compare to ALS participant L-DDK rates. Thirdly, the participants in this study were evaluated in two 30-minute sessions that had a mean duration of 142 days from one session to another. The fact that ALS is a degenerative disease would result in poorer performance over the duration of the study.

Studies have supported the use of L-DDK as clinical tool in identifying a disordered population in degenerating diseases such as Parkinson’s disease and ALS. Although more research needs to be completed to solidify the findings above, the
collection of normative data on L-DDK rates would serve as an important clinical tool for speech-language pathologists to use when diagnosing these populations.

**Clinical Reliability of Diadochokinesis**

Although oral and laryngeal diadochokinesis are used as clinical tools for identifying normal functioning populations and to diagnose disordered populations, it should be acknowledged that reliability and validity weaknesses exist. Because DDK and L-DDK rates are often obtained perceptually in a clinical setting, it is unclear as to whether these perceptual judgments are reliable measures. Therefore, L-DDK rates should be collected objectively and then compared to perceptual measures in the future.

As stated throughout this literature review, many researchers have claimed that L-DDK could be a useful clinical tool in assessing disordered populations. Most of the research on L-DDK, however, only assesses one of the two L-DDK tasks. For example, Canter (1965), Shanks (1966), and Renout et al. (1995) only assessed the abductory task /ʌ/ in their research. On the other hand, Ptacek et al. (1966), Leeper & Jones (1991), and Verdolini & Palmer (1997) only assessed the adductory task /ʌ/. In order to strengthen validity of L-DDK rates, obtaining both the adductory task /ʌ/ and the abductory task /ʌ/ should be collected and compared. Comparison of both abductory and adductory L-DDK measurements can provide the most valid information on laryngeal functioning.

Research has been conducted to test the reliability of DDK test measurements. In a research study conducted by Gadesmann and Miller (2006), ten speech-language
pathologists and ten untrained controls rated 12 DDK samples of speakers with different neurological speech disorders. The perceptually rated scores of the speech-language pathologists were compared to the untrained control group for inter-rater reliability. The perceptually rated scores from both the speech-language pathologists and the untrained control group were then compared to the objective measurements from sound spectrograms. The authors of the study found that inter- and intra-rater reliability was lower than should be acceptable for clinical diagnostic and outcome assessment. Gadesmann and Miller (2006) also stated that more research is necessary to prove DDK as a clinically reliable tool for diagnostic measurements.

Although research exists challenging the reliability of DDK measures, no studies have been completed on the reliability of L-DDK rates. It is important to collect normative L-DDK data on both adductory and abductory tasks to prove L-DDK as a reliable and valid measurement of laryngeal function in future research.

**Summary and Statement of the Problem**

Research supporting L-DDK as a useful clinical tool in speech-language pathology has been discussed throughout the literature review. It is evident, however, that the current research performed on L-DDK presents weaknesses that need to be addressed.

Laryngeal diadochokinesis tasks have been used in previous studies with Parkinson’s disease (Canter, 1965; Verdolini & Palmer, 1997), ALS (Renout et al., 1995), normally aging (Parnell & Amerman, 1987; Ptacek et al., 1966), and normal laryngeal functioning patients (Leeper & Jones, 1991; Shanks, 1966). It has been noted in previous research that L-DDK rates could be an indicator of organic abnormalities within
the larynx (Verdolini & Palmer, 1997). Aging individuals have been reported to have lower L-DDK rates than early adults and adults (Shanks, 1966; Canter 1965; Ptacek et al., 1966). It has also been noted that L-DDK rates in disordered populations, such as Parkinson’s patients and ALS patients fall in a much lower range, overall, than those of normal speaking populations (Canter, 1965; Verdolini & Palmer, 1997; Renout et al., 1995).

It is clear that L-DDK has been used in many studies in an attempt to prove that it is a potentially useful clinical tool for assessment and intervention with disordered populations. However, in order to maximize the clinical usefulness of this measure, normative L-DDK data for both men and women needs to be acquired. This normative data can serve as a comparison for identifying normal or disordered laryngeal function. The current overall gap in research, however, is that there is a lack of normative L-DDK data in both men and women of all ages to which patients with suspected disorders could be compared.
CHAPTER II

PURPOSE

Inconsistencies among reported laryngeal diadochokinesis rates exist in all studies that have been completed in the past. Not only are there inconsistencies in the research, but also the inability to compare the data collected in research to normative L-DDK data in men and women reduces the accuracy with which these rates for disordered subjects have been interpreted. Laryngeal diadochokinesis could be a non-invasive and cost-effective way for speech-language pathologists to assess normal laryngeal functioning in a clinical setting.

Based on the observations made above, research completed on normative L-DDK data in males and females between the age of 60 and 90 years is needed in order to identify laryngeal function in a normal population. For this purpose, the following questions were addressed in this study:

(1) Is there a difference between laryngeal diadochokinetetic rates for the adductory task /ʌ/ and the abductory task /hʌ/ in adults between the ages of 60 and 90 years?

(2) What are the normative values for laryngeal diadochokinetic rate for the adductory task /ʌ/ and the abductory task /hʌ/ in adults between the ages of 60 and 90 years?

(3) Is there a difference between normative values of laryngeal diadochokentic rate for males and females between the ages of 60 and 90 years?
CHAPTER III

METHOD

Design

This study is a subset of an existing IRB approved study (11-131) by Dr. Lori Lombard (primary investigator) that aims to bridge the gap in previous literature by collecting normative laryngeal diadochokinesis data on both men and women across the adult lifespan (ages 20-90 years). This student investigator has been a co-investigator on the larger study since December 5, 2011. In that time, this student investigator has been involved with data collection and management. The current study subset focuses on the normal aging adult (60 – 90 year) population in both males and females.

Normative data on L-DDK rates in the normal aging population were collected and compared in the current study. Laryngeal diadochokinetic rates for adductory and abductory tasks were compared using a differential research design. Differential research designs are used when comparing two or more groups of participants. In the present study, participants are grouped by gender (Graziano & Raulin, 2007). Therefore, gender serves as the independent variable of this study where L-DDK tasks operate as the dependent variable.

Participants

Participant Selection

Thirty-nine participants between the ages of 60 and 90 years were selected to participate in the study. Individuals that met the inclusion criteria were required to complete the Voluntary Consent Form in order to participate in the study.
Recruitment

The investigators of this study recruited family members, friends, neighbors, coworkers, and family friends to participate in the study. Individuals who met the inclusion criteria (described below) to participate in the study were provided with a copy of the *Informed Consent Form*. This form identifies the risk, benefit, and procedures for participating in the study. Each participant was then required to sign the *Voluntary Consent Form* to confirm the fact that they understand the risks, benefits, and requirements of choosing to participate in the study. The protocol, *Informed Consent Form*, and *Voluntary Consent Form* were reviewed and approved by the Indiana University of Pennsylvania Institutional Review Board (Approval ID: 11-131).

Inclusion and Exclusion Criteria

In order to be considered for the study, participants were required to have perceptually normal voice quality and no known laryngeal abnormalities. The participant’s voice quality was evaluated by an experienced speech-language pathologist using the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V) (“Consensus Auditory-Perceptual Evaluation of Voice [CAPE-V],” 2006). Exclusion criteria included the participant having one or more of the following conditions: (a) a score of over 20 on the CAPE-V; (b) no vulnerability as defined by IRB terminology; (c) symptoms of cold or illness on the day of testing; (d) history of respiratory, laryngeal, or neurologic disease; (e) previous surgeries of the larynx; (f) history of structural or dynamic laryngeal abnormalities; (f) profound hearing loss; and (g) lack of comprehension of the task.
Final Sample Size

Forty-four participants were recruited for the study. Four (three female and one male) participants were excluded from the study secondary to the microphone not recording during data collection. One participant was excluded from the study due to having a medical history of a previous stroke and speech therapy services. The final sample size of the study included 39 healthy normally aging participants (22 females and 17 males) ranging in age from 60 – 90 years old.

Data Collection

Participants were asked to complete four tasks: (a) produce L-DDK tasks /ʌ/ and /hʌ/ for seven seconds three times each; (b) sustain the vowels /a/ and /i/ for five seconds three times each; (c) read six sentences; and (d) maintain natural conversation for thirty seconds. All tasks completed by the participants, with the exception of producing L-DDK tasks /ʌ/ and /hʌ/ for seven seconds three times each, were acquired from the CAPE-V protocol (“Consensus Auditory-Perceptual Evaluation of Voice [CAPE-V],” 2006). All four tasks were recorded in a quiet room using a Roland CD-2 CF/CD Recorder and recordings were copied onto a recordable CD-ROM. Participants were asked to sit six inches away from an Audio-Technica ATR20 Dynamic Cardioid Low Impedance Professional Microphone (Leeper & Jones, 1991). Participants were provided with the following verbal instructions, based upon the Fletcher (1972) study, when completing L-DDK /ʌ/ and /hʌ/ tasks:

“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 7 seconds three times. I'll tell you when to start. Don't stop until I tell you. Ready. (Start recording).

Now I would like you to perform the same task, but this time with the sound . . . (/ʌ/ or /hʌ/).”

Participants completed three trials of each sound to ensure consistency of measurements across tasks. Calculating all three measurements of L-DDK tasks ensures reliability across tasks.

After performing the L-DDK tasks, participants were asked to produce the voice samples necessary to implement the CAPE-V perceptual assessment of their voice quality as inclusion criteria study. Participants sustained the lax vowel /a/ and the tense vowel /i/ for five seconds three times each. They were asked to try not to “sing” the vowels, but to rather just produce the sound without vibrato. After sustaining the vowel sounds, participants were asked to read six sentences aloud. These six sentences were used to measure laryngeal behavior and included: (a) 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. For the final task, participants were asked to give a thirty second speech sample using a simple prompt question such as: “Tell me what you did yesterday” or “Tell me a little bit about yourself” (“Consensus Auditory-Perceptual Evaluation of Voice [CAPE-V],” 2006).
**Measurement Procedures**

Measurements collected for this study were converted into oscillogram audio file tracks using Multidimensional Voice Program™ software (MDVP). All three repetitions of both adductory and abductory tasks for each participant were converted into an oscillogram for analysis. The beginning .5 second of the converted oscillograms was deleted to ensure consistency of the task. The following 5 seconds was then used for analysis. The number of amplitude peaks (representing one repetition of /ʌ/ or /hʌ/) on the oscillogram for each 5 second segment was counted to calculate repetitions per second. The amplitude peaks were confirmed with audio playback to represent a production of the intended syllable. The number of peaks was then divided by 5 to determine repetitions per second (Leeper & Jones, 1991; Ptacek et al., 1966; Renout et al., 1995; Shanks, 1996).

**Ethical Use of Data**

All data collected were used only for the purpose of this study. The current study is a subset of an existing IRB approved study collecting normative L-DDK data across the adult lifespan by Dr. Lori Lombard. All participants were assigned a file number. No identifying information from participants was included on recordings or data collection paperwork. All identifying information was stored in a locked office and only available to the investigators of this study. Upon completion of the larger study, all data and recordings will be destroyed.
Statistical Analysis

A mixed ANOVA (analysis of variance) statistical analysis was used for this study ("SPSS Statistics Data Editor," 2010). ANOVA is defined by Graziano & Raulin (2007) as a “statistical procedure that analyzes mean differences between two or more groups by comparing between-groups and within-groups variance,” (p. 403). In the current study, the within-groups variance answers whether there is a difference between L-DDK rates for the adductory task /ʌ/ and the abductory task /ʌ/ and what normative values are for the adductory task /ʌ/ and the abductory task /ʌ/ in adults between the ages of 60 and 90 years. The between-groups variance measures whether there is a difference between normative values of L-DDK rate for males and females.

The first analysis was implemented to determine whether there is a difference between L-DDK rates for the adductory task /ʌ/ and the abductory task /ʌ/ in adults between the ages of 60 and 90 years. The previous question was summarized using a multivariate test analysis. A multivariate test answers whether there is a change in rate over time for two different groups. Results are summarized in Table 1, *Multivariate Tests for Production Rates*.

The second analysis was to determine what the normative values are for the adductory task /ʌ/ and the abductory task /ʌ/ in adults between the ages of 60 and 90 years. The previous question was summarized using a descriptive statistics analysis. Descriptive statistics summarize and/or describe a sample of scores (Graziano & Raulin, 2007). Results are summarized Table 2, *Descriptive Statistics for Repetitions for Five Seconds* and Table 3, *Descriptive Statistics for Repetitions for One Second*. 
The third and final analysis was to determine whether there is a difference between normative values of L-DDK rates for males and females. This was summarized using tests of between-subjects effects. This analysis compared normative L-DDK rates between males and females. Results are summarized in Table 4, *Between-Subjects Effects for L-DDK Rates*. Results are also summarized in Graph 1, *Estimated Marginal Means of L-DDK Rates Between Males and Females*. 
CHAPTER IV

RESULTS

Results revealed no statistically significant difference between laryngeal diadochokinetic rates for the adductory task /ʌ/ and the abductory task /hʌ/ (.75, F(5.00, 33.00) = .75, \( p = .08 \)). Normative L-DDK data consisting of mean, standard deviation, and range was collected for both males and female between the ages of 60 and 90. Statistical significance was found between gender (\( p = .02 \)).

The first ANOVA was completed to determine whether there is a difference between L-DDK rates for the adductory task /ʌ/ and the abductory task /hʌ/ in adults between the ages of 60 and 90 years. Results revealed no statistically significant interaction effect for L-DDK rate using an alpha of .05, Wilks' Lamda = .75 F(5.00, 33.00) = .75, \( p = .08 \). Results are summarized in Table 1, Multivariate Tests for Production Rates.

Table 1

Multivariate Tests for Production Rates

<table>
<thead>
<tr>
<th>Effect</th>
<th>Value</th>
<th>F</th>
<th>Hypothesis df</th>
<th>Error df</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Rates</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wilks' Lambda</td>
<td>.75</td>
<td>2.22</td>
<td>5.00</td>
<td>33.00</td>
<td>.08</td>
<td>.25</td>
</tr>
</tbody>
</table>
The second ANOVA was completed to determine what the normative values are for the adductory task /ʌ/ and the abductory task /hʌ/ in adults between the ages of 60 and 90 years. Normative data for /ʌ/ in males was $M=22.35$ repetitions per five seconds (range=15-29 repetitions per five seconds; $SD=3.94$) and for females $M=18.30$ repetitions per five seconds (range=7-28 repetitions per five seconds; $SD=5.21$). Normative data for /hʌ/ in males was $M=19.51$ repetitions per five seconds (range=9-28 repetitions per five seconds; $SD=4.12$) and for females $M=17.30$ repetitions per five seconds (range=8-27 repetitions per five seconds; $SD=4.55$). Mean, standard deviation, and range for total repetitions per five seconds are summarized in Table 2, *Descriptive Statistics for Repetitions for Five Seconds*. Normative data for /ʌ/ in males was $M=4.47$ repetitions per second (range=3.0–5.8 repetitions per second; $SD=0.79$) and for females $M=3.66$ repetitions per second (range=1.4-5.6 repetitions per second; $SD=1.04$). Normative data for /hʌ/ in males was $M=3.90$ repetitions per second (range=1.4-5.6 repetitions per second; $SD=0.82$) and for females $M=3.46$ repetitions per second (range=1.6-5.4 repetitions per second; $SD=0.91$). Mean, standard deviation, and range for total repetitions per one second are summarized in Table 3, *Descriptive Statistics for Repetitions for One Second*. 
Table 2

*Descriptive Statistics for Total Repetitions for Five Seconds*

<table>
<thead>
<tr>
<th>Trial Segment</th>
<th>Gender</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Range</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>/ʌ/ Trial 1</td>
<td>m</td>
<td>22.59</td>
<td>4.24</td>
<td>15-29</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>19.36</td>
<td>4.91</td>
<td>10-28</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>20.77</td>
<td>4.85</td>
<td>10-29</td>
<td>39</td>
</tr>
<tr>
<td>/ʌ/ Trial 2</td>
<td>m</td>
<td>22.47</td>
<td>3.74</td>
<td>16-29</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>18.14</td>
<td>5.33</td>
<td>8-28</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>20.03</td>
<td>5.13</td>
<td>8-29</td>
<td>39</td>
</tr>
<tr>
<td>/ʌ/ Trial 3</td>
<td>m</td>
<td>22.00</td>
<td>3.84</td>
<td>16-28</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>17.41</td>
<td>5.41</td>
<td>7-26</td>
<td>22</td>
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<tr>
<td></td>
<td>Total</td>
<td>19.41</td>
<td>5.27</td>
<td>7-28</td>
<td>39</td>
</tr>
<tr>
<td>/hʌ/ Trial 1</td>
<td>m</td>
<td>19.94</td>
<td>4.72</td>
<td>9-28</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>18.50</td>
<td>4.84</td>
<td>8-27</td>
<td>22</td>
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<tr>
<td></td>
<td>Total</td>
<td>19.13</td>
<td>4.78</td>
<td>8-28</td>
<td>39</td>
</tr>
<tr>
<td>/hʌ/ Trial 2</td>
<td>m</td>
<td>19.88</td>
<td>3.79</td>
<td>14-26</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>16.73</td>
<td>4.30</td>
<td>9-22</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>18.10</td>
<td>4.33</td>
<td>9-26</td>
<td>39</td>
</tr>
<tr>
<td>/hʌ/ Trial 3</td>
<td>m</td>
<td>18.71</td>
<td>3.85</td>
<td>12-27</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>16.68</td>
<td>4.51</td>
<td>9-23</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>17.56</td>
<td>4.30</td>
<td>9-27</td>
<td>39</td>
</tr>
</tbody>
</table>
Table 3

*Descriptive Statistics for Total Repetitions for One Second*

<table>
<thead>
<tr>
<th>Trial Segment</th>
<th>Gender</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Range</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>/ʌ/ Trial 1</td>
<td>m</td>
<td>4.52</td>
<td>0.85</td>
<td>3-5.8</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>3.87</td>
<td>0.98</td>
<td>2-5.6</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>4.15</td>
<td>0.97</td>
<td>2-5.8</td>
<td>39</td>
</tr>
<tr>
<td>/ʌ/ Trial 2</td>
<td>m</td>
<td>4.49</td>
<td>0.75</td>
<td>3.2-5.8</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>3.63</td>
<td>1.07</td>
<td>1.6-5.6</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>4.01</td>
<td>1.03</td>
<td>1.6-5.8</td>
<td>39</td>
</tr>
<tr>
<td>/ʌ/ Trial 3</td>
<td>m</td>
<td>4.40</td>
<td>0.77</td>
<td>3.2-5.6</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>3.48</td>
<td>1.08</td>
<td>1.4-5.2</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>3.88</td>
<td>1.05</td>
<td>1.4-5.8</td>
<td>39</td>
</tr>
<tr>
<td>/hʌ/ Trial 1</td>
<td>m</td>
<td>3.99</td>
<td>0.94</td>
<td>1.8-5.6</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>3.70</td>
<td>0.97</td>
<td>1.6-5.4</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>3.83</td>
<td>0.96</td>
<td>1.6-5.6</td>
<td>39</td>
</tr>
<tr>
<td>/hʌ/ Trial 2</td>
<td>m</td>
<td>3.98</td>
<td>0.76</td>
<td>1.4-5.2</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>3.35</td>
<td>0.86</td>
<td>1.8-4.4</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>3.62</td>
<td>0.87</td>
<td>1.8-4.4</td>
<td>39</td>
</tr>
<tr>
<td>/hʌ/ Trial 3</td>
<td>m</td>
<td>3.74</td>
<td>0.77</td>
<td>2.4-5.4</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>3.34</td>
<td>0.90</td>
<td>1.8-4.6</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>3.51</td>
<td>0.86</td>
<td>1.8-5.4</td>
<td>39</td>
</tr>
</tbody>
</table>
The third and final ANOVA was completed to determine whether there is a difference between normative values of L-DDK rates for males and females. Tests of Between-Subject Effects results revealed a statistically significant difference between normative values ($p=0.02$) when averaging and comparing both adductory task /ʌ/ and the abductory task /hʌ/. Gender differences were significant for both L-DDK tasks. Results for both tasks averaged and compared are summarized in Table 4, *Between-Subjects Effects for L-DDK Rates*. Results for both tasks compared individually are also summarized in Graph 1, *Estimated Marginal Means of L-DDK Rates Between Males and Females*.

Table 4

*Between-Subjects Effects for L-DDK Rates*

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>86328.06</td>
<td>1</td>
<td>86328.06</td>
<td>847.27</td>
<td>.00</td>
<td>.96</td>
</tr>
<tr>
<td>Gender</td>
<td>563.10</td>
<td>1</td>
<td>563.10</td>
<td>5.56</td>
<td>.02</td>
<td>.13</td>
</tr>
<tr>
<td>Error</td>
<td>3769.89</td>
<td>37</td>
<td>101.89</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Graph 1

*Estimated Marginal Means of L-DDK Rates Between Males and Females*

<table>
<thead>
<tr>
<th></th>
<th>/ʌ/ Trial 1</th>
<th>/ʌ/ Trial 2</th>
<th>/ʌ/ Trial 3</th>
<th>/hʌ/ Trial 1</th>
<th>/hʌ/ Trial 2</th>
<th>/hʌ/ Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>22.59</td>
<td>22.47</td>
<td>22</td>
<td>19.94</td>
<td>19.88</td>
<td>18.71</td>
</tr>
<tr>
<td>Females</td>
<td>19.36</td>
<td>18.14</td>
<td>17.41</td>
<td>18.5</td>
<td>16.73</td>
<td>16.68</td>
</tr>
</tbody>
</table>
Previous research involving laryngeal diadochokinesis has been conducted using inconsistent measurement techniques from study to study on how to obtain a true L-DDK score. Although it is evident that L-DDK could be used as a useful clinical tool to assess both normal and disordered populations, normative data on L-DDK rates is lacking in the literature. The current study asked the following three questions: (1) Is there a difference between L-DDK rates for the adductory task /ʌ/ and the abductory task /hʌ/ in adults between the ages of 60 and 90 years?; (2) What are the normative values for L-DDK rate for the adductory task /ʌ/ and the abductory task /hʌ/ in adults between the ages of 60 and 90 years?; and (3) Is there a difference between normative values of L-DDK rate for males and females?

First, results revealed no statistical significance between L-DDK rates for the adductory task /ʌ/ and the abductory task /hʌ/ (.75, F(5.00, 33.00) = .75, p=.08). The abductory task /hʌ/ requires more respiratory control to manage the extra air being released during the abductory segment /hʌ/ of the syllable. The adductory task /ʌ/ requires fine motor control of the vocal folds to manage the extra medial compression and subglottic pressure of continuous adduction during syllable production. It can be inferred that as the normal aging process occurs, the fine motor control of the phonatory system changes with relative similarity during both the adductory and abductory tasks. The lack of a significant difference may indicate that L-DDK measures
may only need to include one of the phonatory tasks. It is yet to be determined how the
tasks differ on other L-DDK measures of strength and consistency.

Secondly, normative values for the adductory task \(/\lambda/\) and the abductory task
\(/h\lambda/\) in adults between the ages of 60 and 90 years were reported. Inconsistencies in the
methods collection in previous studies, such as only collecting one of the two L-DDK
tasks (adductory \(/\lambda/\) or abductory \(/h\lambda/\)), differences among number of trials collected,
and inconsistent directives to participants have been noted in the literature review.

Most research on L-DDK only assesses one of the two L-DDK tasks. For example, Canter
(1965), Shanks (1966), and Renout et al. (1995) only assessed the abductory task \(/h\lambda/\) in
their research. On the other hand, Ptacek et al., (1966), Leeper & Jones (1991), and
Verdolini & Palmer (1997) only assessed the adductory task \(/\lambda/\). The collection of both
the adductory task \(/\lambda/\) and the abductory task \(/h\lambda/\) strengthens the validity of L-DDK
data collected in the current study. Three trials of the L-DDK tasks also strengthens
validity when compared to research such as Canter (1965), who only collected one trial
of data. Precise directions given in this study ensure that all participants were given
clear directives on how to complete the task asked of them. Precise directions can also
ensure external validity if the study is ever replicated by another researcher.

The final analysis found a statistically significant gender difference in L-DDK rates
produced by adults between 60-90 years of age \((p=.02)\). It is interesting to find that
gender influences one’s rate in L-DDK tasks in the geriatric population. Shanks (1966)
suggested that the aging population might perform worse on L-DDK tasks than a young
adult population. Shanks (1966), however, only collected data from women on the
abductory task /hʌ/. Similarly, Ptacek et al. (1966) found that the geriatric population had lower rates on the L-DDK task /ʌ/ when compared to a young adult population. Although these findings are significant, there was no distinction between whether the geriatric participants were male or female. The current study found that men and women have significantly different L-DDK rates. This finding coincides with the fact that the effect of the natural laryngeal aging process in females differs significantly from that in males (Linville, 2004). It is also important to note that hormonal, structural, functional (Linville, 2004) and elasticity related (Ptacek et al., 1966) changes in the phonatory and respiratory systems occur throughout the natural aging process at different rates for different individuals. This factor could have also affected the statistical significance analysis. The finding of statistical significance in L-DDK rates between gender ($p=.02$) poses a question as to whether Ptacek et al. (1966)’s results would be affected if there were more females than males in the study or vice versa.
CHAPTER VI

LIMITATIONS

There were several limitations to the study that should be addressed in future research. First, a hearing test should be administered to ensure that participants have normal hearing. According to Shanks (1966), participants had lower L-DDK rates when their hearing was masked as opposed to when they were hearing normally. Natural hearing loss occurs as part of the normal aging process of the auditory system. Therefore, some participants in the study may have had hearing loss, which may or may not have affected their L-DDK rates. As stated in the literature review, it is extremely difficult to conduct a study with an adequate sample size when excluding person’s with a hearing loss due to the high prevalence of presbycusis in the geriatric population.

Another limitation to the study was the sample size. The total sample size for this study was 17 males and 22 females for a total of 39 participants. Additional research should utilize a larger participant pool to more adequately represent the normal laryngeal functioning geriatric population. A larger sample size would also strengthen external validity and make research results more powerful. It would also be interesting to have a sample size large enough to divide the participants into groups by decade rather than the expansive 30-year range.

Sample group sizes should also be similar for each gender. The current study utilized 39 participants (22 female and 17 male). Although this is an adequate sample size, the uneven group numbers could be a threat to the internal validity of the study.
The uneven group numbers could have affected the statistical significance in L-DDK rates between gender.

Previous studies on L-DDK have included measurements on strength, intensity, range, and rhythmia (Verdolini & Palmer, 1997; Leeper & Jones, 1991). The current study used an oscillogram to count the number of amplitude peaks (representing one repetition of /ʌ/) or /hʌ/). Future research would benefit from counting the peaks and rating strength, intensity, range, and rhythmia to further assess L-DDK function and to be able to compare data to previous studies more precisely.

Four participants (three female and one male) were excluded from the study secondary to the microphone not recording their data samples. Future research could benefit from making sure that there is replacement equipment from the same company and of the same model (to keep consistent measurement procedures). Having replacement equipment would ensure that data would not be lost due to equipment malfunctions.

The final limitation to the current study is that it did not account for systemic effects and behavior choices that may contribute to abnormal laryngeal and respiratory function. Systemic influences such as gastroesophageal reflux, allergies, hormones, and pharmaceuticals may affect laryngeal function (Stemple et al., 2000). Behavioral influences such as alcohol, tobacco, drug, and caffeine use may also affect laryngeal and respiratory function. Laryngeal function of some of the participants may have been affected by systemic effects or behavior choices, which may or may not have affected
their L-DDK rates. Future research should aim to monitor these behaviors in their participants and/or use them as exclusion criteria for the study.
CHAPTER VII

CONCLUSION

The current study aimed to bridge the gap in current literature by collecting L-DDK normative data on both males and females between the ages of 60 and 90. No statistical significance was found between the adductory task /ʌ/ and the abductory task /hʌ/. Statistical significance was found in L-DDK rate between gender.

The current study established the groundwork for a more comprehensive study to evaluate normative values for L-DDK. Further analysis of other L-DDK measures of consistency and strength of the data should be included to determine if the tasks differ. If not, the L-DDK procedure can be simplified by eliminating one of the tasks. Future research should focus on: (a) administering a hearing test to participants; (b) expanding the sample size; (c) ensuring that sample sizes are equal between groups; (d) collecting measurements on strength, range, and rhythmia; (e) utilizing replacement equipment to ensure consistency and prevent loss of data; and (f) monitoring systemic and behavioral effects that may influence laryngeal and respiratory function. Future research should also focus on collecting further L-DDK normative data on adolescent, young adult, and adult aged populations. Comparison of normative L-DDK rates with L-DDK rates of groups with neurological impairment and laryngeal abnormalities would also be important data to collect and assess in future research. Utilization of normative data on L-DDK can potentially help speech-language pathologists, in the future, make early referrals to physicians for symptoms consistent with these diseases.
The objective data collected serve as normative values that can be compared in future research to a perceptual task collected by speech-language pathologists in clinical settings. In the future, speech-language pathologists will hopefully be able to utilize the task of collecting perceptual L-DDK data as opposed to the objective task of using an oscillogram in a clinical setting to assess laryngeal and respiratory function.
REFERENCES


Appendix A

Informed Consent Form

Project Title: Laryngeal Diadokokinesis: Clinical measurement and age related values.

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

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

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

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

Professor
Speech-Language Pathology Program
Indiana University of Pennsylvania
203 Davis Hall
Indiana, PA 15705
Phone: 724/357-2450
llombard@iup.edu

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

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

Name (PLEASE PRINT)

__________________________________________________________

Signature

__________________________________________________________

Date _______________________

Phone number or location where you can be reached:

_____________________________________________________

Best days and times to reach you:

_____________________________________________________

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

___________________________

Date Investigator's Signature