THESIS

THE EFFECT OF GROUP VOCAL AND SINGING EXERCISES FOR INDIVIDUALS WITH PARKINSON'S DISEASE

Submitted by

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ABSTRACT

THE EFFECT OF GROUP VOCAL AND SINGING EXERCISES FOR INDIVIDUALS WITH PARKINSON'S DISEASE

The majority of individuals with Parkinson's disease (PD) experience voice and speech deficits, collectively called hypokinetic dysarthria; however, treatment outcomes are inconsistent and often unsustainable. The purpose of this study was to replicate the music therapy protocol for hypokinetic dysarthria (MTPHD) completed by Azekawa and LaGasse (2018) in an effort to investigate the effects of a group music therapy treatment for individuals who exhibited voice and speech deficits due to PD. The MTPHD consisted of three neurologic music therapy (NMT) techniques that specifically target voice and speech characteristics. A total of 17 participants with PD completed eight weekly group music therapy sessions. Pretest and posttest measurements were documented for three speech assessments to address vocal function, vocal quality, articulatory control, and connected speech intelligibility. Significant differences were found in vocal quality and the number of inter-word pauses. Positive trends were observed in all other measurements, indicating that music therapy may be a viable treatment option to address hypokinetic dysarthria in persons with PD.

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CHAPTER 1: INTRODUCTION

The purpose of this study was to investigate the effects of a group music therapy treatment for individuals who exhibited voice and speech deficits due to Parkinson's disease (PD). The treatment consisted of a group music therapy protocol (Music Therapy Protocol for Hypokinetic Dysarthria, MTPHD) that was based on three neurological music therapy (NMT) techniques to improve voice and speech deficits commonly seen in individuals with PD. These deficits include reduced volume of speech, monotone pitch and reduced prosody in speech, breathy and hoarse voice quality, imprecise articulation, and varied rate of speech. The study examined the effect of MTPHD on vocal/phonatory function, vocal quality, articulatory control, and connected speech intelligibility by comparing baseline data and post-treatment data in adults with PD.

Parkinson's disease (PD) is the second most prevalent neurodegenerative disease after Alzheimer's disease, affecting approximately 1 million people in the U.S. and 10 million worldwide (Parkinson's Foundation, 2020; Parkinson's Foundation of the National Capital Area, 2020). PD can be effectively managed with medication, lifestyle choices, and surgery. The cause of PD is unknown (Galaz et al., 2016). The risk for developing this disease increases with age, with a prevalence rate of approximately 1.5% for people over the age of 65 (Galaz et al., 2016). In the U.S. alone, the estimated health care costs including treatment, social security, and loss of income reach $52 billion per year (Parkinson's Foundation, 2020). Due to the degenerative nature of this disease, persons with PD may be affected on a personal, social, and/or economic level, resulting in decreased quality of life.

Individuals with PD can present with a variety of motor and non-motor deficits, including muscular rigidity, tremor, postural instability, and bradykinesia (Anand & Stepp, 2015; Galaz et al., 2016; Skodda, 2011). Individuals might present with a weak voice, monotone pitch, difficulty initiating speech, or impaired articulation and dysprosody, altogether known as hypokinetic dysarthria, ultimately resulting in decreased speech intelligibility (Galaz et al., 2016; Tjaden & Wilding, 2011). An estimated 70% of individuals with PD develop hypokinetic dysarthria (Skodda, 2011). This can be one of the earliest signs of PD onset or it may develop as the disease progresses (Galaz et al., 2016). Current treatment for hypokinetic dysarthria includes speech therapy, pharmacological medication such as levodopa (L-dopa), and sometimes surgery (Anand & Stepp, 2015). Although access to these treatments and therapies may be available, they come at a high cost and long-term care is not routine for individuals with PD (Fogg-Rogers et al., 2016). Yinger and Lapointe (2012) state that fewer than 5% of people with PD receive speech treatment, which may indicate a lack of diagnosis for hypokinetic dysarthria, ineffective treatment, or a dissatisfaction with long-term results. Researchers have brought forth music therapy as an additional treatment option to address voice and speech deficits in persons with PD (Azekawa & LaGasse, 2018; Fogg-Rogers et al., 2016).

Researchers have promoted music therapy as a viable treatment for speech deficits such as dysarthria, dyspraxia, aphasia, dysphonia and dysprosody (Stegemöller, 2017). Preferred music is often used in choral or singing programs, alongside Neurologic Music Therapy (NMT) techniques, to utilize undamaged neural pathways that may result in speech maintenance or improvement (Stegemöller, 2017). Researchers have presented multiple protocols to address voice and speech deficits; however, the literature has confounds such as small sample sizes, varying speech and neurologic impairments, and irregular protocol content, making the findings of these studies difficult to generalize (Fogg-Rogers et al., 2016; Tamplin & Baker, 2017). Tamplin & Baker (2017) expressed that, at this time, more replication studies are needed to test the existing singing-based therapeutic speech protocols. In a recent study, Azekawa & LaGasse (2018) measured differences in vocal function, vocal quality, and articulatory control of individuals with PD who were receiving weekly music therapy to address voice and speech deficits. The purpose of the present study is to replicate the same protocol in an effort to verify the results of using MTPHD to address speech and language needs for individuals with PD.

The following hypotheses are proposed to investigate the effectiveness of the music therapy protocol (MTPHD) to address voice and speech deficits in persons with PD:

1. Music Therapy Protocol for Hypokinetic Dysarthria will produce a pre and posttest difference in vocal function of the participants, measured through the duration of sustained vowel phonation and vocal tract function steadiness, using the first (f1) and second (f2) formants during sustained vowel phonation task as compared to their baseline levels.
2. Music Therapy Protocol for Hypokinetic Dysarthria will produce a pre and posttest difference in vocal quality of the participants, measured through jitter, shimmer, and Harmonics-to-Noise Ratio during sustained vowel phonation tasks as compared to their baseline levels.
3. Music Therapy Protocol for Hypokinetic Dysarthria will produce a pre and posttest difference in articulatory control of the participants, measured through the rate of sequenced syllable repetitions during diadochokinesis test as compared to the baseline levels.
4. Music Therapy Protocol for Hypokinetic Dysarthria will produce a pre and posttest difference in speech intelligibility of the participants, measured by the number of inter-word pauses and the mean duration of the inter-word pauses during the passage reading task as compared to the baseline levels.

CHAPTER 2: LITERATURE REVIEW

Parkinson's Disease: Overview

The National Institutes of Health (2016) describe the older adult population as a growing class of individuals. With this knowledge, the prevalence of Parkinson's disease (PD) can be expected to increase over time. PD is a neurodegenerative disease that currently affects nearly 1 million individuals in the U.S. (Parkinson's Foundation, 2020; Parkinson's Foundation of the National Capital Area, 2020), but this slowly progressing disease has a significant impact not only on the quality of life for the diagnosed individual, but on their family, friends, and caregivers as well. With a prevalence rate of 1% - 2% of individuals over the age of 65 and 3% - 5% of individuals over 85 (Fahn, 2003; Galaz et al., 2016), this disease not only affects the individual on a personal level, but it affects Americans on a national level.

PD was first described by the British physician James Parkinson in his work titled *An essay on the shaking palsy* (Parkinson, 1817). The term *shaking palsy* was used by Parkinson, along with other medical professionals at that time, but the disease was renamed by French neurologist Jean-Martin Charcot in Parkinson's honor (Barnett, 2016). In his studies, Parkinson observed that the disease, then called "paralysis agitans," came on gradually, starting with the hands and arms and then progressing through the rest of the body (Parkinson, 1817). He described six case studies of males over the age of 50 who exhibited symptoms such as tremor, stooped posture, reduced muscle control, and irregular gait patterns (Parkinson, 1817). Although speech and language symptoms were not the primary focus of his findings, he noted that his patients consistently experienced reduced oral motor control and speech intelligibility, varied speech rate, and inaccurate articulation (Parkinson, 1817).

The most documented symptoms for PD in current literature and James Parkinson's essay are reduced motor control (Martens, Van Nuffelen, Wouters, & De Bodt, 2016; Parkinson, 1817); however, speech and language deficits have a significant impact on the individual's communication skills, which can heavily impact quality of life. Roughly 90% of individuals with PD develop speech and voice symptoms such as harsh and breathy voice quality, reduced vocal loudness and prosody, impaired articulation, irregular speech rate, and overall lack of speech intelligibility (Anand & Stepp, 2015; Duffy, 2005; Tanner, Rammage, & Liu, 2016). Collectively, these symptoms can be referred to as hypokinetic dysarthria. With approximately one-third of modern jobs requiring voice use as a primary tool (Tanner, Rammage, & Liu, 2016; Vilkman, 2000), any speech difficulties directly interfere with communication. Therefore, speech and voice deficits can have a significant impact on social engagement, psychological well-being and economic status (Oxtoby, 1982).

Neuropathophysiology of Parkinson's Disease

There is currently no cure for PD and the etiology of the disease is unknown. Researchers have explored the roles of both environmental factors and genetic predispositions and found that they both play important roles in the development of the disease (Bartels & Leenders, 2009; Nolte, 2016). This chronic idiopathic disease is characterized by the progressive loss of dopaminergic neurons in the basal nuclei, specifically substantia nigra pars compacta (SNc) (Galaz et al., 2016). Dopamine carries signals to the brain that are essential for typical movement and coordination; therefore, decreased dopamine levels in the brain lead to the motor symptoms seen in individuals with PD (Parkinson's Foundation of the National Capital Area, 2020). Basal nuclei are collections of cell bodies deep to the cortex that influence motor cortices (Stegemöller, 2017). The most commonly identified basal nuclei include the caudate nucleus and putamen (collectively called the striatum), globus pallidus interna (GPi) and globus pallidus externa (GPe), nucleus accumbens, subthalamic nucleus, and substantia nigra, which is made up of pars compacta (SNc) and pars reticulata (SNr) (Nolte, 2016).

The function of the basal nuclei involves motor control and learning. This includes motor tasks such as initiation of movement, providing sufficient impetus to see these movements executed fully, and attending to postural adjustments prior to movement (Stegemöller, 2017).

For movements involved in speech production, the basal nuclei are involved in the determination of volume, timing, and sequencing of the voice, movement patterns of the tongue and lips, breath control, and speech initiation (Bartels & Leenders, 2009; Murdock & Whelan, 2009; Stegemöller, 2017). These nuclei are connected to the cortex via paired parallel loops that either reinforce or suppress a planned behavior. The direct loop of the motor system promotes or reinforces movement, while the indirect loop inhibits movement (Nolte, 2016; Stegemöller, 2017). The ability to carry out desired movements and suppress undesirable ones requires the normal function of these loops. While there are many sources of input to the loops, the dopaminergic axons from the SNc are a particularly critical source of influence that facilitates movement. Reduction in dopamine deviates basal nuclei functioning away from facilitating movement toward inhibitory movement, resulting in hypokinetic signs associated with PD (Bartels & Leenders, 2009; Murdock & Whelan, 2009; Nolte, 2016). Although the basal nuclei do not directly issue motor commands, their influence on cortical motor regions are an indispensable part of voluntary movement, and their dysfunction can produce a range of movement disorders (Nolte, 2016).

Treatment for Hypokinetic Dysarthria

While there is currently no treatment to cure PD or stop the progression of the disease, researchers have found that symptoms can be managed in a variety of ways. The administration of levodopa (L-dopa) was developed in the late 1960s and continues to be a successful drug to treat PD (Parkinson's Foundation, 2020). Over time, it has become the "gold standard" therapy for PD (Lane, 2019), as it is synthesized in the brain into dopamine (Parkinson's Foundation, 2020). This drug has the potential to reverse some of the movement deficits that are so commonly seen with PD (Nolte, 2016). Although the effects of this medication on motor movements have been thoroughly researched, its effect on speech has rarely been examined (Skodda, Visser, & Schlegel, 2010). In a 2010 study, researchers administered short-term L-dopa and long-term dopaminergic treatment to 23 PD patients and found no significant difference in phonation, intonation, articulation, or speech velocity (Skodda, Visser, & Schlegel, 2010). While this treatment has been shown to effectively reduce motor symptoms such as rigidity and bradykinesia (Lane, 2019), its ability to address hypokinetic dysarthria has not been verified (Skodda, Visser, & Schlegel, 2010). L-dopa may be successful for some individuals; however, some patients have experienced a wearing off effect, wherein the effect of the medication fluctuates and will unpredictably start and stop working (Parkinson's Foundation, 2020). Dyskinesia (spontaneous, involuntary movements) has also been documented as a possible side effect of L-dopa if used over a period of approximately three to five years (Lane, 2019; Parkinson's Foundation, 2020). Surgery is a viable option for individuals who have exhausted all other options or who did not respond well to medication.

There are currently three different surgical treatments that address motor and speech symptoms for individuals with PD: deep brain stimulation (DBS), Duopa therapy, and lesion therapy (Parkinson's Foundation, 2020). DBS is an appropriate treatment for people living with PD for a minimum of four years and who have motor symptoms that could not be controlled through the use of medicine (Parkinson's Foundation, 2020). This treatment option involves the surgical implantation of a battery-operated medical device known as a neurostimulator, to distribute electrical stimulation to target areas of the brain that control movement (Parkinson's Foundation, 2020). Typical target areas include the thalamus, subthalamic nucleus, and part of the globus pallidus (Parkinson's Foundation, 2020). DBS has an average motor improvement of 40% and often decreases the need for medication by about 50%; however, several patients have reported mixed evaluations in terms of postoperative satisfaction (Geraedts et al., 2019). Risks of this surgery include infection, stroke, cognitive deficits, and reduced speech intelligibility (Parkinson's Foundation, 2020). Furthermore, DBS surgery may not be the right treatment for every individual with PD and although studies have shown benefits lasting at least five years (Parkinson's Foundation, 2020), there is still a risk that speech and language symptoms may worsen.

Duopa therapy is an alternative to the pill form of L-dopa, but this therapy combines L-dopa with carbidopa (a medication to prevent nausea) and pumps Duopa directly into the intestine in gel form (Parkinson's Foundation, 2020). This treatment has the same side effects as L-dopa but it has the potential to improve the fluctuation of motor symptoms.

Types of lesion therapies include thalamotomy (lesion to the thalamus), pallidotomy (lesion to the globus pallidus), and subthalamotomy (lesion to the subthalamus) (Parkinson's Foundation, 2020). After the lesion is created, movement symptoms such as tremor and rigidity are expected to improve within a six-week period (Parkinson's Foundation, 2020). Today, doctors rarely perform lesion therapy and furthermore, lesion therapy does not assist with speech and language deficits, leaving individuals experiencing hypokinetic dysarthria to seek out alternative treatment options (Parkinson's Foundation, 2020).

Speech therapy is an additional treatment option that has been shown to be most effective for individuals with PD (Yinger & Lapointe, 2012). The Lee Silverman Voice Treatment (LSVT)® LOUD is a thoroughly researched approach with positive speech outcomes for individuals with PD (LSVT Global, 2020; Ramig, 1992; Tanner, Rammage, & Liu, 2016). This approach was developed by Dr. Lorraine Ramig and is used in over 30 countries to treat speech disorders for PD (LSVT Global, 2020; Yinger & Lapointe, 2012). This one-month intensive protocol emphasizes increasing vocal effort, resulting in increased loudness and pitch variation (LSVT Global, 2020; Tanner, Rammage, & Liu, 2016). While this protocol has been thoroughly researched, less than 5% of people with PD receive speech treatment (Yinger & Lapointe, 2012) and research has indicated a lack of carryover and long-term effects of the treatment (Ramig, Fox, & Sapir, 2004; Tanner, Rammage, & Liu, 2016; Yinger & Lapointe, 2012). Altogether, no single treatment option has demonstrated consistent, long lasting effects to address hypokinetic dysarthria in individuals with PD.

A viable treatment option that researchers have begun to explore more in the past decade is the use of music, and more specifically, the use of singing. Singing can naturally intensify various aspects of speech production, making music therapy a viable treatment option for hypokinetic dysarthria (Haneishi, 2001; Tanner, Rammage, & Liu, 2016; Yinger & Lapointe, 2012). The Music Therapy Voice Protocol (MTVP) for PD, drawing on principles from LSVT, was developed by Eri Haneishi in an effort to provide a treatment that appropriately addressed speech needs for individuals with PD (Haneishi, 2001; Yinger & Lapointe, 2012). MTVP is a 60-minute protocol for individuals, consisting of an opening and closing conversation, facial and breathing warm ups, vocal exercises, singing exercises, practicing sustained vowel sounds, and speech exercises (Haneishi, 2001). This protocol focuses on phonation, respiration, speech intelligibility, and acoustic parameters as well as overall mood (Haneishi, 2001). In this 2001 study, statistically significant increases were found in speech intelligibility and vocal intensity (Haneishi, 2001). Confounds of this study were the small sample size (*N*=4), high variability in session pretest scores, and lack of a separate control group (Haneishi, 2001). In a later study by Haneishi (2006), a larger sample size of 20 individuals with PD were randomly assigned to a MTVP treatment group or control group. Speech intelligibility, vocal intensity range, intonation, and positive affect showed significant improvement in the MTVP treatment group (Haneishi, 2006). While the sample size increased for this study, the time frame for data collection and variance in session scheduling weakened the validity of the data (Haneishi, 2006). Yinger and Lapointe (2012) made a group adaptation for the MTVP (G-MTVP), and the results showed significant increases in intensity of conversational speech. Sample size continues to be a limitation for many music therapy studies (*N*=10), along with a lack of a control group. Although emerging literature shows promising results for music therapy as a treatment for hypokinetic dysarthria, further research with larger sample sizes is necessary before generalizing results.

Neural Representation of Music Processing

Music processing is widely distributed in the brain (Thaut, 2005), influencing cognitive, affective, and sensorimotor processes (Thaut, McIntosh, & Hoemberg, 2014). Evidence from neuroimaging has revealed shared and extended neural networks between singing and speech

(Patel, 2003); this can be referred to as the musical and linguistic syntax (Patel, 2003). Maess, Koelsch, Gunter, and Friederici (2001) used magnetoencephalography (MEG) to find that Broca's area and its right hemisphere homologue were both involved in the processing of musical syntax, indicating a strong relationship between the processing of language and music (Patel, 2003). The inferior frontal gyrus, known for its function in speech comprehension, is Broca's area, comprised of Brodmann areas 44 and 45. Another study used functional magnetic resonance imaging (fMRI) and found that harmony and language integrate resources in Broca's area (Kunert, Willems, Casasanto, Patel, & Hagoort, 2015). Brown, Martinez, and Parsons (2006) used positron emission tomography (PET) to track brain activation in amateur musicians while they improvised melodic or linguistic phrases. Results showed that brain areas highlighted for both tasks included the primary motor cortex, supplementary motor area, Broca's area, anterior insula, primary and secondary auditory cortices, temporal pole, basal ganglia, ventral thalamus, and posterior cerebellum (Brown, Martinez, & Parsons, 2006). This research highlights the areas of the brain where music and language processing overlap, indicating that music could be a valuable tool to address speech needs in individuals with neurologic impairments.

The effects of rhythmic auditory stimulation (RAS) on motor performance for individuals with PD has been documented (Buard, et al., 2019), but using RAS for oral motor entrainment has rarely been explored (LaGasse, 2013; Thaut, McIntosh, McIntosh, & Hoemberg, 2001). Buard et al. (2019) used MEG to measure motor performance using a finger tapping task with RAS, for persons with and without PD. Findings revealed that persons with PD rely more on parietal areas of the brain compared to typically functioning older adults. Although this research was addressing motor tasks for persons with PD, the neurologic processes involved may be correlated with rhythmic speech patterns. Music exercises that mimic speech motor patterns are likely to cause neural adaptation that will facilitate positive change in speech accuracy (Tamplin, 2008).

Auditory Rhythmic Entrainment on Speech Motor Control

External auditory cues have been utilized to address speech patterns in persons with PD (Thaut, McIntosh, McIntosh, & Hoemberg, 2001), but there has been little research specifically addressing oral motor synchronization (LaGasse, 2013). The oral motor system is complex, and currently this neurologic process is not fully understood. In a 2013 study, LaGasse used kinematics to test oral motor entrainment of the upper lip, lower lip, and jaw for 24 typically developing children and adults. Participants repeated the bilabial “pa” in three conditions: preferred tempo without a stimulus, preferred tempo with a rhythmic auditory stimulus, and 10% faster with a rhythmic auditory stimulus. Results of the Spatiotemporal Index and Synchronization Error indicated that external auditory cues can positively influence oral motor entrainment (LaGasse, 2013). Priming and cueing of the motor system was observed in this current study, as well as previous studies looking at limb motor synchronization (Thaut et al., 1998). These data indicate that the speech motor process operates similarly to motor synchronization of the limbs, implying that these two processes may share neurologic representations. These data provide insight into possible shared neural networks and have implications for speech rehabilitation for individuals with PD; however, further research should be completed to target those who are diagnosed with the disease.

Neuroscience-based Approaches for Speech Rehabilitation

Prior research has used neuroscientific findings to inform music therapy protocols to address speech intelligibility (LaGasse, 2013; Tamplin, 2008; Tamplin & Baker, 2017; Thaut, McIntosh, McIntosh, & Hoemberg, 2001). Neurologic music therapy (NMT) “focuses on music as a biological language whose structural elements, sensory attributes, and expressive qualities engage the human brain comprehensively and in a complex manner,” (Thaut, McIntosh, & Hoemberg, 2014, p. 6). A handful of music therapy protocols have been developed to specifically address speech needs in individuals with aphasia, dysarthria, dyspraxia, stroke, traumatic brain injury (TBI), and degenerative speech disorders such as PD (Stegemöller, 2017; Tamplin & Baker, 2017), but few have used neuroscience-based approaches (Azekawa & LaGasse, 2018; Tamplin, 2008). Tamplin (2008) completed a pilot study to explore the effects of NMT techniques on speech intelligibility and naturalness in individuals with dysarthria following a TBI or stroke. Results indicated significant improvements in speech intelligibility and naturalness. Yinger and Lapointe (2012) adapted Tamplin's music therapy voice protocol (MTVP) for a group (G-MTVP) of individuals with PD. Results from this study showed significant improvements in intensity of conversational speech. Research addressing hypokinetic dysarthria is persons with PD (Azekawa & LaGasse, 2018; Di Benedetto et al., 2009; Elefant et al., 2012, Evans et al., 2012; Haneishi, 2001; Perez-Delgado, 2007, Yinger & Lapointe, 2012) has indicated that neuroscience based approaches have the potential to positively impact speech needs in persons with PD; however, further research needs to be completed with larger sample sizes, and replication studies are needed to test the current music therapy protocols (Tamplin & Baker, 2017).

The three NMT techniques used in in Tamplin (2008), Yinger and Lapointe (2012), and Azekawa and LaGasse's (2018) research included 1) Oral Motor and Respiratory Exercises (OMREX), 2) Vocal Intonation Therapy (VIT), and 3) Therapeutic Singing (TS). Through the use of sound vocalization exercises, OMREX can be applied to address articulatory control and respiratory strength (Mertel, 2014). These exercises elicit a neurologic response, causing the individual to exert conscious control over an automatic function such as breath cycle (Tamplin, 2008). VIT utilizes vocal exercise that incorporate musical elements such as inflection, pitch, breath control, timbre, and dynamics to address aspects of voice control that are damaged (Thaut, 2014). In a 2001 study, Haneishi found improvements in vocal intensity after participants with PD completed 14, 60-minute music therapy sessions to address hypokinetic dysarthria. Perez-Delgado (2007) adapted this protocol for Spanish speakers and found improvements in breath control, voluntary speech production, and vocal loudness. TS is often integrated with

OMREX and VIT to use singing activities for therapeutic purposes (Johnson, 2014). Studies have found that group singing has been known to increase speech intelligibility, overall mood, and vocal intensity (Haneishi, 2001; Perez-Delgado, 2007), and decrease pause time (Azekawa & LaGasse, 2018).

Altogether, researchers have clearly demonstrated that a large population of individuals with PD experience hypokinetic dysarthria along with a variety of motor deficits; however, music therapy treatment options lack consistent efficacy and need to be replicated before results can be generalized. While recent literature has correlated neurologic findings with music therapy techniques used to address speech, only a handful of music therapy protocols implement this knowledge (Azekawa & LaGasse, 2018; Tamplin, 2008). Replication studies are necessary to investigate what music therapy techniques and protocols are most successful in addressing hypokinetic dysarthria for individuals with PD.

CHAPTER 3: METHODS

This study is replicating the music therapy protocol (Music Therapy Protocol for Hypokinetic Dysarthria, MTPHD) used in a recent study completed by Azekawa & LaGasse (2018).

Participants:

Participants were recruited from a local PD support group that was held in the University Center for the Arts (UCA) at Colorado State University, Fort Collins, CO. The study was approved by the Institutional Review Board of Colorado State University. Seventeen individuals (2 females, 15 males) participated in the study. Five participants did not complete the study due to absences.

The inclusion criteria were current diagnosis of Parkinson's disease with the severity of the disease determined by Hoehn & Yahr scale (Hoehn & Yahr, 1967) from 1 to 3 according to their self-reports as recorded by the research team. Participants were native English speakers and exhibited one or more characteristics of hypokinetic dysarthria including reduced volume of speech, monotone pitch, reduced stress in speech pattern, breathy and hoarse voice quality, imprecise articulation, and varied rate of speech. All participants were over the age of 46, and the onset of PD was after 46 years of age. The mean age (standard deviation) of the participants was 66.1 (8.989) years and their mean Hoehn and Yahr scale rating was 2.7 (0.393). Informed consent was obtained from all participants before beginning the study.

The exclusion criteria were individuals who were currently receiving music therapy treatment addressing voice and speech deficits. Since Parkinson's disease affects people over the age of 50, minors were not included. The participants were not diagnosed with any other neurological impairments or cognitive deficits. The participants were not recruited based on sex and ethnicity.

Table 1

Participant Demographics

Baseline Characteristics	Mean (SD)
Age	66.06 (8.99)
H & Y	2.68 (0.39)

Measurement Instruments:

Participants completed a pretest and posttest of three speech tasks to assess: (a) vocal function and voice quality (sustained vowel phonation task), (b) articulatory control ability (diadochokinesis test), and (c) connected speech intelligibility (Rainbow Passage Reading). The audio samples were recorded using the Edirol R-09HR 24-bit/96KHz WAV/MP3 Recorder manufactured by Roland to assure accurate and reliable audio recording for data analyses. The recorded data was then transferred into spectrogram by a vocal signal analysis software PRAAT (Boersma & Weekink, 2019), which was installed in Apple MacBook Pro.

1. Sustained Vowel Phonation Task.

Vocal (Phonatory) Function Assessment. Phonation is the process in which the vocal folds vibrate to create sound (The National Center for Voice and Speech, 2019). Individuals with PD may experience abnormal vocal fold vibration resulting in poor vocal quality and increased vocal fatigue (Baken & Orlikoff, 2000). At least 50% of people with PD present with vocal fold bowing (lack of medial vocal fold closure), as well as asymmetrical vibratory patterns, laryngeal tremors, and insufficient glottal closure (Baken & Orlikoff, 2000; Elefant, Baker, Lotan, Lagesen, & Skeie, 2012). The duration measurement of sustained vowel phonation has been used in previous studies (Di Benedetto et al., 2009; Haneishi, 2001) to explain glottal function that affects vocal phonation (Azekawa & LaGasse, 2018). This measurement also indicates steadiness of vocal tract functioning, which can be expressed in variances of the first formant (*f*1) and second formant (*f*2). Formants are a series of resonances created by the vocal tract and their varying frequencies are directly related to the changing shape of the vocal tract (Azekawa & LaGasse, 2018; Nair, 1999; Sataloff, 2005). The mandible, tongue, lips, larynx, and the side walls of the pharynx are moving articulators that can influence the shape of the vocal tract (Azekawa & LaGasse, 2018; Sataloff, 2005). The first two formants, *f*1 and *f*2 are specifically influenced by the opening of the mandible as well as the tongue shape; these are both required for the sustained vowel phonation assessment (Azekawa & LaGasse, 2018; Nair, 1999; Sataloff, 2005).

Voice Quality Assessment. Jitter and shimmer are significant acoustic descriptions of the abnormalities in voice quality that have been measured in previous music therapy and PD research (Adams & Dykstra, 2009; Azekawa & LaGasse, 2018; Di Benedetto et al., 2009). These measurements are indicators of the distress level in the vocal sound for acoustic analyses (Adams & Dykstra, 2009; Azekawa & LaGasse, 2018). Specifically, jitter describes cycle-to-cycle variation in frequency and shimmer describes cycle-to-cycle variation in amplitude (Adams & Dykstra, 2009; Azekawa & LaGasse, 2018; Kent & Ball, 2000). Any measurements for jitter above 1.040% and shimmer above 3.810% are considered in the PRAAT program as above threshold of pathology (Azekawa, 2011; Boersma & Weenink, 2010). Abnormal increments of these two factors create sounds of “harshness” in the voice (Azekawa & LaGasse, 2018; Laver, Hiller, & Beck, 1992).

Harmonics-to-Noise Ratio (HNR) is another acoustic index that refers to the proportion of vocal sound to noise ratio; lower HNR scores indicate more noise in the voice (Azekawa & LaGasse, 2018; Forrest & Weismer, 2009). Measurements of HNR at 20 dB or below are considered threshold of pathology in the PRAAT program (Azekawa, 2011; Boersma & Weenink, 2010).

Table 2.

Jitter, Shimmer, and the Harmonics-to-Noise Ratio - Threshold of Pathology

	Threshold of Pathology
Jitter (%)	> 1.040 %
Shimmer (%)	> 3.810 %
Harmonics-to-Noise Ratio (dB)	< 20 dB

2. Diadochokinesis Test for Articulatory Control Assessment

The diadochokinesis test uses three monosyllables /pa/, /ta/, /ka/ as a sequence to test articulatory control (Azekawa & LaGasse, 2018; Kent, Kent, & Rosenbek, 1987). Participants were asked to select or alternate their place for syllabic productions with similar voiced stops within a five second period. This enabled the assessment of speech motor control without the influence of language production since the assessment test only involved repetitions of monosyllables (Azekawa & LaGasse, 2018; Padovani, Gielow, & Behlau, 2009).

3. Rainbow Passage Reading Task for Inter-word Pause Assessment

The Rainbow Passage reading task is another speech test that has been used in previous PD research (Stepp, 2013) to assess connected speech intelligibility. This piece of text contains all vowel and consonant sounds in the English language and is available on public domain (Fairbanks, 1960, p. 127). The first paragraph of the Rainbow Passage contains 35 words and was used for the pretest and posttest measurements for all participants. During each test, all participants were asked to read the entire paragraph aloud; however, only the third and fourth sentences of each paragraph were used for data analyses.

Inter-word pauses (i.e. pauses between words) were assessed by measuring the number of inter-word pauses, and the duration of each inter-word pause. Duration of inter-word pauses was determined by spectrogram analysis as greater than 200 milliseconds (Kent, Kent,

& Rosembek, 1987; Van Nuffele, Bodt, Vanderwegen, de Heyning, & Wuyts, 2010). Irregular number and duration measurements affects rate of speech and might be related to speech prosody (Azekawa, 2011; Duffy, 2005; Skodda & Schlegel, 2008). Any pause that was recorded between the end of the third sentence and the beginning of the fourth sentence was excluded from the analysis.

Altogether, these speech tasks reveal information that is essential when examining voice and speech characteristics for individuals with PD. Results from these assessments will contribute to the effectiveness of the MTPHD.

Design

The research design replicated the pilot study completed by Azekawa (2011) using a one group pretest posttest design. As indicated in Azekawa (2011), the MTPDH was the independent variable, and the dependent variables included the following three speech measures: (a) sustained vowel phonation task, which measured the duration of the sustained vowel phonation, the mean of the first (f1) and second (f2) formants for vocal function, the percentages of jitter and shimmer, and the Harmonic-to-Noise Ratio (HNR) for vocal quality, (b) the diadochokinesis test, which measured the number of sequenced syllable repetitions for articulatory control, and (c) Rainbow Passage reading task, which measured the number of inter-word pauses, and the mean duration of inter-word pause time for connected speech intelligibility.

Procedures

Recruitment flyers were approved by the Institutional Review Board and distributed to participants in a PD exercise group that took place at the UCA. Individuals who were interested in participating in the study responded to the researcher by phone or email to set up an appointment to complete the pretest. Prior to completing the pretest, each participant was assigned a number to ensure anonymity. Informed consent was acquired from each participant and then a pre-study questionnaire was distributed. The questionnaire addressed information regarding the participants musical preferences as well as their past and present level of involvement with music. Results of the questionnaire were used to select preferred music for the singing exercises. An in-person interview was also completed in order to obtain general information such as age and PD onset from the participants. Following the questionnaire and interview, participants were given three speech tasks for a pretest measurement. Data were recorded and securely stored. Within the week following the pretest, participants began group music therapy sessions lasting 50-minutes for a total of six weeks (i.e. six sessions). In these sessions, a board-certified music therapist used the MTPHD. Each participant took the posttest within a week after the last session. Both the pretest and posttest took place at the UCA.

Music Therapy Protocol for Hypokinetic Dysarthria (MTPHD)

MTPHD is a protocol designed by Azekawa and LaGasse (2018) for individuals with PD who display characteristics of hypokinetic dysarthria. MTPHD is based on three Neurologic Music Therapy techniques: Vocal Intonation Therapy (VIT), Therapeutic Singing (TS), and Oral Motor and Respiratory Exercises (OMREX). Azekawa and LaGasse (2018) used OMREX techniques in their treatment protocol but did not explicitly state that the OMREX was being used. The protocol was delivered over a six-week period of time in which the participants attended weekly group music therapy sessions. Each session was approximately 50 minutes, consisting of a 5-minute opening/relaxation exercise, a 15-minute vocal warm-up, two 10-minute singing exercises, and a 5-minute closing/relaxation exercise, with a 5-minute water break in the middle of the session. Sessions were facilitated by a board-certified music therapist with 15 years of experience and advanced training in neurologic music therapy, using piano accompaniments and verbal instructions, along with PowerPoint slides for visual cues. All participants were seated in chairs during each session. All sessions were comprised of the following activities:

Opening/Movement Exercises

The 50-minute sessions began with the music therapist explaining the purpose of the session, the role of the music therapist, and the targeted goals and objectives. Next, the music therapist led the group in a warmup exercise, completing simple motor movements such as toe taps, heel lifts, and marching to decrease muscle tension.

Oral Motor and Respiratory Exercises (OMREX) and Therapeutic Singing (TS)

OMREX was used to lead a series of vocal exercises addressing articulatory control and respiratory strength. Certain consonant, vowel, and syllabic sounds were repeated within the context of singing. After the completion of these exercises, participants would sing through a preferred song that addressed the targeted areas. For example, the participants would first practice forming vowels, and then would sing through the song "Witch Doctor" to practice articulatory control within words.

Water Break

A cup of water was distributed by the facilitator to all participants who were interested. This was done in an effort to prevent dry mouth or sore throat, and to give the group time to rest their voice.

Vocal Intonation Therapy (VIT) and Therapeutic Singing (TS)

VIT was used to lead a series of vocal exercises addressing respiratory control, improving phonatory controls, and expanding vocal prosody or pitch range. After the completion of these exercises, participants would sing through a preferred song that addressed the targeted areas. For example, the participants were prompted to sing an entire phrase of a song in one breath in order to practice respiratory control.

Closing Exercises

The session ended with a farewell song and cool down exercises where the music therapist facilitated movements such as neck stretches, shoulder/arm extensions, and deep breathing to release any muscle tension. The music therapist reviewed key points highlighted in each exercise and acknowledged the participants for their hard work. All participants were reminded of the next session date and time and then a few minutes were left for participants to ask any additional questions.

Data Analysis

A board-certified music therapist, who was also trained in vocal analysis, completed acoustic analyses on spectrograms and waveforms that were displayed in the PRAAT vocal analysis software program. PRAAT is the name of the program and Dutch for "speak" (Azekawa & LaGasse, 2018). A spectrogram is a graphic representation of sound in time and frequency, and a waveform displays a shape of a sound in a given period of time (Azekawa, 2011). The X axis on the graph represents time and the Y axis represents frequency. The color of the lines represents amplitude and each horizontal band or group of lines represents a different harmonic in the sound spectrum (The National Center for Voice and Speech, 2019). The program provided a visual representation for the duration of the sustained vowel phonation, the mean of the first (*f*1) and second (*f*2) formants, jitter, shimmer, and the HNR of the voiced sound from the sustained vowel phonation audio samples. Additionally, PRAAT provided a visual representation for the number of syllable repetitions from the diadochokinesis test audio samples and the presence and duration of each inter-word pause from the Rainbow Passage audio samples.

CHAPTER 4: RESULTS

The data were analyzed using the Microsoft Excel data analysis package. A paired samples *t*-test was used to determine whether there was a significant difference between pretest and posttest data among all of the participants for voice and speech parameters. An alpha level of 0.05 was used as the threshold for two-tailed significance. The parameters included vocal function, vocal quality, articulatory control, and inter-word pauses. Due to the small sample size, significant results were verified using a Wilcoxon signed ranks test.

Vocal Function Assessment

Results of a paired samples *t*-test comparing the pretest and posttest data for vocal function variables is presented in Table 3.

Sustained Vowels

Pretest and posttest measurements for each participant's duration of sustained vowel phonation showed that the majority of participants increased their duration time; however, Participant 11 improved their duration by 52%. A paired samples *t*-test that compared pretest and posttest data for vocal functions is shown in Table 1. The mean for sustained vowel duration increased from 14.3 (*SD* = 6.72) seconds to 15.18 (*SD* = 6.84) seconds; however, results showed no significant changes between pretest and posttest measurements.

Formant Measures

Outcome measurements for the mean are displayed in Figures 2. The majority of participants increased in Hz for both measurements; however, Participant 16 demonstrated a large decrease in the first formant ($f1$) while Participant 6 demonstrated a large increase in the second formant ($f2$). Although the mean for the first formant ($f1$) and second formant ($f2$) increased overall from pretest to posttest, there were no significant differences.

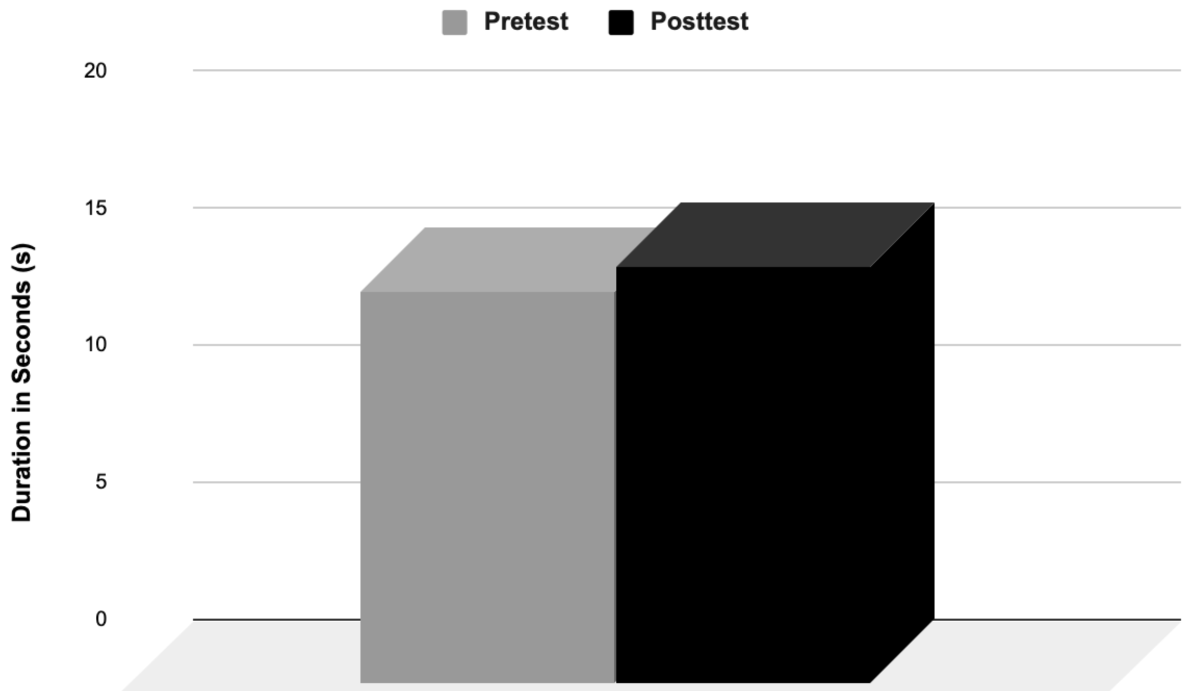

Figure 1. Changes in the Mean Duration of Sustained Vowel Phonations

Table 3

Results of a Paired Samples t-Test Measuring Vocal Functions

Dependent Variables	Pretest	Posttest	$t(16)$	p (2-tailed)	Cohen's d
	Mean (SD)	Mean (SD)			
The Duration of Sustained Vowel Phonations (s)	14.3 (6.72)	15.18 (6.84)	-1.15	0.27	0.13
Mean $f1$ (Hz)	667.95 (119.56)	688.28 (86.56)	-0.72	0.48	0.2
Mean $f2$ (Hz)	1177.22 (121.78)	1237.98 (206.56)	-1.03	0.32	0.36

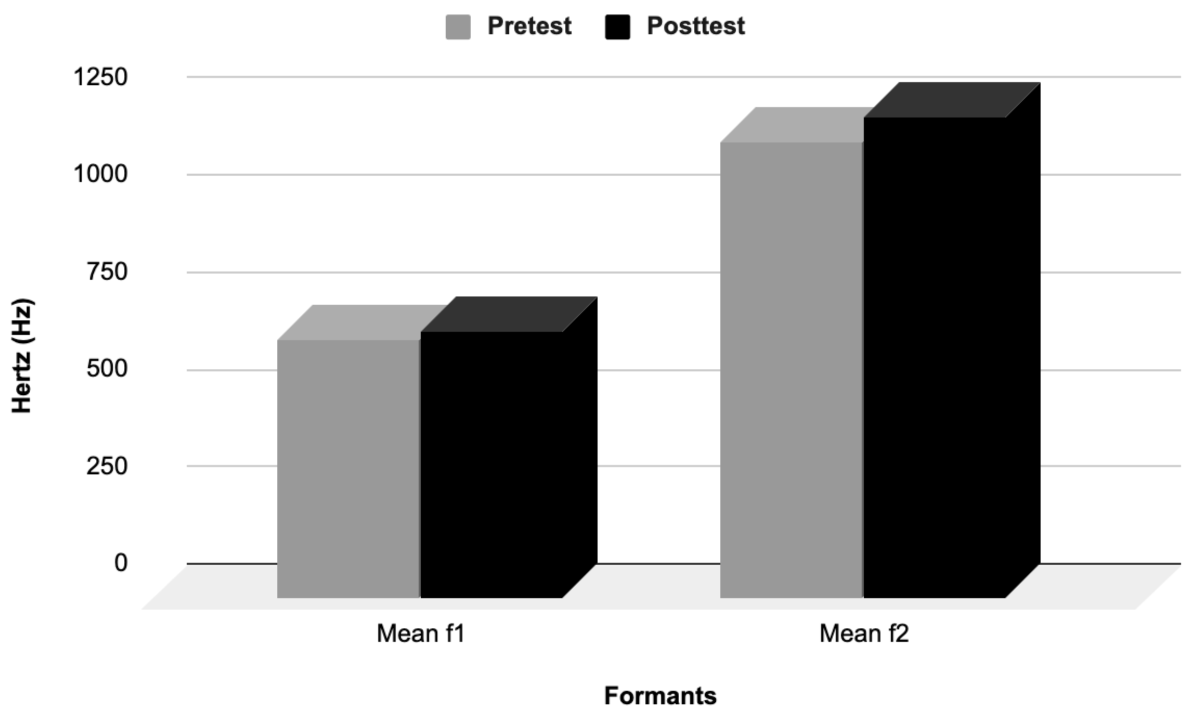

Figure 2. Changes in the Mean of the First (*f*1) and Second Formant (*f*2)

Vocal Quality Assessment

Results of a paired samples *t*-test comparing the pretest and posttest data for voice quality variables is presented in Table 4.

Jitter

The overall mean for jitter measurements decreased from pretest (M = 0.49; SD = 0.58) to posttest (M = 0.33; SD = 0.75); however, the results did not indicate a significant difference. A decrease indicates vocal quality improvement.

Shimmer

A significant difference was found ($t(16) = 2.62$, $p = 0.05$), indicating a decrease from pretest (M = 4.84; SD = 4.04) to posttest (M = 2.3; SD = 3.49). A decrease indicates vocal quality improvement.

Harmonic to Noise Ratio (HNR)

The overall mean for HNR measurements increased from pretest (M = 17.8; SD = 3.63) to posttest (M = 18.1; SD = 4.49); however, the results did not indicate a significant difference. An increase indicates vocal quality improvement.

Table 4

Results of a Paired Samples t-Test Measuring Vocal Quality

Dependent Variables	Pretest	Posttest	t(16)	*p* (2-tailed)	Cohen's *d*
	Mean (SD)	Mean (SD)			
Jitter (%)	0.49 (0.58)	0.33 (0.75)	1.49	0.16	0.25
Shimmer (%)	4.84 (4.04)	2.3 (3.49)	2.62	0.02	0.67
Harmonics-to-Noise (dB)	17.8 (3.63)	18.1 (4.49)	-0.34	0.74	0.07

Note: Thresholds

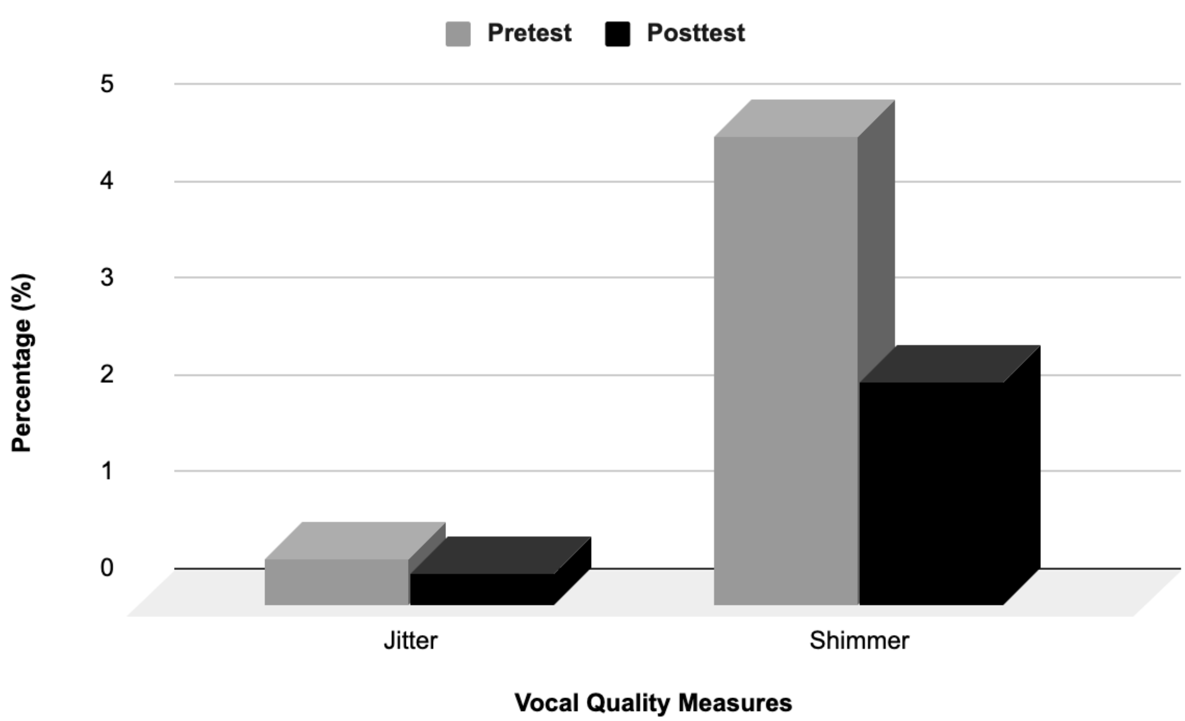

Figure 3. Changes in the Mean for Jitter and Shimmer

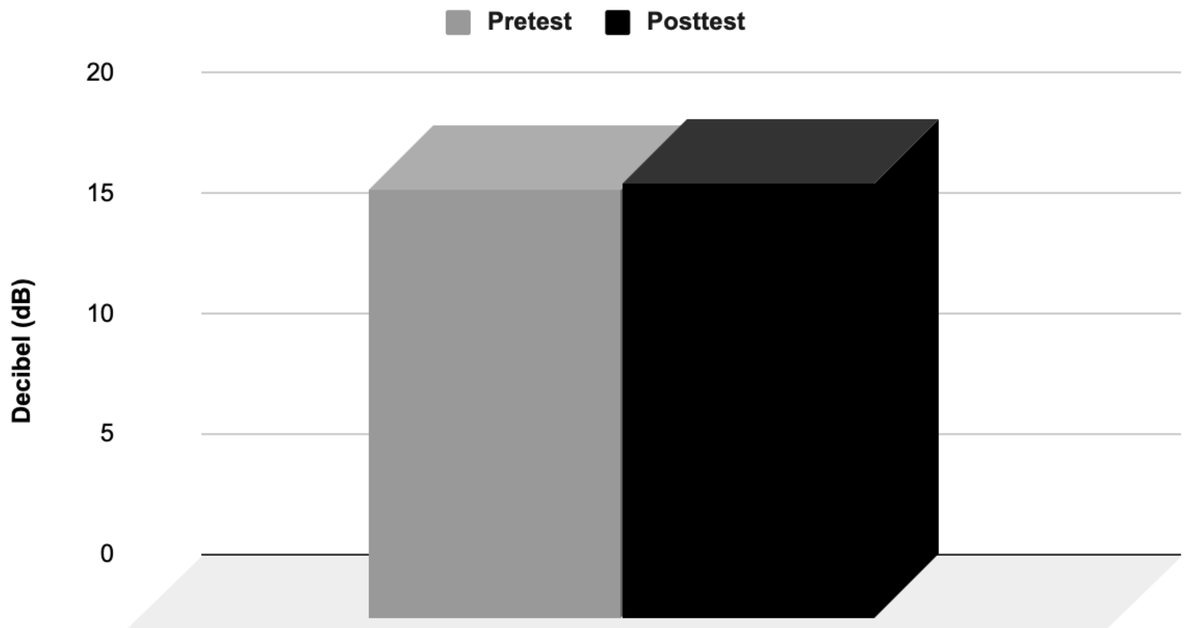

Figure 4. Changes in the Mean for Harmonics-to-Noise Ratio

Articulatory Control Assessment

The results of a paired samples t-test for the diadochokinesis test comparing pretest and posttest measurements is shown in Table 5. No significant differences were found. The majority of participants required less time during the posttest to complete 10 repetitions of the /pa/ /ta/ /ka/ syllable series and participants were able to complete more repetitions of the series within five seconds during the posttest.

Connected Speech Inter-Word Pause Assessment

The results of the paired samples *t*-test comparing pretest and posttest measurements for inter-word pauses is shown in Table 6. A significant difference was found in the number of pauses ($t(16) = -2.17$, $p = 0.05$); indicating that the pause time increased from pretest (M=0.41; SD = 0.51) to posttest (M= 0.94; SD = 1.25).

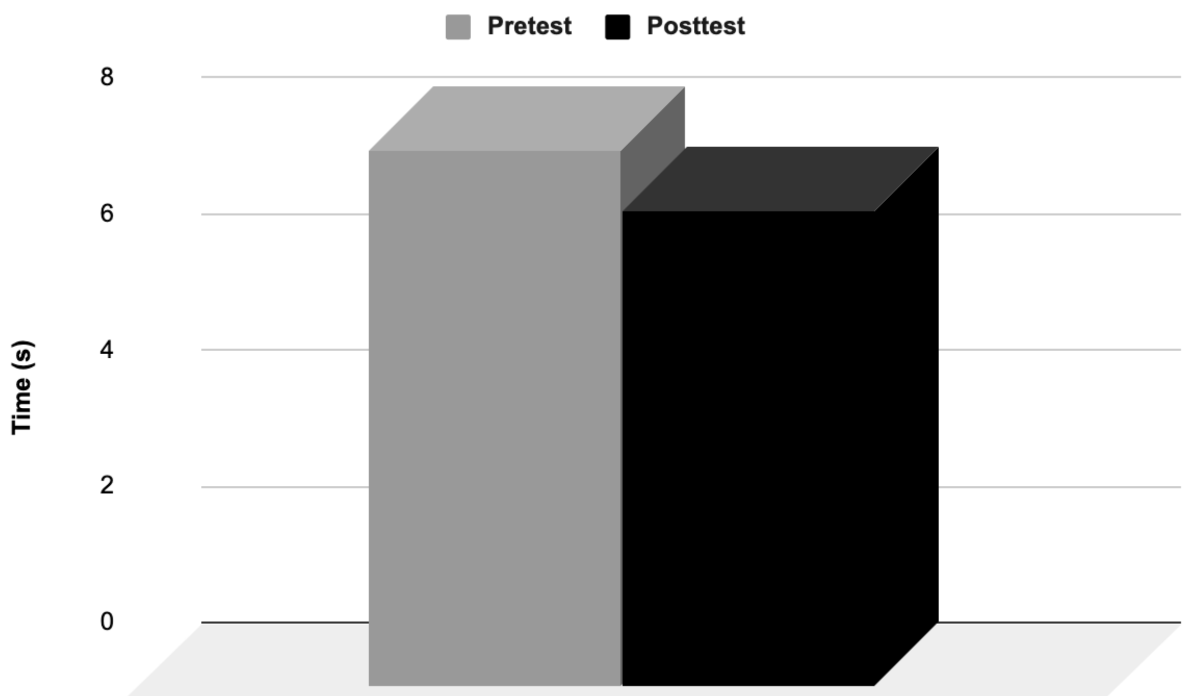

Figure 5. Results of Diadochokinesis Test for the Mean Time Needed to Complete 10 Repetitions

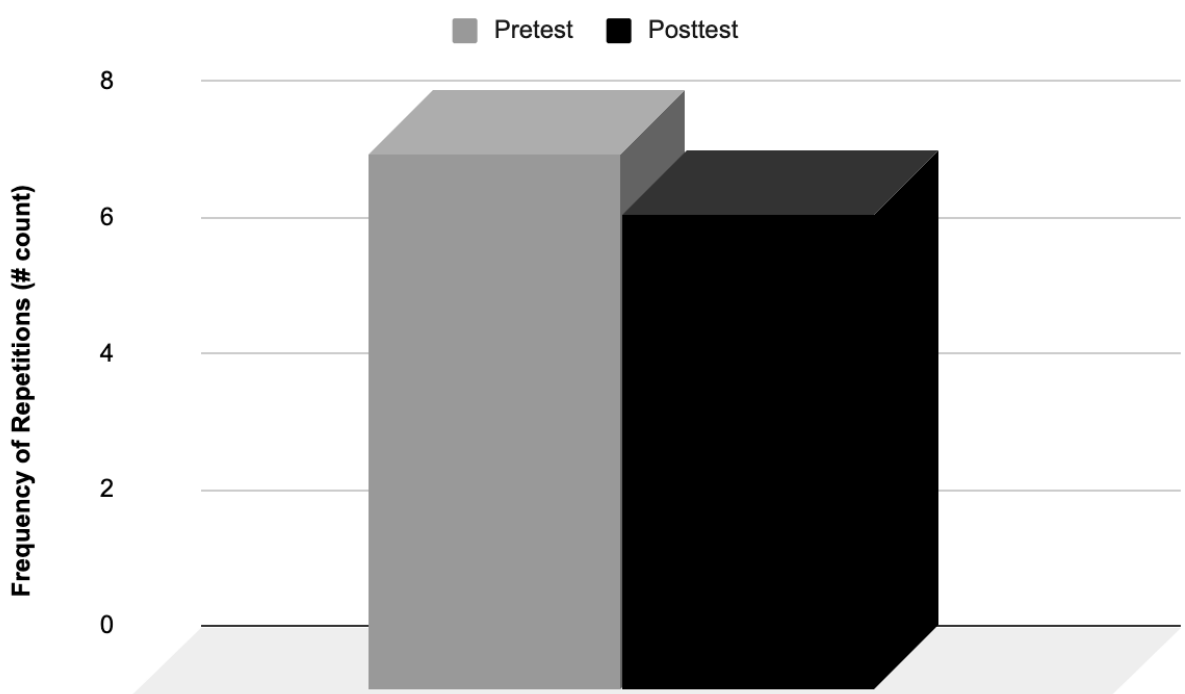

Figure 6. Results of Diadochokinesis Test for the Mean Frequency of Repetitions in 5 Seconds

Table 5

Results of a Paired Samples t-Test for Diadochokinesis Test

Dependent Variables	Pretest	Posttest	t(16)	p (2-tailed)	Cohen's *d*
	Mean (SD)	Mean (SD)			
Time needed for 10 repetitions	7.86 (4.74)	6.99 (2.93)	1.15	0.27	0.22
Frequency of repetitions in 5 seconds	7.59 (2.42)	7.71 (2.12)	-0.34	0.74	0.05

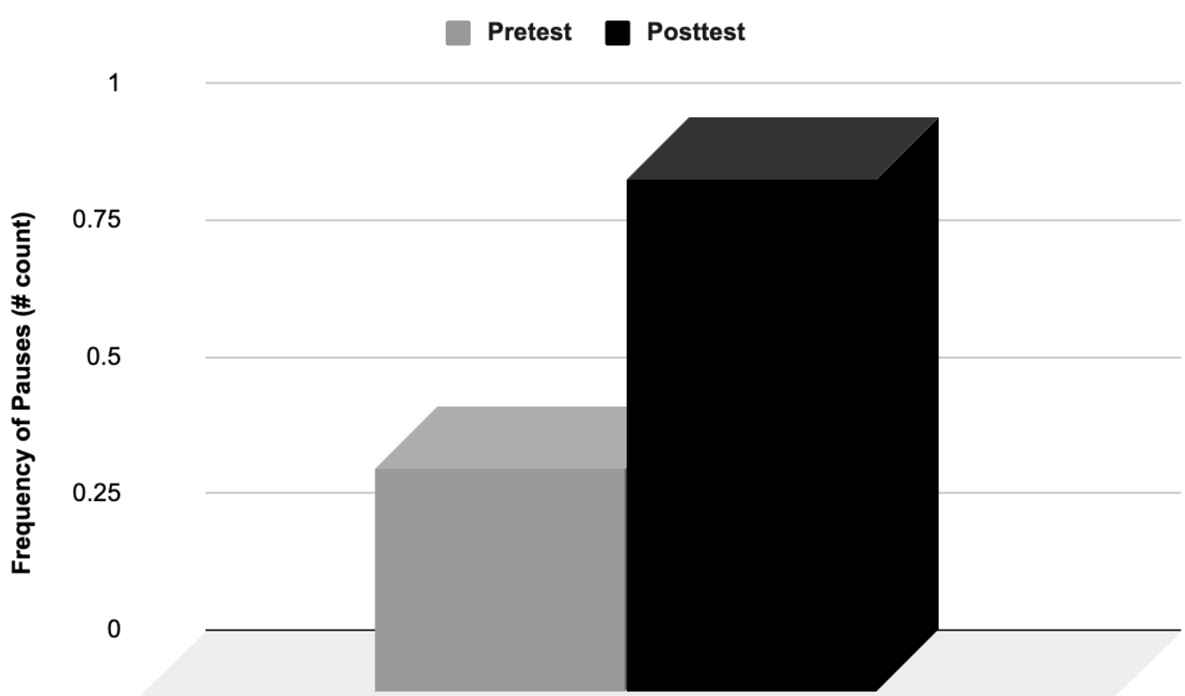

Figure 7. Results of Mean for Inter-word Pause Count

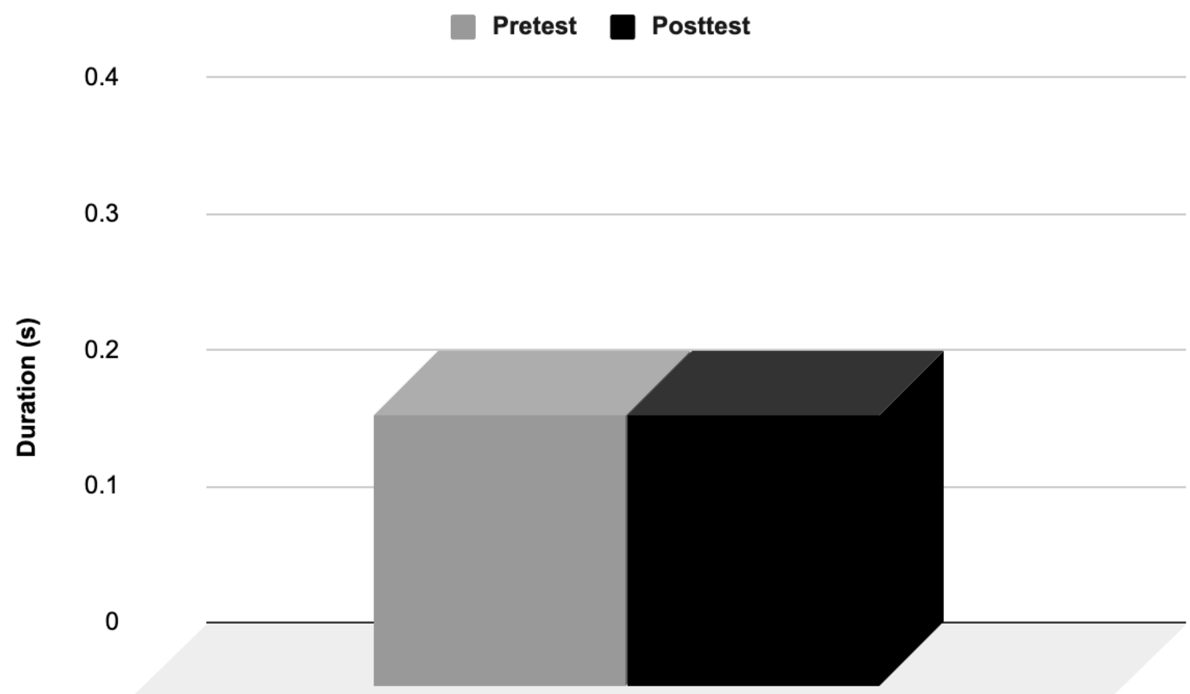

Figure 8. Results of Mean for Inter-word Pause Duration

Table 6

Results of a Paired Samples t-Test for Inter-word Pauses

Dependent Variables	Pretest	Posttest	t(16)	*p* (2-tailed)	Cohen's *d*
	Mean (SD)	Mean (SD)			
Number of Pauses	0.41 (0.51)	0.94 (1.25)	-2.17	0.05	-0.55
Duration of Pauses (s)	0.2 (0.38)	0.2 (0.27)	0.03	0.98	0.01

CHAPTER 5: DISCUSSION

The purpose of this study was to replicate the music therapy protocol for hypokinetic dysarthria (MTPHD) completed by Azekawa and LaGasse (2018) in an effort to investigate the effects of a group music therapy treatment for individuals who exhibited voice and speech deficits due to Parkinson's disease (PD). Although there were few statistically significant changes in the dependent variables, there were positive changes observed within most participants. This indicates that music therapy may be a viable treatment option to address voice and speech needs in people with PD.

Participants had statistically significant changes from pretest to posttest for shimmer and number of inter-word pauses; however, the number of inter-word pauses increased which was an unfavorable outcome. In Azekawa and LaGasse's (2018) study, results were contrary to the current study, with findings that shimmer increased (meaning vocal quality decreased) and the number of inter-word pauses decreased/improved (approaching significance). This difference could be due to the larger sample size difference in the current study ($N = 17$), compared to ($N = 5$) in Azekawa and LaGasse's (2018) study. A larger sample size for both studies would minimize variability in the mean scores and provide a better representation of the population. It should also be noted that the participants of this study read the same paragraph of the Rainbow Passage during pretest and posttest, while the participants in Azekawa and LaGasse's (2018) study read the second paragraph during the posttest.

The descriptive data indicate that, while not significant, there were changes in pre to posttest scores for participants in the study. Twelve out of the 17 participants improved their duration of sustained vowel phonations. Participant 11 made the most progress for duration, increasing their duration by 52%. Positive trends were also observed in the first formant ($f1$) and second formant ($f2$), a small indication of what this positive trend was. A look at these measures shows that some participants improved in some measures and regressed in others. For example, although Participant 16 made progress during sustained vowel phonation, they regressed in both formant measurements. Changes in *f*1 relate to the openness of the mandible while changes in *f*2 are influenced by the shape of the tongue (Azekawa & LaGasse, 2018; Nair, 1999; Sataloff, 2005). While these mouth and tongue positions are both essential for sustained vowel phonation, an individual would still be able to sustain a vowel with a restricted or otherwise less open oral position. Although PD is a neurodegenerative disease, individuals demonstrated positive trends towards improved or maintained vocal function.

Results from vocal quality measures of jitter, shimmer, and HNR displayed mixed results among participants. These findings are consistent with the results from Azekawa and LaGasse's (2018) study. For example, Participants 1 and 16 showed a large increase in both jitter and shimmer, while Participants 2 and 15 showed a large decrease. Participant 16 surpassed the threshold of pathology in their posttest measurements for both jitter and shimmer, and conversely, Participant 2 had jitter and shimmer measurements that were both below the threshold of pathology during posttest. The majority of participants demonstrated a reduction in HNR, indicating a decline in vocal quality; however, Participant 5 had a pretest score of 21.28 that then increase during posttest measurements to 26.31, indicating vocal quality improvement.

Overall, articulatory control improved after posttest showing continued positive trends. The majority of participants required less time to complete 10 repetitions and were also able to complete more repetitions of the syllable series within a five second duration. Outliers included Participant 7 who demonstrated a 34% increase in time needed to complete 10 repetitions and a 29% decrease in frequency of repetitions in five seconds. Contextual factors might have played a role in these mixed results due to the fact that only a handful of participants demonstrated reduced articulatory control during posttest measurements. The time of day and previous use of their voice during that day may have had a negative effect.

Limitations of the present study include a small sample size and lack of a control group for comparison. Out of the 17 participants, only two were female which is not representative of

PD, even though men are 1.5 times more likely to have the disease (Parkinson's Foundation, 2020). The participants were chosen from a convenience sample and there was no randomization. Additionally, throughout the study medication changes were recorded but were not used as a variable of consideration. This was a replication study based off of the protocol used in Azekawa and LaGasse's (2018) study. While this study increased in sample size and overall treatment length, expanding from six weeks to eight weeks, it was completed in the same state and at the same University. This limits external validity because the contextual characteristics remained constant throughout both studies.

Future replication studies should further explore this protocol along with other music therapy voice protocols that specifically address hypokinetic dysarthria in individuals with PD. Studies completed at varying locations with larger sample sizes and control groups would be more representative of this population and would add to the validity and efficacy of the study. Additional areas for this population that have been explored in research (Elefant et al., 2012, Evans et al., 2012; Haneishi, 2001; Perez-Delgado, 2007) include quality of life, mood, and socialization. These topic areas would be beneficial to explore in research protocols that implement group treatment.

In conclusion, this replication study showed varying results from the original study completed by Azekawa and LaGasse in 2018. Some measures were consistent, such as vocal quality measures, while others varied, such as shimmer and number of inter-word pauses. These mixed results should encourage future researchers to replicate existing protocols as they are needed in our field (Tamplin & Baker, 2017). This study showed positive trends towards improved voice and speech health for individuals with PD through the use of the MTPHD.

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